LAND-USE DECISION MAKING, UNCERTAINTY AND EFFECTIVENESS OF LAND REFORM IN ACRE, BRAZILIAN AMAZON

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Dedicated to Ana,

to the acreanos,

and to my family

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ABSTRACT

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LAND-USE DECISION MAKING, UNCERTAINTY AND EFFECTIVENESS OF LAND REFORM IN ACRE, BRAZILIAN AMAZON

From 1970 to 1999, almost 700,000 families were settled through land reform programs in Brazil. However, lot turnover contributed to re-concentration of land and to the limited success of these programs. This dissertation explores land-use decision-making in an aging land reform settlement in the Amazon. It focuses on how farmers respond to limited access to the information and to opportunities that are typical of the frontier context. I analyze the interactions among variables affecting families, communities and the agrarian structure of the settlement, and changes in land-use and cover (LUCC) resulting from these interactions. The study site is a government sponsored colonization project (P.C. Humaitá) in the State of Acre, Brazil. Variables affecting land-use choices were analyzed studied through a micro-level approach using remote sensing linked to social sciences' techniques. A property grid (n=739) overlaid to satellite images (1981-2003) was used to analyze LUCC during this period. It was found that differences among social groups, access to urban centers, and use of agricultural credit contributed to explain LUCC along settlement's lifetime. Additionally, lot consolidation into larger properties was found to correlate with accessibility to urban centers, but not with deforestation. It was also found that diversification of livelihood strategies

through time comprises an important adaptive mechanism to the uncertain conditions that are present on frontier settlements. Additionally, it was found that social learning processes help farmers deal with uncertainty and to take advantage of economic opportunities. There have been enough experiences in the Amazon to inform better governance approaches to promote rural development; despite failures and problems, land redistribution and regularization is an historical need in Brazil and should continue to be a policy priority. However, land markets and infrastructure constraints during different stages of settlement formation are important forces undermining the goals and successes of land reform in the region.

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ACT - Anthropological Center for Training and Research on Global Environmental Change

ARBORETO – Projeto Arboreto: Educação e Pesquisa Agroflorestal (Arboreto Project: Agroforestry Education and Research)

ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer

BASA – Banco da Amazônia S.A. (Bank of Amazônia)

BLR – Binary Logistic Regression

CEPLAC – Comissão Executiva do Plano da Lavoura Cacaueira (Agency for Cacau Cultivation Research)

CNPq – Conselho Nacional de Desenvolvimento Científico e Tecnológico (National Counsel of Technological and Scientific Development)

EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agency for Agriculture Research)

FASE – Federação dos Órgãos para a Assistência Social e Educacional (Federation of Organizations for Social and Educational Assistance)

FETAGRI – Federação dos Trabalhadores na Agricultura (Federation of Workers in Agriculture)

FNO – Fundo Constitucional de Financiamento do Norte (Constitutional Fund for the Financing of the North Region)

GAP – Gross Annual Production

GIS – Geographic Information Systems

IBAMA – Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis

IMAC – Instituto de Meio Ambiente do Acre (Environment Institute of Acre)

INCRA – Instituto Nacional de Colonização e Reforma Agrária (National Institute for Colonization and Agrarian Reform)

INPE – Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research)

LANDSAT TM – Landsat Thematic Mapper (Sensor)

LANDSAT ETM – Landsat Enhanced Thematic Mapper (Sensor)

LUCC – Land-use / land-cover change

MLR – Multinomial Logistic Regression

PRODES – Programa de Cálculo do Desflorestamento da Amazônia (Program for the Calculation of Deforestation of the Amazon)

PRONAF – Programa Nacional de Fortalecimento da Agricultura Familiar (National Program of Strenghtening of Family Agriculture)

P.C. HUMAITÁ – Projeto de Colonização Humaitá (Humaitá Colonization Project)

PIN – Programa de Integração Nacional (Program of National Integration)

PZ – Parque Zoobotânico

RESEX – Reserva Extrativista (Extractivist Reserve)

SEATER – Secretaria de Estado de Assistência Técnica e Extensão Rural (Acre State Technical Assistance and Rural Extension Agency)

SETEM - Setor de Estudos do Uso da Terra e Mudanças Globais (Center for the Study of Land Use and Global Change)

SUDAM – Superintendência para o Desenvolvimento da Amazônia (Agrency for Development of the Amazon)

TAC – Termo de Ajustamento de Conduta (Behavior Adjustment Term)

UFAC – Universidade Federal do Acre (Federal University of Acre)

ZEE – Zoneamento Ecológico-Econômico do Estado do Acre (Ecologic-Economic Zoning of Acre State)

CHAPTER 1 – THE CHALLENGES OF AN UNCERTAIN AMAZON FRONTIER

1.1 - Introduction

From 1970 to 1999, almost 700,000 families were settled through land reform programs[1] in Brazil (INCRA, 2000). However, and despite social movements' pressure and government efforts to decrease the huge gap in land distribution in the country, the *Gini* index of actual land ownership concentration in Brazil was estimated at 0.84[2] (Hoffman, 2002), remaining among the highest in the world. Lot turnover in land reform areas contributes to re-concentration of land and to the low efficiency of land reform programs. Migrating families are normally among the first to bear the negative outcomes of failing land reform projects, but society as a whole ends up paying the price since these outcomes include unplanned rural to urban migration (and the related social problems in urban areas), failure of investments, lost opportunities of agricultural development, and, in the case of Brazilian Amazônia, the environmental impacts from privatization of public land followed by forest conversion to agropastoral uses.

This dissertation presents the story of settlers overcoming challenges common to the environment of expanding agricultural frontiers. The central theme is the land reform puzzle in Brazil and particularly in Amazônia. After the pioneer work of Frederick J. Turner in the late 19th century on the historic importance of frontier expansion to the formation of

[1] According to the Brazilian Constitution of 1988, unproductive agricultural land or rural property, not withstanding its social function, is subject to agrarian reform or private land expropriation (with indemnification) by the government for redistributive purposes among landless farmers. Colonization programs, on the other hand, refer to settlements on public lands (in the case of Brazil, mostly in the Amazon region). In this dissertation, I refer to land reform as including both agrarian reform initiatives (as defined above for Brazil's case) and colonization projects.

[2] The *Gini* index was originally conceived as a measurement of income equity, where the minimum value of zero (0) corresponds to a society with a perfectly equal distribution of wealth, whereas the maximum value of one (1) corresponds to all wealth owned by a single individual. The *Gini* index might also be used to assess equity in land distribution, as in the case mentioned in the text.

American society, frontiers have become the subject of intense study in political and social sciences (McClintock, 1986). Turner's assumptions have been largely debated, and, as pointed out by Richard Hofstadter's (1968) statement "…This mountain of Turner criticism is his most certain monument," it set the tone for substantial work on discussing agricultural frontier expansion worldwide and its socio-economic and political importance.

Colonization of new agricultural frontiers is associated with uncertain conditions and high rates of out-migration. Effectiveness of land settlement, measured by social, economic and environmental outputs after occupation, depends thus largely on how settlers and governments handle decision-making processes under incomplete information, or uncertainty. In this sense, it has been argued that human choices involving uncertainty cannot be addressed by neo-classic economic approaches alone (Ostrom and Walker, 2003). Neo-classical economic models have traditionally assumed complete information about payoffs associated with investments (or certainty); or about the probabilities of occurrence of each of these payoffs (or risk) (Kreps, 1988). When such probabilities are unknown we have uncertainty. In the land-use decision-making context of agricultural frontiers, other tools than the ones provided by neo-classical economic models are needed. New approaches based on more holistic perspectives, focusing on social networks and on social learning processes rather than on analysis centered on individuals trying to cope alone with a wide range of uncertainties (Pahl-Wostl, 2002), might be more helpful to understand the changes that take place as frontiers evolve.

Frontiers are, by definition, places where formal, legal and governmental agencies are largely absent (Alston et al., 1998), or exerting force from a distance. In the absence of formal institutions, or the non-enforcement of the rule-of-law, informal institutions or nonwritten rules or norms are usually created to deal with rights of access, usufruct and transferability of resources needed for economic activity (E. Ostrom, 1990). Enforcement of formal and informal institutions is, however, uncertain on most agricultural frontiers. Under such circumstances, opportunistic behavior, such as free-riding and rent seeking is expected to rise among stakeholders. Also, and as asserted by the Turner hypothesis of frontier expansion, individualism and entrepreneurship among stakeholders are strengthened by the wide range of economic opportunities that are present in the frontier environment. Depending on the stage of frontier development, however, investments might be affected by the lack of infrastructure and access to markets.

The lack of knowledge about the biophysical environment is also a source of uncertainty in agricultural frontiers, especially because land-use decision-making frequently involves multiple dimensions with multiple goals (Chibnik, 1994; Ozório de Almeida and Campari, 1995). Migrant farmers develop adaptive strategies to cope with the new environment, including experimentation with new crops and learning from local communities about their culture and how to make efficient use of the available resources (Moran, 1981). The learning process that takes place might be regarded as the base to adaptation in the frontier context. Farmers and migrant families are, however, largely on their own to experiment and learn new strategies, facing adverse conditions of frontiers, and having often to build social capital "from scratch." In their struggle to overcome difficulties, families cooperate and form new communities, exchange experiences and promote social learning, under which adaptation to the new environment is facilitated. Social learning, as a learning process that takes place in arenas of social interaction (such as work meetings, markets, religious encounters, or group hunts), might be as important or more important than learning processes based on more individualistic experiences.

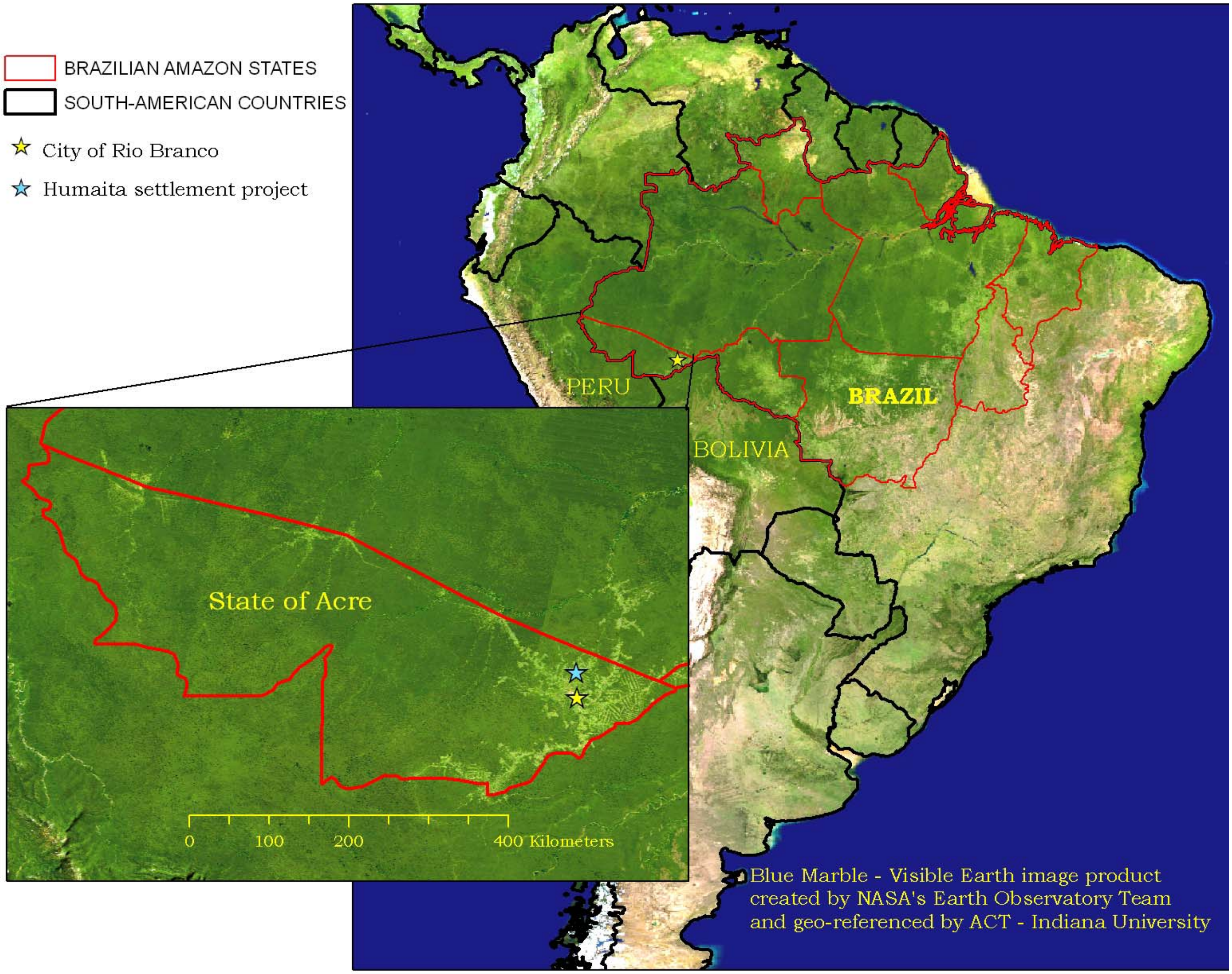
The theoretical basis of social learning is rooted in experiential learning (Kolb, 1984) and on participatory decision-making. Its conceptual body is still scattered throughout the social sciences and needs to be better defined (Goodin, 1996; Pahl-Wostl, 2002). Nevertheless, it has been gaining strength in the study of human-environment systems, particularly in the fields of adaptive management and integrated assessment, and in discourses involving questions of sustainable development within the human dimensions framework (Gunderson et al., 1995; Pahl-Wostl 1995 and 2005). Some of the main attributes of processes of social learning include the build-up of a shared perception of problems among actors, build-up of trust as a base for critical self-reflection, recognition of mutual dependencies and interactions, and engagement in collective decision and learning processes (Pahl-Wostl, 2002).

Processes of social learning, when reasonably understood, might represent an important opportunity to understand decision-making under adverse and uncertain conditions, or when information about the factors affecting decision-making, and its complex web of interactions is incomplete (Pahl-Wostl, 2002). Social learning processes might be used as tools to address some of the changes that take place as frontiers mature, such as land-use and cover change (LUCC) and socio-demographic transitions impacting the overall landscape of a region, or the agrarian structure of a colonization area.

In this dissertation, I explore land-use decision-making in an aging land reform settlement in the Brazilian Amazon. Specifically, I am focusing on how farmers respond to limited access to the information and to opportunities that are typical of the agricultural frontier context they live in, and the social learning processes that emerge in response. In this process, I analyze the interactions among variables affecting families, communities and the agrarian structure[3] of the settlement, and the land-use and land-cover changes resulting from these interactions (LUCC). The overall objective is to examine relationships between land-use decision-making at the level of farm-lots, and settlement-level conditions (e.g. infra-structure), policies and processes. The study site is a government sponsored colonization project in the State of Acre, Brazil (Western Amazon region), named Humaitá settlement project (P.C. Humaitá, see Figure 1.1).

[3] The following definition of "agrarian structure" will be used throughout this dissertation: "The term *agrarian structure* denotes all of the existing and lasting production and living conditions found in a rural region. It comprises social, technological, and economic elements and determines the achievable productivity, income and its distribution, and the rural population's social situation. The agrarian structure includes the system of land tenure (social agrarian structure) and the system of land management (technical and economic agrarian structure)" (Kuhnen, 1982).

Figure 1.1 - The study area:



This dissertation addresses the conditions underlying variations in land-use decision-making and livelihood choices affecting the permanence of settlers in areas of agrarian reform, and their land-cover consequences over the lifetime of the settlement project. It examines interactions between farmer lots, environmental conditions of the lot (soil, water), family characteristics (organization, size, and composition), and the spatial context of the lot. Particularly, it will address the following questions and hypotheses:

Question (1) What are the rates of land-cover change since the beginning of settlement at the level of farm lots, social groups of farmers[4] and the whole settlement?

Land-use and land-cover change might be seen as the evolving human footprint on new colonization areas and elsewhere, telling the story about migrant households and the economic cycles of agro-pastoral production (Brondizio et al., 2002). In this sense, common patterns of land-cover change might be observed among lots sharing common attributes (or might be hypothesized), such as belonging to the same cohort[5]. In P.C. Humaitá, the study site used for this dissertation, it was not possible to test the cohort effect, once roughly 95% of the families were settled throughout a single period of time. Instead, I tested for differences in land-cover rates among different social groups of farmers, according to their economic and occupational experience. The hypothesis to be tested in relation to this question is:

Hypothesis 1 (H1) - *Variation on rates of land-cover change between farmers belonging to different social groups is larger than the same variations observed among farmers belonging to the same social group, during the 1975 – 2003 period of analysis.*

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[4] Three groups of farmers are being considered: a) local/ex-rubber tapper farmers, b) colonist (migrant) farmers, and c) land investors (outsiders buying land in the settlement), to be explained in detail further.

[5] Cohorts correspond to groups of migrant families arriving at similar periods at the frontier; land-cover changes in lots of migrants arriving between 1970 and 1973 (cohort 1970-73) might be different from the ones observed in lots of migrants arriving between 1974-1977 (cohort 1974-77). A research design based on the cohort effect over changes observed in land-cover was used in McCracken et al. (1999) and Brondizio et al. (2002).

The underlying assumption on testing this hypothesis is that farmers belonging to the same group share a similar background, experience, and preference for particular production systems, and might adopt land-use strategies that respond in a way similar to the factors of uncertainty they face in a day-to-day basis. The rationale for this hypothesis is further explained in Chapter 2.

Question (2) How do differences in land-use strategies at the farm level reflect variation in the spatial context (time-distances[6] to urban centers) and in access to agricultural credit?

Access to local urban centers and access to agricultural credit are believed to be two important factors influencing land-use decision-making (Helfand, 2001; Alves, 2002). Farmers face uncertainty in both terms: roads are frequently non-trafficable, unreliable or non-existent; and credit involves uncertainty in the capacity of repayment. I explored the relevance of these variables in land-use decision-making through a Multinomial Regression Model, testing the following hypotheses:

Hypothesis 2A (H2A) – *Time-distances from farm lots to local urban centers are significant for explaining variation in land-use strategies adopted by farmers.*

Hypothesis 2B (H2B) – *Enrollment in agricultural credit programs is not significant for explaining variation in land-use strategies adopted by farmers*.

Typologies for land-use strategies have been established based on the variability of land-use systems found during fieldwork, and on their capacity to reflect theoretical relationships between land-use systems and the two variables of interest: distances to urban

[6] This is a measurement of distance based on road network conditions throughout the year, and calculated through network analysis, a technique used in Geographical Information System (GIS).

centers and access to agricultural credit. The rationale for each of these hypotheses is further explained on Chapter 3.

Question (3) What is the role of farmer income, level of education, possession of titles to land and credit history on explaining credit adoption rates among farmers during the past 5 years?

The use of agricultural credit involves uncertainty on the capacity of repayment, but might also contribute to reduce risks related to future income and to eventual emergencies, as shown by Chibnik for the Peruvian Amazon (1994). He noted that the use of credit was affected by factors such as land tenure, income, farm-lot size, size of households, access to markets and farmers, previous credit experiences. Credit might be ineffective to reduce income uncertainties, if only better endowed households, or the ones possessing titles to land, have access to it. Farmers' previous credit experiences might also affect the likeliness they engage in credit programs. If re-payment of credit loans had been problematic in the past, or if the outcomes of engaging in such programs did not achieve the expected results, farmers might be unwilling to engage in future programs, even considering that credit policy is extremely variable, and that credit rules might be more favorable in the future.

Null Hypothesis 3 (H3) – *Neither household income, level of education, possession of titles to land, or credit history are significant for explaining credit enrollment variation across households from 1998 to 2004.*

I propose to explore these questions and this Hypothesis through a Binomial Logistic Model that has credit enrollment as a binary dependant variable, and household income, level of education, possession of titles to land and credit history as explanatory variables. Further explanation of Hypothesis 3 is provided in Chapter 4.

Question (4) How do differences in access to urban centers and land-use/cover change reflect different rates of lot consolidation?

Lot turnover and consolidation comprise one of the most serious problems affecting Amazon colonization projects today. Lot turnover might be understood as the replacement of a previous owner of a lot by a new one, while lot consolidation refers to a single owner acquiring more than one lot in a settlement project. There are two main "reaction chains" (or processes) that might lead to lot turnover and consolidation: the first takes place preferentially during the early stages of frontier development, and appears mainly as a consequence for the lack of infra-structure development. Settlers find themselves isolated from markets to commercialize their products, and suffer from the absence of health and education services (Martine, 1981; Moran, 1981). They either abandon their lots or sell them at low prices to third parties. The second process happens during a more advanced stage of frontier development, and refers to the valorization of land, as infra-structure develops (Ozório de Almeida and Campari, 1995). Farmers face capitalization incentives as competitive demand for land and land speculation raise the prices of their land, resulting in farmers selling their land for much higher prices, when compared to the first group. Which of these two processes is more relevant to picturing actual lot consolidation rate in the P.C. Humaitá study area? This question led me to the following hypothesis:

Hypothesis 4A (H4A) **-** *Lot consolidation is higher where time-distance to local urban centers is higher.*

Another related question which has been receiving considerable academic and political attention in Amazon development and conservation debates, regards the impact of lot turnover and consolidation on deforestation. The Turnover hypothesis of deforestation, formalized by Campari (2002) states that this process is a central mechanism leading to deforestation. After selling their lots to newcomers, farmers move forward into the frontier, where they clear forested areas as a form to secure rights to land. Later, as frontiers mature and infra-structure develops, these areas are also sold to newcomers or capitalized entrepreneurs, who typically buy many lots and consolidate deforestation into large cattle-ranches. Hypothesis 4B tests for a relationship between lot consolidation and rates of deforestation:

Hypothesis 4B (H4B) – *Deforestation rates are higher where lots are consolidated into larger properties.*

Both Hypotheses 4A and 4B are tested through correlation analysis using indexes for time-distance, lot consolidation and rates of deforestation observed at the farm-lot level. Details on the index for lot consolidation and on the rationale used to test each hypothesis are provided in Chapter 5. The outcomes of this analysis are compared to two other settlement projects in the Amazon, based on recent work on land-use, lot turnover and land reform in the Brazilian Amazon (Ludewigs et al., under review).

Question (5) What kinds of economic systems (e.g. land-use, fisheries, off-farm employment) do farmers adopt during their life in a settlement? How do these systems change? What patterns emerge? Do different farmers specialize and/or diversify their economic portfolio?

Research findings of McCracken et al. (2002) at the Altamira colonization settlement confirmed that households engaged increasingly on land-use and other income-related diversification strategies (such as employment, commercial activities and remittance) as a function of time spent on the farm-lot (or aging) and along frontier development (except for conditions where soil quality constrains the number of land-use options). I propose to test whether this pattern can be re-confirmed for P.C. Humaitá settlement:

Hypothesis 5 – *Households present a wider range of related income activities in 2003-04 than when they arrived at the settlement. As households mature on the frontier, they engage in an increasingly larger number of economic activities, aiming at diversifying income and minimizing risks.*

I addressed this hypothesis by descriptive analysis derived from household surveys and participant observation on land-use decision-making and by comparing previous with actual economic strategies through analysis of variance.

The research questions were approached through a framework that combines agency (decision-making under different levels of information and social learning processes) with structural conditions affecting land-use (environmental conditions, transportation networks, agricultural credit policies and settlement policies), which are dynamically interacting with each other. Variables affecting land-use choices and farmers' reactions to them were studied through a micro-level approach using remote sensing linked to social sciences' techniques, including formal and informal interviews and survey research. A property boundary grid overlaid to satellite images, encompassing the 1981-2003 period, helped to analyze land-use strategies and land-cover change taking place during this time frame, at the levels of farm lots and settlement, and their larger regional context. The research design and data analysis allowed for comparison with growing volume of literature on land reform, lot turnover, livelihood strategies and other factors affecting land-use and land-cover change in the Amazon and elsewhere.

1.2 - Dissertation motivation and significance

The idea of this dissertation started with the following question: how to analyze the complex patterns of interaction present in diversified land-use systems from a holistic perspective and based on concepts of sustainability of resource use as evaluation parameters? The idea of adapting systemic, integrative approaches to deal with limiting factors and potentialities of sustainable land-use systems for the Amazon is not new, and there are already substantial contributions to it (Anderson, 1990; Wood and Porro, 2002; Zarin et al., 2004). Given that I have been working in the State of Acre since 1998, I participated in many inter-disciplinary workshops for developing socio-economic-ecologic diagnostics in rural communities and participatory research-extension agendas. As a long-term challenge, such integrative approaches require intensive dedication. The State of Acre seemed to offer an appropriate environment to develop my research questions. The history of Acre offers an important example of social movements shaping the use of extractive resources such as the rubber tree. In this sense, a rich laboratory on the interaction between social, economic and bio-physical drivers of land-use change already existed.

The current federal government policy of road network expansion (*Avança Brasil* Program) may increase access to markets and therefore change the structure of incentives affecting land-use in the Amazon. Other infra-structure projects are expected to exacerbate the continuous process of frontier expansion. On the other hand, deforestation rates for the Brazilian Amazon announced by the National Institute for Space Research in Brazil (INPE) for the years 2004-2005 and 2005-2006[7] are substantially less than the rates for previous years (Nossa, 2006). According to the viewpoints expressed by some experts on LUCC in the

[7] Estimates for the 2005-2006 deforestation rates are not definitive, once they are based on a smaller sample of satellite images. Official rates of deforestation for this period will be published by INPE by the end of the first semester of 2007.

Amazon, this reduction is probably due to the combined effect of falling international prices of commodities such as, soybeans and frozen meat, and more effective monitoring of deforestation promoted by the actual federal government (Derivi, 2006). Such interplay of forces contributes toward making integrative studies on land reform, markets and land-use/land-cover change relevant for the understanding of actual and future scenarios. At the State level, the actual "*Governo da Floresta*"[8] ("Forest Government") has been promoting a detailed ecologic-economic zoning of the State's resources.[9] Acre's progressive agenda for the forestry sector and for community development opens several opportunities for research projects oriented toward balancing conservation of natural resources with regional development (Acre, 2006; ZEE, 2000).

There are factors shaping the decision-making process of colonizing families that are endogenous to the household while other factors are more strongly correlated with the social, biophysical and economic context of the settlement and with regional and national scales. Lessons derived from case studies might be important to understanding the trade-off built in multiple levels of decision making. Also pointed by Chibnik (1994), land-use choices in frontiers often involve multiple goals; integrated studies are important for addressing the farmers' rationale under such settings.

The social learning approach to households' adaptive strategies in the frontier might help to better understand the conditions that determine lot turnover rates in settlement projects, and the related consequences in LUCC and in the agrarian structure of agricultural settlements.

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[8]It's Nickname for the actual government administration in Acre, given it's orientation toward development of the forestry sector.

[9] The Ecologic-economic zoning was implemented first at the 1:1,000,000 scale (ZEE, 2000); a refined version at the 1:250,000 scale is being published by the end of 2006.

Agricultural frontiers are shaped by a combination of multiple scale factors, that might change even faster than the frontier itself (Campari, 2002). Therefore, many of the relationships observed during fieldwork in 2003/2004 might be temporary and no longer applicable. However, the driving principles that explain these relationships, such as the role of social networks and social learning in land-use decision-making within the contest of uncertainty, are probably of a broader theoretical importance for predicting and interpreting future changes. Moreover, if these driving principles are better understood, one might be able to address structural problems affecting the permanence of settlers in land reform projects in a more effective way, as well as shaping better policies for future land reform projects.

The following chapters of this dissertation aim to show that the factors driving land-use change in settlement projects in Amazonia are interrelated. More than by these factors themselves, the decision-making environment is shaped by differential access to information, depending on the temporal context within which households and settlements are analyzed. Farmers respond to uncertainty by means of social learning. Social learning takes place in several arenas of community gathering, such as markets, schools, churches, unions or meetings with INCRA (National Agency for Land Reform) staff. Thus, no single factor can explain land-use options at any time or location. Rather, I use a perspective on land-use decision-making in the Brazilian Amazon based on a social learning approach rooted in historical factors. The historical factors of relevance are focused on the outcomes of differential roles played by actors in the social arena of rural development in Brazil, as for example the paternalistic relationship embedded in historical interactions between landlords and rural workers (e.g. rubber landlords and rubber-tappers in Acre). In this dissertation, I argue that this paternalistic structure is still present and operant in the interplay between providers of public goods (Brazilian public sector) and users of public goods (Brazilian society), and may be identified in government-sponsored land reform projects. There are some patterns that emerge from this structure and that influence the outcomes of land reform projects, as for example the role of opportunity and opportunistic behavior (present in both providers and users of public goods). Opportunity and individualism were, according to Frederick Turner back in 1893, two cornerstones shaping the expansion of the American frontier toward the West (McClintock, 1986).

Next, I present an overview on some topics that are relevant to the research questions outlined above. Theories of tropical deforestation are needed to address land-use and land-cover change in settlement projects in the Amazon, and relate to questions 1, 2, and 4 of this dissertation. An overview on land reform and agrarian change (related to question 4) follows. Next, I discuss two topics that are important to all my questions: migration, frontier expansion and lot turnover, and land-use decisions under limited access to information. An overview on agricultural credit programs and how these programs relate to dissertation questions is provided on Chapter 3.

1.3 – Theories of tropical deforestation

Interest in the mechanisms of tropical deforestation started to grow worldwide by the end of the 1980s and gained breadth along the 1990s. This came in response to a growing demand for "less destructive" land-use alternatives, given the substantial increases in the rates of tropical deforestation observed since the 1970s. While most of this research has been focused on the causes of tropical deforestation, a considerable body of research has been oriented towards equity issues (how are benefits of deforestation shared?) (Kaimovitz and

Angelsen, 1998) and on understanding the trade-offs between deforestation and socio-economic development. Following examples of developed countries, it is argued that there is a transition point in developing countries where the forest conversion is reversed, and forest conservation and development go hand-in-hand establishing a win-win situation (Rudel, 1998).

Most of the research on tropical deforestation along the 1980s used explanatory models based on single factor causation. In Asia and Africa, for example, deforestation has been largely blamed on population growth (Lambin et al., 2001), while colonization policies and roads were established as the main drivers of deforestation in South America (Pacheco, 2005). There were however exceptions, including Margolis' detailed analysis on the moving frontier in Southern Brazil (1973 and 1977), and some detailed micro-level case studies in the Amazon, where actors were given varied in the frontier expansion process, and where specific attributes of locality were explored (Moran, 1981; Smith, 1982; Fearnside, 1986). These studies made a huge contribution to the understanding of household dynamics in the frontier setting.

By 1990, political and socio-economic trends in Brazil leading to Amazon colonization were already fairly well explored. Census data provided opportunities to establish correlations between in-migration and the increase in deforestation rates (Schmink and Wood, 1984; Fearnside, 1986 and 1993; Wood and Skole, 1998). Detailed analysis on the effects of colonization policies (such as agricultural subsidies and fiscal incentives for ranching) over forest conversion to agro-pastoral uses had been already performed extensively by Mahar (1979 and 1989), Schmink and Wood (1984) Hecht (1985), Fearnside (1986), among others.

A significant shift in land-use and cover change (LUCC) research priorities took place along the 1990s, as scholars began to establish multiple causality factors and levels, such as proximate and underlying driving forces of tropical deforestation (Kaimovitz and Angelsen, 1998). As the relationships observed at aggregated levels of analysis often differed from the ones observed at disaggregated levels, much attention has been put on recognizing the importance of scale in LUCC studies, as well as on creating mechanisms to investigate the conditions under which links across scales would be allowed to operate (Geist and Lambin, 2002; Wood and Porro, 2002; Lambin et al., 2001).

Multi-scale and integrated assessments to LUCC in the tropics allowed several myths to be dispelled (Lambin et al., 2001). Perz (2002), for example, noted that Amazon deforestation in the 1990s could not be understood as a cause of population increase, once a) in-migration to the region dropped significantly; and b) urbanization during the 1990-1996 period led to negative rates of population growth in rural areas in the same period. Moreover, policies causing forest conversion to pastures in the 1980s (subsidies, tax incentives) could not be blamed either, since these have been dropped or substantially reduced by the early 1990s. In this sense, Lambin et al. (2003) pointed to three sets of factors leading to regional variation in LUCC: a) historic conditions specific to each region; b) different combination of causes leading to LUCC; and c) the feedback mechanisms of LUCC itself (which can affect farmers choices depending on the mediating factors such as institutions).

More recent debates on LUCC might be seen as following two main theoretical approaches (Pacheco, 2005): a) Analysis centered on decision-making actors; and b) Structures posing differential constraints to individuals. The first one has been traditionally lead by neoclassical economics, with land-use choices being driven by profit maximization.

Some developments of this type of approach include the ongoing debate on agricultural intensification in the context of the trade-off between forest conservation and economic growth (Angelsen and Kaimowitz, 2001; Lee and Barrett, 2001). By addressing the impact of new technologies over forests, most authors have been challenging the "full belly hypothesis," under which deforestation can be better controlled once minimum livelihood conditions are met (Lee and Barrett, 2001). Instead, pressure over forests is expected to increase as new and profitable technologies overcome capital and labor restrictions. However, and according to Lambin et al. (2003), as mentioned above, deforestation factors are site and context specific, and thus require specific mediating institutions and policies (Angelsen and Kaimovitz, 2001). Other debates following actor-based approaches include works in institutional economics, such as land markets as drivers of deforestation (Ozório de Almeida and Campari, 1995), and the role of property rights enforcement on curbing down deforestation levels (Schneider, 1995; Alston et al., 1999). A more detailed discussion on institutional economics and LUCC is provided on Chapter 5.

Biophysical factors conditioning land-use and Household Lifecycle Theory (HLT) are examples of type (b) approach (structures posing differential constraints to individuals, following Pacheco's interpretation (previously cited, 2005)). Poor soils or steep terrain might determine the location of roads and other transportation networks, which in turn influences spatial location of land-use changes (VanWey et al., 2005). HLT combines earlier work by Goody (1958) on household stages as the focus of social reproduction with the household-farm economy approach developed by Chayanov ([1925] 1966) for Russian peasants (VanWey et al., 2005). HLT establishes relationships between the extent and pace of agricultural cultivation with cycles of household expansion, dispersion and aging, and has been recently used to address land-use change at the farm-household level in the Amazon (Walker and Homma, 1996; McCracken et al. 1999). In the Transamazon region, land-use has been shown to vary according to phases of lot expansion and consolidation and to regional and national conditions in Brazil (McCracken et al., 1999; Brondizio et al., 2002; and Moran et al., 2002). While constrained by macroeconomic conditions and market opportunities, variations on the extent and rate of deforestation are related to differences on time of settlement, availability of capital and technology and on changes on household composition and land-use strategies as they mature in the frontier (Brondizio et al., 2002).

Recent models on human-environment interactions have been driving away from the traditional approach of equilibrium analysis and fully rational actors, to assume more broadly conceptualized rational actors (VanWey et al., 2005). Thus, a wider scope of modeling possibilities is now available to analysts, who may choose attributes of agents based on assumptions of the following types: a) level of information available to agents; b) different preferences among actors on how outcomes are shared when the economic activity involves public goods or common pool resources; and c) type of calculation involved on decision making: full analysis vs some type of heuristic[10] method (ibid, 2005). This last one, especially, might take into account the level of experience of the decision-making actor whenever modeling land-use change. It is of special interest for the uncertainty based approach used in this dissertation, if we consider that uncertainty affects individuals in different manners, according to their experience on land-use decision making.

[10] *heuristic*: involving or serving as an aid to learning, discovery, or problem-solving by experimental and especially trial-and-error methods <*heuristic* techniques> <a *heuristic* assumption>; *also* **:** of or relating to exploratory problem-solving techniques that utilize self-educating techniques (as the evaluation of feedback) to improve performance <a *heuristic* computer program> (Merriam-Webster, 2006).

1.3.1 – Spatial models of deforestation and road network designs in settlement projects

Much tropical deforestation has been found to be spatially correlated to the location of roads and transportation networks (Alves, 2002; Chomitz and Gray, 1996). The type of road network design might affect rates of deforestation and forest fragmentation in land reform projects (Batistella et al., 2003). It affects also farmers' access to markets, a critical factor for the effectiveness of land reform projects. The most common type of road network design (or road architecture) found in Amazon settlement projects is the *fishbone* pattern. It can be found along the Transamazon settlements (see Moran 1981) and along several settlement areas in Rondônia (Batistella et al., 2003). It is based on several secondary roads connecting perpendicularly to a main road. Since roads are projected to respect regular shapes and sizes of farm lots, most of them follow straight lines, with no regard to relief or watershed drainage. Other road network designs include the ones that follow the watershed drainage system, considered more effective for the maintenance of road quality and soil conservation, as for example in Machadinho do Oeste, described by Batistella et al. (2003). Regions subjected to subsequent colonization projects, such as along the BR-163 and the Santarém municipality, present a "mosaic" of settlement patterns, including fishbone, and an irregular land occupation system resulting from historical trends in land occupation. Other settlement patterns are present in the region. P.C. Humaitá, a re-distributive land reform settlement in Acre, used as a case study for this dissertation, has a radial road network design, with several roads connecting to a central village. This design provides better connection between secondary roads and a main paved road that leads to the local urban center (Rio Branco), but like the fishbone pattern, it was not conceived based on the watershed drainage system.

1.4 - Land reform, agrarian change and land-cover change in Brazil and in the Amazon

The land reform program in Brazil was substantially intensified during the second half of the 1990s, with 370,000[11] families being settled from 1995 to 1999 (Sparovek, 2003). Nevertheless, and as already mentioned in the introductory paragraph, land inequality in Brazil remains among the highest in the world (Hoffmann, 2002). Land reform programs have been used to address not only land re-distribution gaps, but also demographic distribution problems across different regions of Brazil, by settling landless families on public lands. Poor planning in most colonization projects has been leading, however, to high rates of lot abandonment and lot turnover, which lead to several socio-economic and environmental implications, as discussed in the next section. What is the fate of public land in Brazil, and in particular in Amazônia? How much of it is being devoted to land reform under the premise of "fighting inequality" of access to land, but actually working as a frontier expansion mechanism that re-enforces the land distribution gap?

A recent study on lot turnover and deforestation in the Brazilian Amazon (Campari, 2002) showed *Gini* index increases ranging from 0.14 to 0.42 in five out of six land reform settlement projects (in the states of Mato Grosso and Pará) during 1981–1991, thus showing clear evidence of land reconcentration in these areas. Lot turnover is connected to a wide range of social and environmental problems, such as lot abandonment, failure of investments, land conflicts, migration to urban areas, deforestation, and resource depletion. Explanatory models of lot turnover include the frontier expansion model (Ozório de Almeida and Campari, 1995; Alston *et al.*., 1999), also referred to as the Turnover Hypothesis of Deforestation[12] (Campari, 2002), and the neoclassical economic approach, in which, under

[11] This amount corresponds to 53% of the total number of families settled from 1970 to 1999.
[12] A description of the Turnover Hypothesis of Deforestation is provided further in this chapter

favorable institutional settings, market forces select the most competitive farmers and determine the most efficient size of agricultural property (Binswanger and Deininger, 1997; Deininger 1999). It is argued, however, that these models cannot be used to effectively address changes in the agrarian structure and landscape of government-sponsored settlements in the Amazon, because: (1) they are based on a broader context of frontier expansion, which includes spontaneous colonization areas; (2) they do not take into account differences in social and political power among stakeholders competing for land resources, nor the dynamism and multiplicity of factors driving frontier expansion in the Amazon (Browder and Godfrey, 1997; Campari, 2002) ; and (3) favorable institutional settings are absent in most frontiers. These outcomes might be regarded as far from the ones envisioned by the original goals of land reform programs.

Lot turnover and land concentration are inter-related but distinct processes. Lot turnover is defined as the transference (through selling, exchange or other arrangements) of the farm lot from one family to another. In colonization settlements, it usually involves concession of use rights, through purchase receipts; while many lots are turned over as individual units, others are aggregated to neighboring lots to form a new, larger lot, a process we call land concentration. In some cases, this process can be referred as re-concentration, that is, a previous large farm is divided into farm lots (e.g., during agrarian reform), and later purchased by a single owner, thus, re-concentration. Campari (2002) for instance, uses the term re-concentration for a range of situations following lot turnover. Two other equally relevant processes to the agrarian structure of land reform projects are lot abandonment and lot fragmentation (when the lot is subdivided into smaller units).

In this dissertation, I address the importance of land reform planning and policies (such as road infra-structure and agricultural credit) on land-use choices by settlers, and the effect of these choices in the structural changes observed in a land reform settlement. The feedback of structural changes over land-use choices is also important (such as land clearing restrictions imposed by IBAMA, the environmental protection agency in Brazil), and are also discussed. The triggering mechanism linking farmers' land-use choices with the most important structural changes is the process of lot turnover.

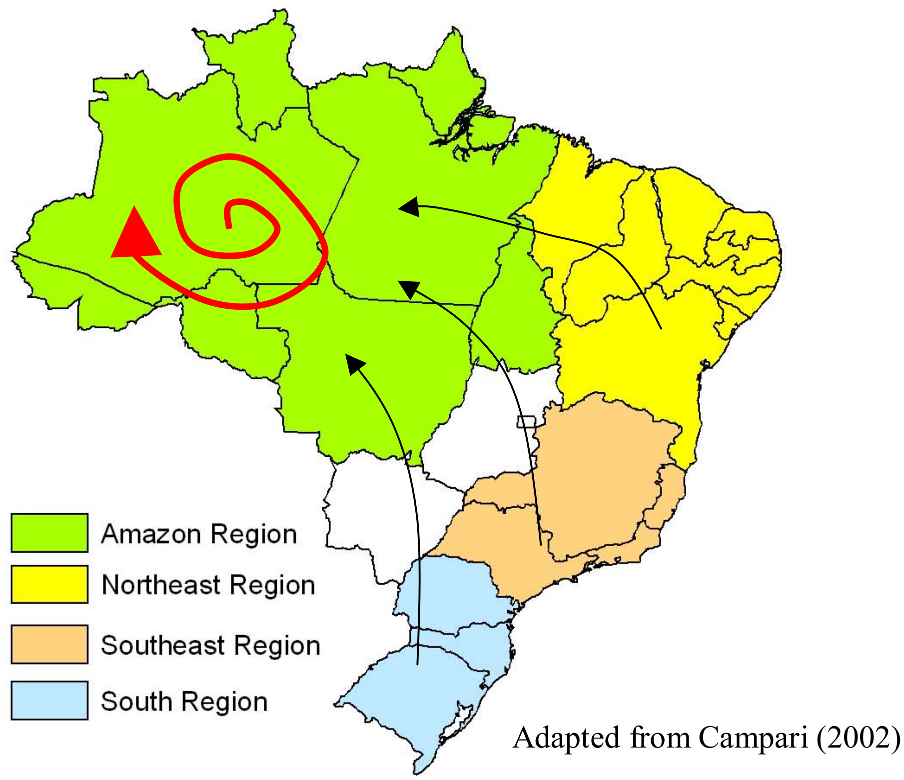
1.4.1 – Migration, frontier expansion and lot turnover

Settlement and re-settlement of rural families constitutes a worldwide phenomenon characterized by inter- and intra-regional migration, and defining the expansion and dynamics of agricultural frontiers (Nelson, 1973; Redman, 1999; Whitten, 1987; Merrick, 1978). Neoclassical dual migration models state that migration responds to differential expected incomes between origin and destiny (Todaro, 1980). Alternatively, migration choices are made based on the increase in human capital stock to be provided in the arriving site, once income differentials alone might not explain variation regarding migration decisions (Massey et al., 1994; van Wey, 2001). Frequently, migrants might be drawn from landless families in more densely populated rural areas or by reasons linked to environmental events, such as prolonged drought (Moran, 1981; Wood and Carvalho 1988; Ozório de Almeida and Campari, 1995; Browder and Godfrey, 1997). These migrants are eager for a chance to work their own land as a pathway to prosperity (Ozório de Almeida and Campari, 1995). Sometimes, facilities to acquire land titles or to establish rights of use to land are offered by government programs (Moran, 1981; Smith 1982; Whitten, 1987). In other instances, such as spontaneous migration in Amazônia, settlers occupy public lands informally, and disputes with private estate enterprises have led to increasing social tension in the region (Sawyer, 1984; Schmink and Wood, 1992; Alston et al., 1995).

During the 1970s and 1980s, it is estimated some 3.5 million people[13] migrated from elsewhere in Brazil to the Amazon (IBGE, 1991). Contrary to what is commonly taught, most of the initial rural-rural migration was soon replaced by a rural-urban migration, contributing to the rapid urbanization of the Amazon (Browder and Godfrey, 1997). During the late 1980s and 1990s, however, the inter-regional migration pattern was replaced for a intra-regional one (Figure 1.2). Another important trend is that migration is followed by high rates of occupational changes (ibid: 260). In the rural sector around new settlements, for example, where risks of crop and market failure are high, migrants seek off-farm employment as an insurance against income shortfalls (Moran 1981; Ozório de Almeida and Campari, 1995). In the frontier setting of the Amazon, however, wage labor markets do not advance at the same rate as expansion of the peasant economy (Sawyer, 1984). Thus, many farmers facing livelihood constraints end up migrating to urban centers (Martine, 1990; Moran, 1981) or to new frontier areas (Ozório de Almeida and Campari, 1995 – see discussion on turnover hypothesis below).

[13] Estimation based on IBGE census data for 1970 and 1991: total increase in Amazon population was of 5.7 million (158%), while Brazil's population increased by 57 million (61%) during this period.

Figure 1.2 - Changing migration dynamics in Brazil:



1970s and early 1980s: Inter-regional migrations

Late 1980s and 1990s: Intra-regional migrations

Relocation of settlers, along with incentives for large-scale farmers has been a major force shaping land-use and land-cover change in the Brazilian Amazon during the past two decades. This holds for both spontaneous migration, where expelled peasants move towards the expanding frontier (Schmink and Wood, 1992; Alston et al., 1995), and in government-sponsored settlement projects (Ozório de Almeida and Campari, 1995). Since the early 1970s' frontier expansion began receiving not only stronger support from the government through the construction of major road networks, connecting "men with no land to land with no men"[14] (Moran, 1981; Smith 1982), but also to guarantee territorial sovereignty through occupation (Mahar, 1989). Settlers migrating from the Northeast, South and Southeast regions of Brazil have remained on their assigned lots to different degrees. A large percentage of families ended up abandoning their lots or selling them to nearby urban merchants or to large cattle ranchers, and have either migrated into local urban centers or relocated to new settlement fronts (Ozório de Almeida and Campari, 1995; Schmink and Wood, 1992; Alston et al., 1995). This process contributes to the poor performance of land reform programs in helping to narrow the *Gini* indexes in Brazil.

Some of the major factors leading to high turnover rates in many of those settlement projects include the lack of all-weather roads (Nelson, 1973, Moran 1990), government agents' use of poor criteria to select settlers (Moran 1981:146), and the overall lack of environmental baseline studies and institutional support (Moran, 1981; Smith, 1982; Fearnside, 1986). Others found that the lack of property rights of pioneer settlers in spontaneous migration fronts, such as in the "contested frontier" of South of Pará State, made them vulnerable to be expelled by ranchers, who claimed the land as their own (Schmink and Wood, 1992). Alternatively, ranchers buy untitled land already deforested, and later obtain land titles to it (Alston et al., 1995). As frontiers develop, rents for land tend to be much higher than returns to labor, and settlers are encouraged to sell their land and move on (Ozório de Almeida and Campari, 1995). Dropout rates up to 95% in the first two years were observed in some colonization projects, as for example in the Bolivian Alto Beni (Nelson, 1973).

[14] This was the Brazilian government slogan for PIN (National Integration Plan) launched by the military in the 70's.

In the Transamazon colonization scheme, access to basic services such as health and credit was initially good. The quality of these services decreased, however, after an unplanned increase in the flux of in-migration overrun government's capacity to deliver basic services (Moran, 1984:292). Poor soils, steep terrain, malaria and commercialization problems contributed to aggravate the problem. Lot abandonment rates along the Transamazon were reported to be around 30% in the first decade and continued to climb in the second decade of settlement (Moran, 1993:59). A recent study shows that lot turnover rates in this region have been closely correlated with soil quality and with time of arrival at the frontier (Moran et al., 2002). Altamira's "*terra roxa*" soils allow for higher crop productivity in a limited portion of lots benefited by such soils. It was found that local residents and early settlers (arriving in Altamira before 1975) were able to choose lots with higher proportion of such soils, and that most lots put for sale by 1975 were of lower quality soils, suggesting that lot turnover was higher on the latter. It was found, also, that landowners that purchased lots with higher percentage of *terra roxa* soils tended to have a more diversified land-use portfolio and remain on their land holdings.

Dropout rates also have been high in the state of Acre, Western Amazonia. Pedro Peixoto Colonization Project, for example, established in 1979 and the largest settlement project of the state, has 9,174 INCRA[15] registers issued (records of land sales and/or settlement) for a total of 4,225 lots, pointing to the accentuated turnover rate in course in this settlement (ZEE, 2000). Such problems also bring implications to an increase in deforestation rates. As for Rondonia, very high rates of lot abandonment during early stages of settlement were reported, especially in regions severely attacked by malaria (Martine, 1990).

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[15] INCRA – National Institute for Colonization and Agrarian Reform

Migration histories of individual settlers have been found to be one of the best predictors of agricultural performance in the Transamazon frontier (Moran, 1981:91), thus influencing turnover. Farmers involved in entrepreneurial activities, such as commercialization, transportation, or intensive agriculture normally experienced a single migration event. Conversely, subsistence and wage-labor oriented farmers have been correlated with multiple migrations (ibid: 92), and have a high likelihood of selling their land and turning exclusively to wage-labor, or beginning anew in another frontier (ibid: 158).

Land-use options reflect opportunities and preferences upon which most farmers make their decisions. Under frontier conditions, however, farmers face uncertainty in relation to a wide range of factors, such as access to markets and to credit, weather conditions, crop prices and access to technologies able to ensure crop productivity. How do agents make decisions concerning economic strategies, including land-use allocation, under the context of limited access to information? A few insights into recent work on uncertainty might throw some light on this issue.

1.4.2 - Farmers' decision-making under risk and uncertainty

Neo-classical economists have traditionally assumed complete information when dealing with decision-making problems. Rational individuals seeking income maximization by giving priority to payoffs regardless of the variance have been treated as *risk indifferent*, while individuals concerned with this variability have been called *risk sensitive*. Real-world decisions, however, are frequently made under conditions of incomplete information (uncertainty), which makes the decision-making process more complex to model.

The process of building up information might be seen as an experiential process of decision making, where the number of participants and levels of action might play an important role, as suggested by Claudia Pahl-Wostl (2002). This author criticizes the deterministic approach in the management of fresh water in Switzerland and elsewhere. Under such an approach, water management agencies follow rules based on linear models of demand and supply. The problem of such models is that they account only for variables with known behavior, or ignore the non-linear behavior of many variables, giving rise frequently to estimations that are unrealistic, and to situations that agencies are not prepared to handle. Moreover, decisions are centralized under a limited number of actors, making it difficult to incorporate the dynamic character of the hydrological cycle. As a consequence, the price paid by society is often too high. The author proposes a new approach to urban water management in Switzerland (ibid). Her argument is that by changing the institutional setting under which it is currently centralized, more accurate knowledge about patterns of resource-users interactions could be produced. Natural resources subject to uncertain outcomes would be better managed under a more dynamic and intuitive approach, based on the participation of society and social learning processes.

Anthropologists coping with decision-making in peasant economies propose that instead of maximizing payoffs or "economizing," farmers are generally more concerned with minimizing risks (Ortiz, 1967; Johnson 1971; Barlett 1982). They defined such strategies as being "risk-averse," and defined risk as the probability of returns to investment that fall below a critical "disaster level" (Johnson 1971; Barlett 1982). Earlier, risk had been defined as a simple measure of consistency of returns (Freund 1956; Lin et al. 1974). Others claimed, however, that the chances of disastrous outcomes influence decision-making more than the consistency of returns (Boussard and Petit, 1967; Kunreuther and Wright 1979).

Also in contrast to the neo-classical "economizing" concept, it has been argued that "satisficing" takes place (Chibnik, 1990 and 1994). The "satisficing" idea stems not only from balancing between maximizing outcomes and minimizing risks, but also considering that the previous knowledge about the payoff structure is incomplete. While analyzing the decision-making process of *ribeireño* peasants along the Amazon River in the Iquitos region, Peru, this author calls attention to the fact that instead of discrete categories separating risk from uncertainty, there is actually a *continuum* from uncertain to risky decisions, according to the amount of information available (ibid, 1994). He notes also that since most farmers make land-use decisions directed by multiple inter-connected goals, poor information in relation to a decision involving one goal often affects other decisions oriented toward other goals.

Uncertainty is both endogenous and exogenous to land-use decision-making in expanding frontiers. Forest conversion to pasture might respond, for example, to the lack of enforcement of property rights (Schmink and Wood, 1992; Ozório de Almeida and Campari, 1995; Alston et al., 1995) and difficult access to markets[16] (Moran 1981; Sawyer, 1984; Ozório de Almeida and Campari, 1995). On the other hand, farmers might respond to income uncertainties by seeking larger households and by investing in subsistence strategies (Wilk, 1991), by buying more land (Hecht 1993), investing in cattle (Mertens et al., 2002), by different types of labor contracts (Ortiz, 1990), or by contracting credit for investments in agriculture (Chibnik, 1994).

[16] Forest conversion to pasture relates also to macro-economic conditions, and to market opportunities. Economic strategies adopted by farmers in settlement projects respond to multi-scale factors, as referred elsewhere along this dissertation.

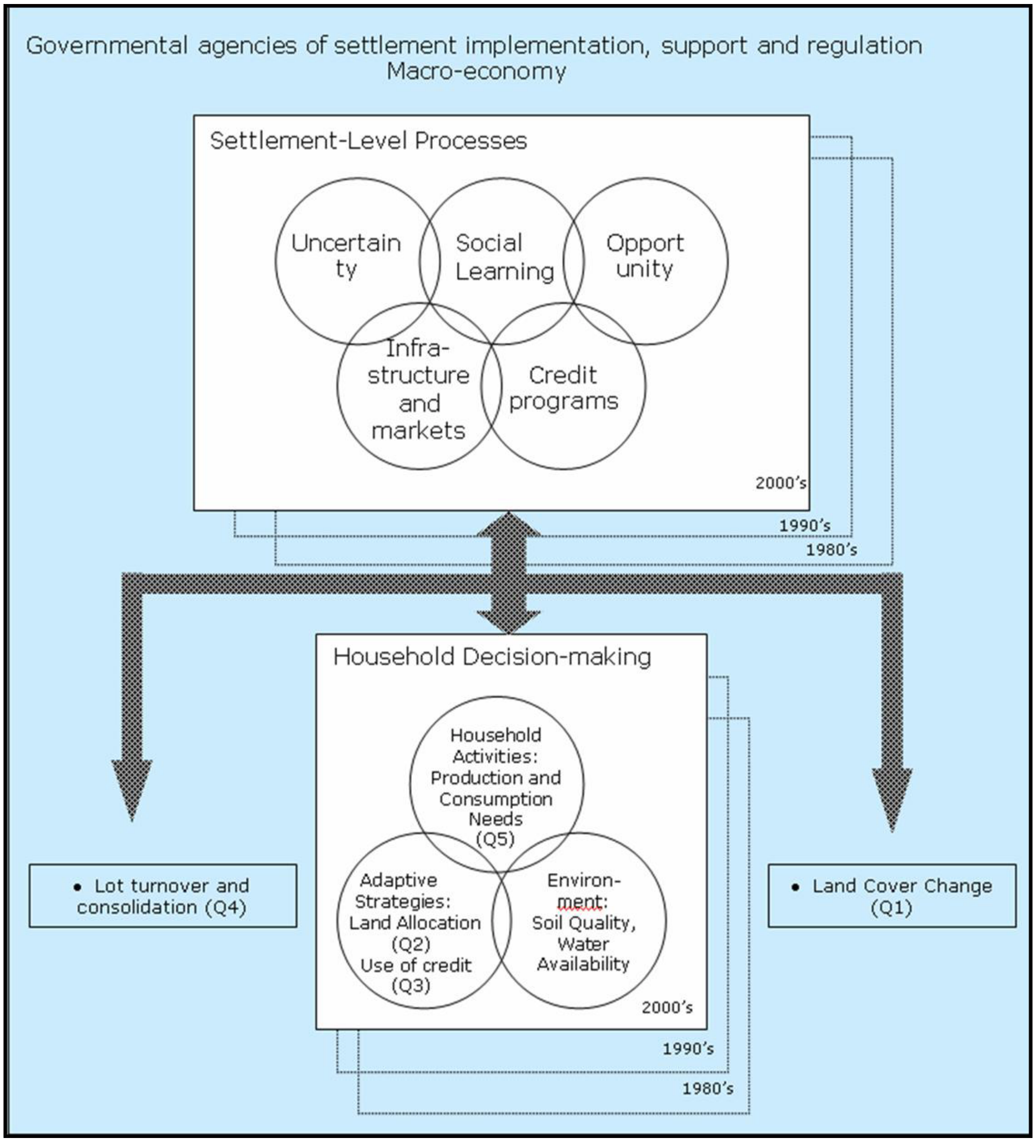
1.5 – The conceptual model

The theories on tropical deforestation and land-use decision-making under risk and uncertainty, explored above, help to address land-use and land-cover change in settlement projects in the Amazon. The connection of the latter with the main objective and with the five research questions that compose this dissertation depends, however, on an approach that embeds farm-lot agency into the settlement-level structure in a bi-directional relationship, and explores the outcomes from this relationship at both farm-lot and settlement levels.

The approach used to investigate land-use acknowledges external and internal factors affecting economic and demographic decisions among farming families (see Figure 1.2 – conceptual model). Following Chibnik's argumentation, I refer to decisions made by farming families under different levels of information and during different periods of their lives in the region as "decisions under risk/uncertainty," meaning these decisions fall within the risk – uncertainty *continuum.*

Figure 1.3 is intended to connect LUCC at the farm-lot level and at the settlement level. Households allocate land and capital strategically to deal with differential access to urban centers (infra-structure constraints) and to agricultural credit (Questions 2 and 3), while labor and environmental conditions influence LU decisions at the level of farm-lots, but compound to reflect on settlement-level processes such as lot turnover and consolidation (Question 4), and land-cover change (Question 1). As households and settlement age, changes on household economic strategies take place and contribute to various forms of livelihood to co-exist in the region (Question 5).

Figure 1.3 - Conceptual model of land-use allocation under conditions of uncertainty:



The model is intended to integrate local level processes and decisions with structural conditions shaping these decisions and their larger social and environmental outcomes. This analysis contributes to a growing body of work on integrated assessments of land-use in areas of agricultural expansion and colonization. Understanding the role of transportation networks, proximity to markets and credit is important because it is believed that such factors influence land-cover change and property turnover in colonization areas. Lot dropout leads normally to a wide range of social and environmental problems, such as accelerated deforestation, lower standards of living for landless families and land conflicts on new frontiers. Land concentration emerges and contributes to an increasing inequality in rural Brazil, also affecting rates of forest conversion to pastures.

At the regional level, unequal land distribution is also rooted in factors affecting lot turnover, which has been linked to increasing urbanization (Sawyer 1987; Ozório de Almeida and Campari, 1995) and with class conflict (Schmink and Wood, 1984 and 1992). Complex intra-regional migration webs and their links to land-use decisions under different levels of information in the Amazon deserve further scientific understanding, once they affect regional development and land-cover dynamics.

The conceptual model helps to frame each research question and presents a way to scale-up in the analysis of land-use decisions from individual farm-lots to its larger scale effects. Land-use allocation is initially investigated at the farm-lot level, following methodology developed by McCracken et al. (1999), Brondizio et al. (2002), and Moran et al. (2002)[17]. Then, following this methodology (see details in the methods section of Chapter 2), I will link household interviews to landscape-level remotely sensed images, encompassing the whole settlement. Besides farm-lots and settlement, this research also uses different typologies for farmers' cultural background and economic orientation (details in Chapter 2) and for land-use strategies (details in Chapter 3) as functional units of analysis.

[17] In most cases, households and lots correspond to each other by a one-to-one relationship. In cases where farm-lots have more than one household, they are divided by corresponding units of area management for each household, thus representing a fragmented lot.

This allows me to look for differences on Land-use - Cover Change (LUCC) across specific groups of farmers (such as local ex-rubber tappers, colonist farmers and land investors) and to test for the significance of road network conditions and access to agricultural credit on explaining different land-use strategies. It is expected that areas better served by roads, for example, might exhibit a different land-use pattern when compared to less favored areas. Also, a group of farmers already present at the site by the time of settlement implementation (i.e., rubber tappers) might exhibit a different land-use pattern compared to groups of farmers arriving later. These are some of the questions I explore in the chapters that follow.

1.6 - Study Area

1.6.1 - Historical background and context

This research took place in the State of Acre, located in the Western Brazilian Amazon, bordering the countries of Bolivia and Peru, and located between latitudes 7^{o} and 11^{o} South and Longitudes 66^{o} and 74^{o} West (Figure 1.1). Acre was originally a Bolivian territory, incorporated to Brazil in 1903 through the Petropolis treaty between the two countries (ZEE, 2000). Migration to Acre dates from the 19^{th} century, with rubber tappers coming from the Northeast of Brazil. A patronage system was soon developed by exchanging subsistence goods for rubber. Rubber prices dropped due to competition with highly productive Malaysian rubber, and by the 1930's the rubber economy was significantly reduced (Bakx, 1990).

The arrival of corporate cattle ranchers in the mid 1970's generated conflicts with rubber-tappers, usually dispossessed of land titles and often driven from the forests from which they extracted their economic gains. Chico Mendes, one of the most well-known leaders of social movements in Brazil and Latin America, helped to organize the resistance of rubber-tappers against the *paulistas*[18], while calling the attention of the global community to the destruction of Amazônia (Allegretti, 2006). Extractive Reserves emerged as a new form of agrarian reform and as a way to protect the livelihoods of rubber-tappers, while also helping to conserve forests (Alegretti, 1990), and to reduce rural-urban migrations (Bakx, 1990)[19]. The first Extractive Reserve to be created was the RESEX do Alto Juruá, soon followed by the RESEX Chico Mendes. Under IBAMA (Brazilian Environmental Protection Agency) bylaws, residents are given rights of use to Extractive Reserve resources, and may convert up to 5% of a *colocação*'s forested area to pasture, and other 5% to other land-use types (Gomes, 2001). However, the non-enforcement of these laws in many cases, have been motivating recent sharp critiques to the Extractive Reserve model (Brito, 2005).

In 1977, INCRA established P.C. Pedro Peixoto, the first settlement project in Acre and one of the largest since (an average of 75 hectare lots to each of some 4,200 families); others such as P.C. Humaitá and P.C. Quixadá, both established in 1981, followed (ZEE, 2000). These settlements were part of the Brazilian government strategy of Amazon occupation, while also trying to alleviate social pressure derived from displacement of rubber-tappers from forests in Acre. Acre's population jumped from about 100,000 in 1950 to nearly 570,000 in 2000 (IBGE, 2001). Today, it is estimated that some 16,200[20] families have been settled in 53 agricultural settlement projects in Acre, in an area of some 1,570,000 hectares, which corresponds to 9% of the area of the State (ZEE, 2000).

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[18] Paulistas = natives from the State of São Paulo. While not all cattle-ranchers were native from São Paulo, this was the general denomination given to newcomer representatives of the corporate beef sector.

[19] Critiques to the model of Extractive Reserves include Browder (1992) and Homma (1994), who argue that historically, extractivism has not been able to alleviate poverty.

[20] Official capacity of these 53 settlements is for 19,925 families (around 3,700 families not settled yet in the most recent settlements). However, lot turnover and lot consolidation have been not accounted for in the production of these estimates.

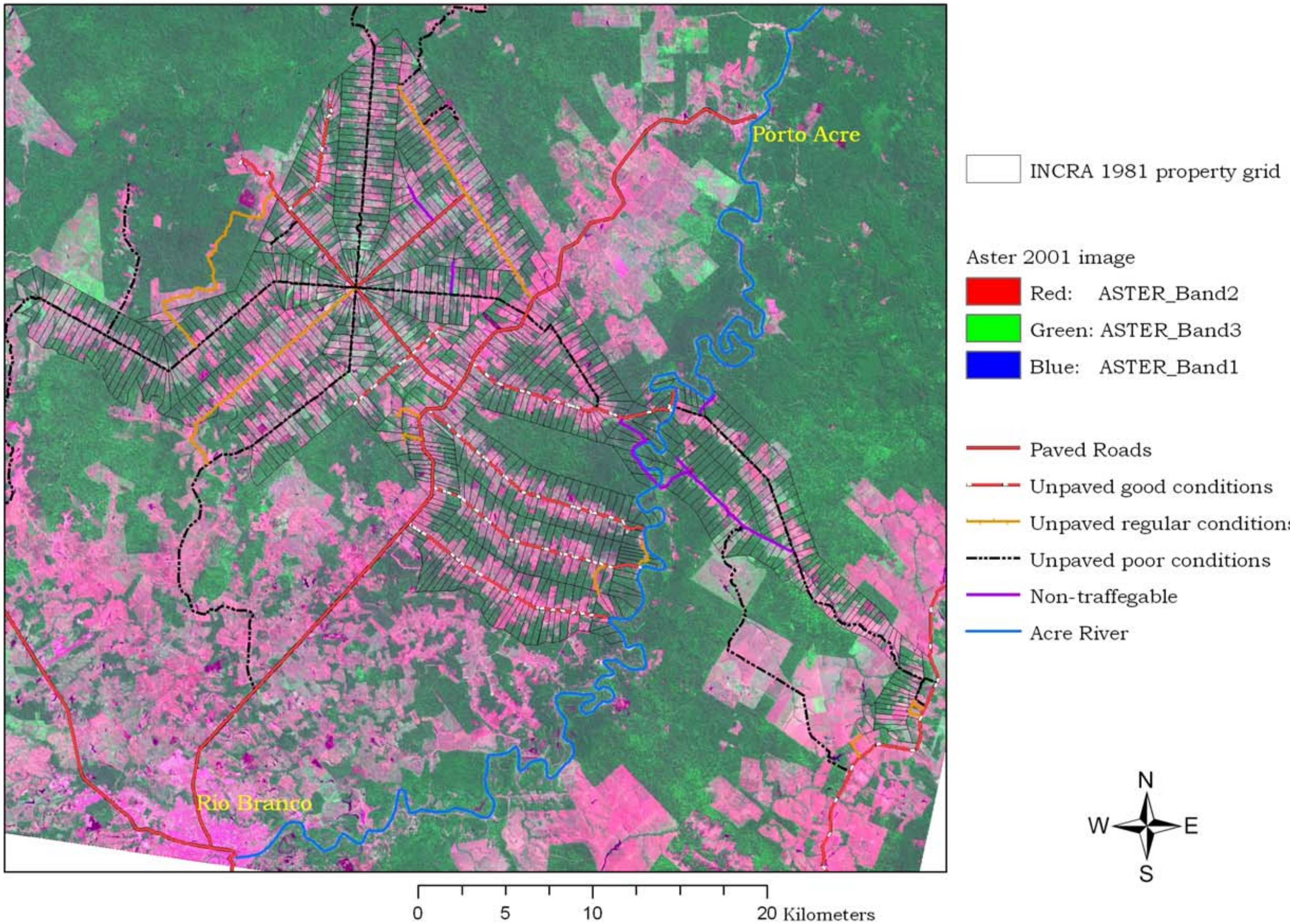
The pavement of BR-317 will eventually link Acre to the Pacific Ocean, as part of *Avança Brasil* Program, a governmental strategy which includes facilitating the shipping of Central Brazil's agricultural production to international markets (particularly in Asia), and enhance economic development in the Amazon (Nepstad et al., 1999). This connection to the Pacific is expected to boost the regional economy and to cause major changes in land-cover along BR-317 (Brown et al., 2002).

A survey with smallholder farmers of INCRA colonization projects conducted in the Western Amazon (states of Acre and Rondonia) revealed that 60% of the farm-area was still under forest cover in 1994 (Witcover and Vosti, 1996). Pasture covered 22% of the area, followed by fallow (8%), annual crops (6%), perennial tree crops (3%), and intercropped annual/perennials (1%). By that time, the official deforested area in Acre was of 12,064 km^2, or 7.9 % of the state; by 2001, these estimates grew to 16,200 km^2, or 10.6% of the state, and by 2005, the deforested area in Acre reached 12.51 % of the State (INPE, 2006).

1.6.2 - Description of the study site

The site under study is the *Projeto de Colonização* Humaitá (Humaitá Colonization Project, or P.C. Humaitá), established in 1981 in the municipality of Porto Acre, Acre State, Western Brazilian Amazon (Figure 1.4). The settlement covers an area of 60,334 hectares situated at both sides of the Acre River, and is connected to state capital Rio Branco (to the South) by 35 km of paved road AC-010. As mentioned above, the settlement design consists of a radial road network around a central village named Vila do "V," and originally was divided in 951 lots (ZEE, 2000:38). The planning and execution of the settlement project was performed by the Brazilian Institute of Colonization and Agrarian Reform (INCRA).

Figure 1.4 – P.C. Humaitá, the study site; INCRA 1981 property grid and road network overlaid to ASTER 2001 image:



Contrary to most government-sponsored colonization projects in the Amazon, which were established in public lands, Humaitá is a re-distributive land reform project established on land that was privately owned. The owners were *seringalistas* (owners of *seringais* or rubber-farms), who were partly willing to sell their land due to the decline of the rubber economy. In the other hand, *seringalistas* were in conflict with 236 rubber tapper families living along the Acre River demanding use rights to land (INCRA, 1990). One ex-*seringalista* told me she would rather have INCRA re-distribute the land she previously owned among the rubber tapper families living in the area, than sell it to newcomer cattle-ranchers[21] who would most likely dispel these families from the land where they used to live. As mentioned above, commercialization of rubber farms by *paulistas* caused several conflicts with local rubber tapers ending in violence and hundreds of displaced families.

P.C. Humaitá is currently undergoing its second generation stage, which means that after 22 years of occupation, original settlers' descendents are as important as their parents or more, in taking their places as active actors shaping lots' dynamics, including LUCC and lot turnover, consolidation and fragmentation processes. A substantial proportion of heads of household[22] were, by the time fieldwork was conducted (August 2003 – July 2004), either born in the settlement or arrived there very young. The conditions shaping contemporary household decision-making are substantially differentiated from the ones that characterize initial stages of frontier development. Infra-structure investments, such as road paving/gravelling, electricity and construction of several facilities (including agricultural production storages, new schools and health centers) make living conditions in Humaitá

[21] Although payment by cattle-ranchers was made in cash, and payment by INCRA is in titles of the agrarian deed, which take up to 20 years or more to compensate.
[22] For the purposes of this dissertation, heads of household are defined as the individuals in charge of land-use decision-making in a household.

much better today than 22 years ago. Humaitá is also considered "emancipated" by INCRA, meaning that most lots have been officially titled by this agency.

Furthermore, the region is experiencing investments in the forestry sector and on a road network that will link the region to the Pacific Ocean, which will help to integrate local markets to global ones. More information on the study site is provided later in this chapter.

1.6.2.1 – The people: local ex-rubber tappers, colonist farmers and land investors

I divided Humaitá residents into three social groups: a) ex-rubber tappers, b) colonist farmers and c) land investors. This division is part of the research design used to address Question 1. Social groups are defined by economic orientation and occupational history (including agricultural background). It is hypothesized that farmers belonging to the same social group respond in a similar manner to the uncertainties present in factors determining land-use in the region. For example: colonist farmers might respond to uncertainties in accessing urban centers by focusing on cattle-ranching, while ex-rubber tappers might prefer to diversify their livelihood strategy portfolio. A detailed characterization of these social groups is important to address this question. Here, I provide only an introductory description of these groups. A discussion on socio-economic characteristics for each of these groups (including descriptive statistics) is provided on Chapters 2 and 6.

Several rubber tapper families were already living in the Humaitá area by the time INCRA purchased the land and established the settlement project, most of them along the shore of the Acre River. Rights of use to the land were variable: some families claimed land as their own (some had even purchased land from landlords before INCRA), while others considered themselves *posseiros* (squatters) under the obligation of providing landlords with their production of rubber, according to the patronage system in place by the time. Under this system, families are given rights to explore 400 hectares on average[23]. These families remained in the same sites where they were living and were given lots of 80 hectares on average by INCRA. Many families were still extracting rubber by 1981, but they told me they had to stop this activity as the reduction in size of land area explored made rubber extraction economically unfeasible. Besides rubber extraction, local families used to rely on hunting, fishing, subsistence agriculture and on the extraction of other forest resources for their livelihood, during the time preceding INCRA administration. More information on livelihood strategies is provided on Chapter 6.

Some colonist farmers in Humaitá are originally from other parts of the State of Acre, and some are subsistence farmers migrating from other Amazon States. The majority of colonist farmers, however, comprise families that migrated from other regions of Brazil in search for a piece of land, and were settled by INCRA between 1981 and 1986. Most families experienced very difficult conditions in the adaptation process to the region, and to the context of physical isolation of the so-called “civilized world,” because of the lack of reliable roads and the costs of air transportation. Interaction with local rubber tappers helped them to learn hunting and fishing strategies, and slash-and-burn and other agricultural techniques. However, interaction with INCRA officers and with neighboring colonist farmers was often easier than with rubber tappers, due to access restrictions.

Land investors are city-based residents who took advantage of opportunities in Humaitá’s flourishing land market, by purchasing (often irregularly) lots from moving-out settlers. Often, purchase of lots was used primarily as a hedge against currency inflation (before 1994), with no intention of putting the land into production. More recently, however,

[23] Average density of rubber trees in Acre is of 1 tree/hectare

land investors have been consolidating lots into larger properties mostly to attend the demand for pasture for growing cattle herds. This will be discussed in Chapter 5.

1.6.2.2 – Climate and hydrology

The climate is Tropical Humid with 2010 mm of average rainfall. The dry season is from June to September, with July and August typically being the driest months. Average daily temperatures fall within the 10 ^{o}C to 32 ^{o}C range, with annual averages around 24.5 ^{o}C (ZEE, 2000).

The settlement area is crossed by several creeks and one main river (Acre River). Water springs are abundant in most of the area to the East of Acre River, and in the area contained within AC-010 and the Acre River (where most creeks are also concentrated). However, access to water has been limited for most lots located in highlands to the West of AC-010. By constructing ponds, however, many farmers have managed to resolve this problem and maintain a regular supply of water. Humaitá settlement shows a high density of ponds, the majority of them were constructed during the 1990s and early 2000s. Most ponds in the area are maintained only by rain water, which is sufficient to keep them full throughout the dry season. Building ponds is also an economically efficient way to meet cattle demand for water (cheaper than pumping water through pipelines). Moreover, ponds attend to multiple goals on local farming systems; besides supplying water for cattle, several local farmers breed fish for both subsistence and commercial purposes, and many use water from ponds for bathing, washing clothes and human consumption. Irrigation is not common in Humaitá. More information and a discussion on the importance of ponds is provided in Chapter 2.

1.6.2.3 – Geology and soils

The geological formation of the Acre Basin is continental sediments of the Tertiary (as in many other basins nested into the Amazon Basin), more specifically part of the *Formação Solimões* erosive process, resulting in areas of highlands interspersed by several depressions or valleys. *Formação Solimões* includes clay rocks (argilitos), carbonatic and gipsy concretions and occasionally carbonized materials, including "pirita" and large amounts of fossils. A mosaic of different kinds of soils is spread through the hilly landscape, with predominance of medium to low fertility Ultisols (including problematic Plynthic Ultisols[24]) and patches of medium to high fertility Alfisols (ZEE, 2000). A recent 1:250,000 scale soil map was produced by researchers of Embrapa-Acre (Brazilian Agency for Agricultural Research), UFV (Federal University of Viçosa - MG) and NEPUT (Land-use Study and Planning Nucleus, a private consulting firm) for the 2nd Phase of the Ecological-Economic Zoning of Acre, and is reproduced on Figure 1.5 (do Amaral et al., 2005). This soil map follows the new soil classification scheme adopted in Brazil. Table 1.1 presents the aerial extents of different soil types according to the terminology adopted in Brazil.

[24] Besides being acidic and with high Aluminium concentrations, the plynthic B horizon of these soils reacts chemically whenever exposed, forming an impediment layer that makes agro-pastoral use difficult. Several farmers have been losing their pastures in P.C. Humaitá and elsewhere in Acre due to morte das pastagens (death of pastures) occurring in areas with Plynthic Ultisols (Argissolos plínticos). Grasses die because of poor soil drainage.

Figure 1.5 – Soil map in P.C. Humaitá produced by do Amaral et al. (2005) for the Ecologic – Economic Zoning of the State of Acre:

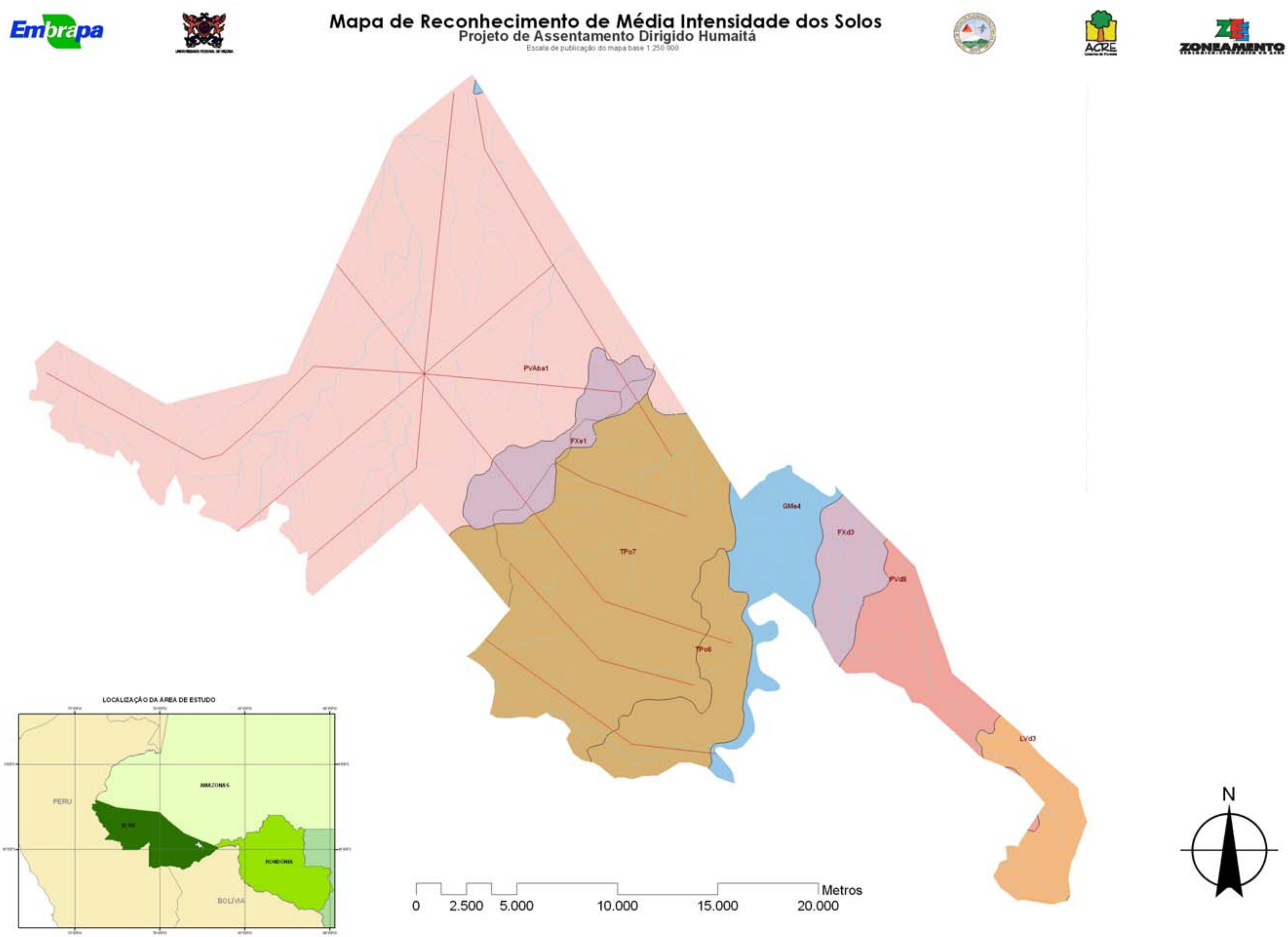


Table 1.1 – Areal extents of soil types in P.C. Humaitá according to Figure 1.5 and to the classification system and terminology adopted in Brazil:

CLASS (most frequent soil type in ZEE's sample)	Approximate correspondence to the USDA soil taxonomy system	Acronyms used in Figure 1.5	Area in P.C. Humaitá (hectares)	% of total area
PLINTOSSOLO HÁPLICO Eutrófico	Alfisol with impediment	FXe4	2574.09	4.3
LATOSSOLO VERMELHO Distrófico típico	Oxisol	LVd3	2379.45	3.9
ARGISSOLO VERMELHO Distrófico típico	Ultisol	PVd8	3039.25	5.0
PLINTOSSOLO HÁPLICO Distrófico típico	Ultisol with impediment	FXd3	1968.41	3.3
GLEISSOLO MELÂNICO Eutrófico e Distrófico	Alluvial soil	GMe4	3315.56	5.5
LUVISSOLO HIPOCRÔMICO Órtico	Alfisol	TPo6/7	15732.29	26.1
ARGISSOLO VERMELHO AMARELO Alumínico	Ultisol	PVAba1	31324.96	51.9
Total			60334.00	100

Source: do Amaral et al. (2005) for the Ecologic Economic Zoning of Acre (ZEE)

1.6.2.4 - Vegetation

There are two broad vegetation domains in the State of Acre: a) the Dense Tropical Forest Domain (DTF) and the Open Tropical Forest Domain (OTF) (ZEE, 2000). These domains are associated with regional climate, geomorphology and soils, producing vegetation sub-types typical of each combination. Dense tropical forests normally occur where annual precipitation levels are higher than 2,250 mm or where air humidity is higher (close to 90%); and in low plateaus of cretaceous and tertiary sedimentary formations, dissected into tabular relief. DTFs are characterized by closed and relatively homogeneous canopies, and a near absence of understory vegetation.

Open tropical forests are associated with annual precipitation levels normally lower than 2,250 mm and with low plateaus formed by "plio-pleistoscenic" sedimentary rocks, dissected into hilly or rolling relief (ZEE, 2000). Depending on the physiographic position in the relief and on soil type, which are important for determining composition of the understory vegetation, OTFs might be classified into the following sub-types: a) open with palms; b) open with dominating bamboos; c) open with dominated palms and bamboos; and d) open with lianas.

Both vegetation domains occur in the study area, with the predominance of Open Tropical Forest. Dense Tropical Forest predominates in the Oxisols of Humaitá, while Open Tropical Forest predominates in Alfisols, Ultisols and along the alluvial soils bordering the Acre River. The most common type of OTF found in P.C. Humaitá is the type c - open with dominated palms and bamboos. Patches of bamboo stands (known locally as *taboca*) are intermingled within the open forest; however, both frequency and density of bamboo stands in Humaitá are substantially lower than in neighboring settlements such as Extractive Reserve Chico Mendes[25] (where type b – open with dominating bamboos predominates).

Economic species abundant in the area include the rubber tree (*Hevea brasiliensis*), Brazil-nut tree (*Bertholettia excelsa*), and hardwoods cumaru-de-cheiro (*Dypterix odorata* (Aubl) Willd), cumaru-ferro (*Dypteris micrantha* Harms), cumaru-cetim (*Apuleia mollaris* Spruce), cedro (*Cedrella odorata*), and jatobá (*Hymenaea courbaril*). However, most of the hardwoods have already been harvested and are no longer present in the area. Among the softwoods, the most important is samaúma (*Ceiba samauma*). Important subsistence species provide sources of calories and vitamins include açaí (*Euterpe precatoria*), bacaba (*Oenocarpus bacaba*), patuá (*Oenocarpus bacaba*), and ouricuri (*Syagrus coronata*). Species used in local construction and fencing include hardwoods bálsamo (*Myrocarpus frondosus*), maçaranduba (*Manilkara bidentata*), pau-pereira (*Platyciannus rignelli*), and itaúba (*Mezilaurus itauba*), the palm paxiúba (*Iriartea exorrhiza*), and secondary succession species mulateiro (*Calycophylum spruceanum*), capoeiro (*Colubrina acreana*), and freijó (*Cordia goeldiana* Hub.). Medicinal species commonly used include copaíba (*Copaifera multijuga* Hayne), sangre-de-grado (*Croton lechleri*), andiroba (*Carapa guianensis*), and the roots of açaí among others.

1.7 - Roadmap to the dissertation

Each of the following chapters, through Chapter 6, addresses one of the five research questions outlined above. Chapter 2 presents a discussion on theories of tropical deforestation that are relevant to Question 1, which is followed by historical trends of

[25] More details on local forest types and on the relevance of bamboo richness to the quality of image classification is given in Chapter 2.

deforestation in the Amazon Basin. Next, it presents the bulk of the methods of this dissertation: household surveys, remote sensing and GIS techniques. Descriptive statistics are presented illustrating differences across the three groups of farmers: locals, colonist farmers and land investors. Then, I present the outputs of image classification first for the whole image footprint, and then at the levels of lot, groups of farmers and settlement[26]. Land-use information derived from the household surveys is then presented and analyzed. Last, I discuss inter- and intra-group variability (Hypothesis 1) on the land-use and cover change (LUCC) patterns observed in Humaitá along the studied period (1975 – 2003).

Chapter 3 begins by discussing the relationship between transportation costs and agricultural credit with land-use choices (Question 2). It presents a typology of land-use strategies developed for Humaitá, and descriptive statistics for time distances and use of agricultural credit. I present also the GIS operations used in establishing the Origin – Destination Cost Matrix (network analysis), and the Multinomial Logistic Regression (MRL) model used to address Hypothesis 2.

Chapter 4 discusses the impact of agricultural credit on deforestation at the regional level, which is illustrated by historical trends of credit use in Amazônia. Next, some of the factors affecting rates of credit adoption among farmers, and how these factors relate to uncertainty in the study area are discussed. Next, it presents the binomial logistic model to test Hypothesis 3, followed by the discussion of the results.

Chapter 5 discusses lot turnover in land reform projects in the Amazon, and its impact on settlements` agrarian structure and in land-cover change (Question 4). Then the methodology used to address the relationships between land consolidation with time

[26] Includes the classification of a Landsat ETM+ image for the whole image of 2003, and three land-cover change matrices: a) a deforestation transition matrix; b) a secondary succession transition matrix; and c) a land-use transition matrix.

distances (H4A) is presented. The same variable (time-distance) is used to analyze land-cover change (H4B). The chapter concludes with a discussion about the implications of lot turnover and consolidation to settlement's agrarian structure land-cover change and regional development.

Chapter 6 discusses changes in land-use and livelihood strategies that take place along with settlement aging (Question 5). It compares the range of livelihood strategies found when farmers first moved into the settlement, with the range observed in 2004 during fieldwork. Next, this variation is illustrated by describing the stories of five farming families, and how their livelihood strategies responded to uncertainties they have been facing since they arrived in the frontier area. The social learning processes are discussed and briefly compared to the processes of build up of social capital.

Chapter 7 concludes this dissertation by first returning to the major issues discussed in Chapter 1. It examines the relationships among the outcomes of each chapter and the basic points brought up in this introduction. It does so by first addressing how land-use choices at the farm level respond to the uncertainties observed in several factors conditioning decision-making in agricultural frontiers. Next, I discuss changes in land-use and cover and in the agrarian structure of settlement projects and in the implications to the actual model of land reform in the Amazon and in Brazil.

CHAPTER 2 – LAND-USE AND COVER CHANGE AT THE LEVEL OF LOTS, GROUPS OF FARMERS AND SETTLEMENT

2.1 – Land-cover change in settlement projects in the Amazon

As mentioned in the introductory chapter, most of the state-led land reform in the Amazon took place in public lands. Lot turnover and land concentration processes in colonization areas are part of the economic transformation that occurs as settlements age, starting from a small scale and consumptive economy toward an export oriented economy based mostly on beef production. The Brazilian society has been supporting land reform programs based on the assumption that these programs are effective in narrowing the huge gap in access to land in Brazil (one of the highest *Gini* indexes in the world). One issue in stake is whether Brazilians are willing to finance the privatization of public lands to cattle-ranching enterprises, especially given the environmental issues involved. This will be discussed in more detail in Chapter 5. Another issue is to understand the interactions between land-use, lot turnover and land-cover change leading to the economic transformations mentioned above. Throughout this dissertation, I examine farmers' responses to internal and external conditions as they make decisions about land-use, and discuss how changes in land-use strategies through time might reflect the experience gained through individual experimentation and social learning. This chapter explores land-use and cover change in Humaitá at the level of lots, groups of farmers and settlement. It uses household survey data to study land-use (n = 63 interviews). Land-cover change analysis is based on multi-temporal satellite data (details in the methods section) covering the entire settlement (n = 739 lots[27]) from 1975 to 2003. Later, in chapter 5, I address relationships observed between land-cover change and lot consolidation.

[27] Originally, there were 951 lots in 1981.

Several factors are believed to interact at different scales of analysis and drive tropical deforestation, which is therefore a complex phenomenon to study. While some hypothesized relationships are supported by empirical evidence, other relationships are supported only by statistical correlations, and others remain only in theory or under debate due to contradictory findings (Kaimowitz and Angelsen, 1998). Methodologically, there has been some considerable advance in the study of land-use and land-cover change (LUCC) over the past 15-20 years. Novel integrative methods have been proposed, for instance, by McCracken et al (1999), Brondizio et al (2002), and Moran et al (2002). Integration of multi-temporal remote sensing data, socio-demographic and land-use surveys within a GIS spatial framework provides a systemic view that links multiple processes occurring within and among settlement projects in the Amazon. It provides also identification of LUCC patterns at different levels of analysis. The incorporation of such integrative methods and principles to an already existing body of demographic theory helped to frame the Household Lifecycle Theory mentioned in the introductory chapter, which might be an extremely useful tool on approaching research questions involving agricultural frontier contexts (McCracken et al, 1999): as households mature in the frontier context, increase in labor supply and in consumption demand lead to higher complexity in demographic fluxes (migration and remittance), land-use systems (expansion and consolidation cycles), and labor relations.

In this sense, the colonist footprint, which can be characterized by the consolidation and progressive expansion of productive activities (Brondizio et al, 2002), is studied with the help of Household Lifecycle Theory and integrative methods of social sciences combining remote sensing and GIS techniques. This analysis is nested into a broader context including development policies, markets and other macro-economic variables, and lot turnover impacts on deforestation. Here, I try to combine insights from the colonist footprint with farmers' responses to uncertainty in land-use related factors. An important question for this dissertation is to explore variability in deforestation trajectories among farm-lots and settlement, and the role of social groups tied to agricultural background on affecting cycles of LUCC:

Research Question 1 - *What are the rates of land-cover change (LCC) since the beginning of settlement at the level of farm lots, social groups of farmers and the whole settlement?*

This question is oriented to test whether land-cover change patterns observed at the Humaitá Settlement Project can be understood based on similarities observed within groups of farmers. More specifically, I am addressing the following hypothesis:

Hypothesis 1 (H1) - *Variation in rates of land-cover change between farmers belonging to different groups is larger than the same variations observed among farmers belonging to the same group, during the 1975 – 2003 period of analysis.*

In the methods section, details on household surveys and on processing of Landsat scenes is provided, as well as descriptive information for each group of farmers (local farmers, colonist farmers and land investors) and on the types of land-cover change being considered.

2.1.1 – Historical trends on Amazon deforestation

Annual deforestation rates in Amazonia are presented in Figure 2.1. The fluctuating pattern observed in deforestation rates has been related (among other factors) to macro-economic phases in the national and global economies (Brondizio et al, 2002; Perz, 2002).

Lower deforestation rates observed during the late 1980s and early 1990s, for example, reflect the economic crisis in Brazilian economy already in place since the late 1980s. With the implementation of Plano Real in 1994, leading to better control of inflation and overall better conditions for investments, record high deforestation rates were observed from August 1994 to July 1995[28].

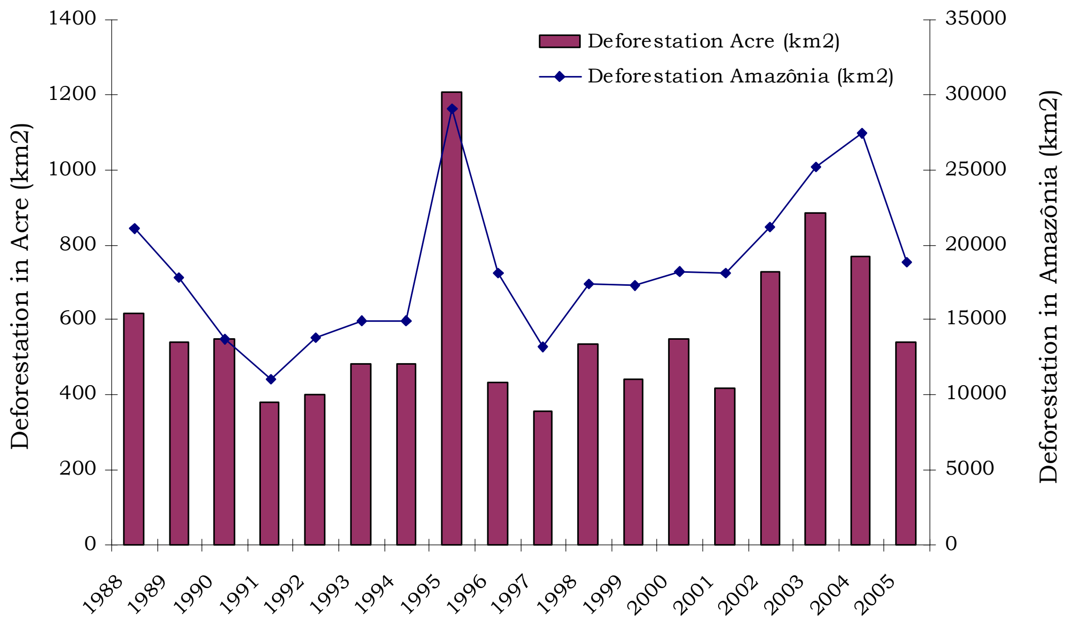
According to a recent study on the size and frequency of deforestation patches in Brazilian Amazonia, it has been estimated that deforestation by smallholders in INCRA settlement projects contribute to 12% of total deforested area, while patches greater than 50 ha respond for 87% of total forest conversion (Pacheco, 2006). This trend is not new. Several analysts of deforestation in the Amazon have been proposing that tax incentives and governmental subsidies to large cattle ranchers were responsible for most deforestation observed during the 1980s (Hecht, 1985; Fearnside, 1993; Gasquez and Yokomizo, 1990; Bunker, 1988). A detailed discussion on the effect of agricultural subsidies and credit on tropical deforestation are presented on Chapter 4.

Landsat satellite data for the 1997/1998 period indicated that patches of 100 ha or more were responsible for slightly over half of total land clearings in the Amazon region observed during the studied the period (INPE, 2000). Small farmers owning lots between 50 to 100 hectares, which are found in most settlement projects in Amazonia, hardly deforest more than 10 – 15 hectares a year[29]. Thus, by deduction, if the threshold used for size of patches is reduced from 100 to 15 hectares, total deforestation attributed to medium and large landholders would increase substantially (not only "slightly over half of total land

[28] Deforestation rates are typically measured for the Amazon dry season (July – September), when forests are normally cleared.
[29] Officially, deforestation licenses given by IBAMA to small farmers are limited to 5 hectares in the State of Acre, but these have been hardly enforced in the 1990s and early 2000s.

clearings"). However, the contribution of different groups/agents to deforestation varies within regions.

Figure 2.1 – Historical series of annual deforestation in Brazilian Legal Amazonia:



2.2 – Methods: household interviews, remote sensing and GIS

2.2.1 – Data

2.2.1.1 – Household surveys

Household surveys included detailed land-use, socio-economic and demographic semi-structured questionnaires with farming families. Interviews were conducted with both male and female heads of household, often including other household members as well. Interviews were scheduled in advance and took normally between 2 and 3 hours. Household surveys also included training samples on lot's land-cover for imagery classification, and personal observation on land-use characteristics of lots. As already mentioned in the introductory chapter, households and farm lots correspond normally to each other in a one-to-one relationship. In cases where farm lots have more than one household, they are divided by corresponding units of area management for each household, thus representing a fragmented lot.

Land-use was estimated through a combination of household interviews with satellite imagery, as in Brondizio et al (1994, 2002), Moran et al (1994), Moran and Brondizio (1998) and Mertens et al (2002). During the interview, I used maps of INCRA's 1981 digitized property grid of the settlement, overlaid to color composites of remotely sensed images covering the 1986[30]-2003 period. This worked as a recall technique for land-use allocation along the history of the lot. Land-use questions included area allocated to annual and perennial crops, pasture, secondary re-growth, forests and ponds, at two time-periods: arrival of settlers at the lot and when interviews took place. Land-cover classification of satellite imagery complements such information, while checking its accuracy. The land-use component of the questionnaire included also information on the agricultural schedule of most important crops, on soil quality on the lot, availability of water, and on total agro-pastoral production and income from sales of agricultural products in the year preceding the survey. It included also questions related to land preparation for agro-pastoral use (such as if it was established in forested or secondary succession area), use of fire, and licensing of land clearing with IBAMA (Brazilian Agency for Environmental Protection).

[30] In some cases, as for example when interviews were conducted with ex-rubbertappers that were living in the area since before INCRA implemented the settlement in 1981, I used also the map of the 1981 property grid overlaid to the Landsat MSS 1975 colored composite.

In the socio-economic and demographic part of the questionnaire, farmers were asked about their place of birth, the places were they lived before moving to Humaitá, their actual and previous occupations, time of arrival at the settlement, level of education, household size and composition, sources of income other than the ones from the lot, participation in farmer unions and other organizations, and several other issues to be mentioned in detail in the next chapters, according to the questions being asked in each chapter.

2.2.1.2 – Remotely sensed imagery

The temporal series of remotely sensed image data is composed by one Landsat MSS image (1975), three Landsat TM images (1986, 1992, 1996), two Landsat ETM+ images (1999 and 2003), and one ASTER image (2001). Landsat images were obtained for Path/Row 02/67, while the ASTER image was obtained specifically for the study area comprising P.C. Humaitá. Clouds and haze are chronic problems in the region so it is practically impossible to get an image sequence of the same days or even weeks for all scenes/years. Therefore, a more open approach was adopted, focusing on securing all imagery during the short dry season between mid-June and early September (Mausel et al. 1993).

These images served as a land-use recall technique during interviews with farmers. The classification of 1975, 1986, 1992, 1996, 1999 and 2003 scenes allowed for the derivation of land-cover change (LCC) matrices at the landscape and individual property levels. This multi-temporal dataset allowed for comparisons between land-cover change rates among farmer lots and groups of farmers, while allowing also for analysis of land-cover change at the level of the whole settlement.

2.2.1.3 – Property grid

A map showing P.C. Humaitá's property grid produced by INCRA in 1981 was initially used for sampling procedures and during interviews with farmers (see Figure 1.4). This map contains the original 951 lots were farming families were settled. During fieldwork, this map was updated to the actual land distribution structure, which shows 739 lots. The difference between original and actual number of lots is due to lot consolidation and fragmentation that took place from 1981 to 2004 (to be further discussed in Chapter 5). This updated version of Humaitá's property grid map was then used to extract information from land-cover change matrices at the level of farm lots. The road network dataset used for sampling purposes was also obtained from this same 1981 INCRA property grid map. Later, during fieldwork, the road network was also updated before being used on the calculation of time-distances of lots to local urban centers (details in Chapter 3).

After scanning INCRA's property grid map and digitizing both farm lots and roads using ESRI's ArcGIS ©, the grid was overlaid to remotely sensed imagery for the 1975 – 2003 period using a Geographic Information System (GIS) of ERDAS Imagine ©, to produce maps which were used during interviews with farmers.

2.2.2 – Sampling strategy

Given the relevance of road quality and access to urban centers to address some of the key questions of this study, the sampling of lots for surveys was stratified according to distances of lots to urban centers. Every road in the settlement had at least one sampled lot and was thus used in the sampling procedure. For sampling purpose, each road was divided into (imaginary) segments[31] which were then stratified according to its distances to Rio Branco, the main urban center. This allowed for lots to be sampled in closest or furthest conditions along each road. Sample size is of sixty-four (64) lots. One household survey had to be later discarded resulting in a dataset composed by 63 household surveys.

The sampling distribution was proportional to the number of lots originally present on each of the 17 roads of P.C. Humaitá, and randomized along road segments. Each segment represents a class of distance of a group of lots to the local urban center. The number of segments on each road was proportional to the number of surveys calculated for this road, and the number of lots in a road was split among the segments. From each segment, one (1) lot was picked randomly to be surveyed. The sampling procedure used INCRA's 1981 property grid for the settlement. There were three conditions under which a replacement lot was chosen for survey purposes: a) family arrived on the lot after 1999 (minimum time required for a household to be part of the sample was of 5 years living on the lot); b) farmer was unable/unwilling to give interviews; c) two sampled lots fell in the same consolidated lot.

2.2.3 - Remote Sensing

The remote sensing portion of this thesis results in part from a collaboration between three researchers[32], sharing similar research interests, but with different research questions. Pre-processing, classification processing and post-processing of Landsat MSS, TM and ETM+

[31] By dividing roads into such segments, and allowing all roads to be part of the sampling universe, I aimed to pick a sample of lots that represents equal proportions, among different access conditions of farmers to urban centers.
[32] My collaborators are Jackie Vadjunec, a PhD Candidate in Geography at Clark University, and Valério Gomes, a PhD Candidate in Geography at the University of Florida.

images were developed together in the laboratory using field data each of us collected for different parts of Landsat scene Path/Row 02/67[33].

Ground data were collected in the field for geo-referencing, as well as over 200 additional training/ground truth samples of various land-cover/land-use types for classification. A training sample protocol was developed based on the specific ecology and land-use of the region and a training sample data base was created based on protocols developed by the Anthropological Center for Training and Research on Global Environmental Change (ACT) and the Center for Institutions, Population and Environmental Change (CIPEC), both located at Indiana University. The data base includes information on the geographic coordinates of the sample using a Global Positioning System (GPS), the land-use/land-cover type, sketch maps, digital photos and, when possible, brief land-use histories given by farmers during the household surveys. Given the resolution of TM imagery we limited our samples to areas 1 hectare or greater.

2.2.3.1 - Preprocessing

Geo-referencing **-** Geometric rectification was carried out on the 2003 image based on ground control points collected in the region using a GPS, mainly using roads and intersections, and when a good geographic distribution was necessary and roads were lacking, both rivers and waterways. All resampling was done using a nearest neighbor resampling algorithm with a linear first-order polynomial fit. The 2003 images were then used as a base to which the remaining scenes were resampled. In all cases, our root mean square error (rms) was equal or less than 0.5 pixel (or < 15 m).

[33] Both Jackie and Valerio are doing their dissertation on the Extractive Reserve Chico Mendes, which falls partially within the Landsat footprint 02/67, and partially within Landsat footprint 03/67. Since the latter footprint was of interest for them, it was also used as part of their dataset.

Radiometric Calibration **-** In order to compare images across scenes, it is necessary to first correct for variations in brightness (or DN) values caused by differences in sensor calibration, as well as differences in solar illumination, and atmospheric conditions such as Rayleigh scattering and haze (Green et al. 2005). To do so, we used a radiometric calibration (RADCAL) and dark subtraction (ATCORR) model which was developed by Green and colleagues (2001) on all images.

2.2.3.2 - Classification Process

The image sequence spans 29 years in an area that has seen rapid and dynamic changes. A traditional supervised classification approach would be difficult because although training samples for the 2003 image were available, land-use maps for the region going back as far as 1975 were not. As a result of these constraints, a hybrid unsupervised/supervised approach was adopted, which allowed us to create a more ample classification scheme even in years where training samples were lacking. The entire classification process was based on methods developed at ACT and CIPEC, and completed using ERDAS Imagine 8.7 (see Brondizio 1996; Moran and Ostrom 2005). To ensure consistency, each image was classified and reviewed by at least two of the three authors.

Hybrid Unsupervised/Supervised Approach

First, an unsupervised classification was carried out on each image using the ISODATA clustering algorithm with a standard number of 100 classes, 12 maximum iterations, and a convergence threshold of 0.950. Our 100 classes were gradually collapsed into 12 classes, based on spectral, textural and spatial characteristics, distinguished through analysis of spectral signature, statistical separability, and visual inspection:

(1) Dense Forest – typically non-deciduous forest, corresponding to the Dense Tropical Forest vegetation type existing in the region; (2) Mixed Open/Bamboo Forest – Open semi-deciduous forest intermingled with patches of bamboo vegetation (Open Tropical Forest dominated by bamboos or dominating bamboo and palms); (3) Initial Secondary Succession – herbaceous, seedling and sapling vegetation up to 2-3 meters high, typical of agricultural land left to fallow or non-managed pastures; (4) Advanced Secondary Succession – woody vegetation up to 10-12 meters high, closed canopy; (5) Pasture with trees – managed pasture intermingled with trees (one tree for every 400 m2 – 2,500 m2); (6) Managed "clean" pasture – open grasslands with substantial green cover (overgrazed pastures fall mostly within class 8); (7) Tall grass/wetlands – lush green vegetation typical of areas with poor drainage or grassy wetlands[34], or of very well managed pastures; (8) Agriculture/Bare Soil/Overgrazed pasture – mostly areas lacking green vegetation cover, and/or showing patches of bare soil; (9) High density urban – presence of asphalt and human-made surfaces with high reflectance; (10) Water – rivers, ponds and other water bodies; (11) Clouds; (12) Cloud shadows.

Class assignment was based on the following procedures:

1) Visual interpretation of the image sequence using expert knowledge and ground data and land-use histories collected in the field to guide decisions. Also, the spectral behavior of individual pixels was studied initially through the SPECTRAL PROFILE tool.

2) Analysis of the spectral behavior of the signatures for each of the 100 classes, as well as groups of classes (using the SIGNATURE MEAN PLOT module).

[34] These areas present very distinct spectral signatures from other managed pasture areas, given that all images correspond to the dry season, when vegetation is commonly under hydrological stress.

3) The interpretation of unsupervised classes based on their spectral separability statistics generated using the TRANSFORMED DIVERGENCE module.

Based on these criteria, the initial 100 classes were individually analyzed and assigned to our final classification scheme, spectrally similar classes were merged with like classes, while others, such as those representing noise, were eliminated altogether from the classification. This was done in several stages producing a series of intermediary signature files for each year: thus, a 100 class signature file might be reduced to 60 classes, then 30, and once again until the final desired 12 classes had been reached. Steps 1-3 were completed at each one of the intermediary stages.

We then used our final signature files representing the 12 land-use/land-cover classes for each image as an input for a supervised classification, using a probability-based Maximum Likelihood algorithm. After classification, our classes were further reduced to a more simple classification scheme, and avoiding excessively large image sequencing with the TRANSITION MATRIX procedure (to be further explained), and according to the specific question being asked. This final classification key is composed by the following classes: (1) Forest; (2) Secondary Succession; (3) Combined Pasture/ Agriculture/Bare Soil; (4) Water; (5) Cloud/Shadow.

2.2.3.3 - Post-Processing

Common problems found during image classification include atmospheric scattering due to cloud cover, and misclassifications and confusion caused by anomalies such as tree shadow. To deal with these problems, we used post-classification techniques such as a nearest neighborhood 3 x 3 kernel filter, and to a lesser extent, polygon filling which was used in some instances and in specific area of interests (AOIs), followed by careful inspection and the visual comparison of problem areas with the original bands geographically linked to the filtered image.

2.2.3.4 - Accuracy Assessment

A hold out sample of roughly 150 ground control points was digitized into polygons and used in an accuracy assessment for the whole Landsat ETM+ 2003 footprint (Path/Row 02/67), totaling 895 sampled pixels. An accuracy level slightly above 85% (p-value of 0.05) was achieved (see a contingency table in Appendix 1).

2.2.3.5 - Transition Matrices

For the purposes of this study, which is to analyze the rates and extensions of different types of land-cover change within P.C. Humaitá across the studied period, transition matrices were created using the MATRIX module. Starting with the 1975 and 1986 images, the MATRIX module was run five times, by adding consecutively each year in the sequence 1975 – 1986 – 1992 – 1996 – 1999 – 2003, resulting in final transition matrices representing all years between 1975 and 2003. From one transition to the next one, classes were combined together (using the *recode* procedure in Erdas Imagine) according to the question being asked. For example, if the question is "What is the rate of deforestation for each period of the 1975 – 2003 range?", each the final 5-class thematic images (6 images, one for each year) were combined into 2 class images[35] (forest and non-forest) before running the *matrix*

[35] In the presence of clouds, this gets more complicated. For the Humaitá region, however, all images were relatively clear of clouds. The few and small clouds present in 1992 and 2003 images covered areas already known to be classified as pastures in the previous images, so it could be reasonably assumed they continued classified as such.

procedure. Thus, transition matrices allowed for the following-up of any given pixel and its change from period to period. This resulted in thematic images showing the area for each class by time interval. Separate transition matrices and transition images were produced for a) deforestation; b) secondary succession and c) a combination of deforestation, secondary succession and cleared areas.

2.2.4 – Extraction of deforestation rates to the level of farm lots

An updated version of the settlement's property grid was then overlaid to each of the three final transition images and combined into a GIS coverage. Then, a pixel extraction technique (*Spatial Analyst Tools\Zonal Statistics\Tabulate Areas*, in ESRI's Arc GIS ©) extracted raster information into each record of the property grid attribute table. This allowed for the calculation of areas of each land-cover change class, for all 739 lots of the settlement. This procedure was repeated for each of the three transition matrices. Last, percentages of lot area under each land-cover change class were calculated.

2.3 – LUCC in Southeastern Acre

A thematic map for the classification of the whole 002/67 scene of the 2003 Landsat ETM+ image is presented in Figure 2.2. As mentioned above, overall accuracy of this classification is slightly above 85%. Note the land-cover pattern of Humaitá settlement architecture (radial network design) located in the top right corner of the image. A rather different land-cover pattern for settlement project Tocantins, established by INCRA in 1997, can be spotted to the northwest border of Humaitá. Four major roads crossing the area depicted in the image can be located based on the pattern of deforestation buffering the trajectory of these roads. The first is BR–364, which crosses the image in the East – Northwest direction. Note the city of Rio Branco (large pink area) located along BR-364. BR-364 was the first road to be built connecting Acre to the rest of the country. It connects also Rio Branco to Sena Madureira, Feijó and Cruzeiro do Sul to the Northwest. The second road is BR-317, which crosses the image in the Northeast – South direction, bending West at some point and later South again. BR-317 connects Assis Brasil, Brasiléia and Xapuri (and most of Extractive Reserve Chico Mendes as well) to Rio Branco. It connects also Rio Branco to Boca do Acre to the Northeast, and to the Pacific Ocean to Southwest (merging into a Peruvian Highway after crossing the border town Assis Brasil). The third road is Rodovia Transacreana, which departs horizontally from Rio Branco toward the West. The fourth is AC-010 connecting Humaitá and the riverine city of Porto Acre to Rio Branco.

Table 2.1 shows the areal extents of different classes for this scene. Note *Dense forests* area predominating to *Open forests* continuous, under our classification criteria and thresholds. Advanced secondary succession is present around development areas and as "islands" surrounded by forest in the central part of the image. Much of the Bare Soil and Urban class represents overgrazed pastures or fields with dry vegetation (this image has been taken in the dry season).

Figure 2.2 – Landsat ETM+ 2003 image classification for Path 002 Row 067:

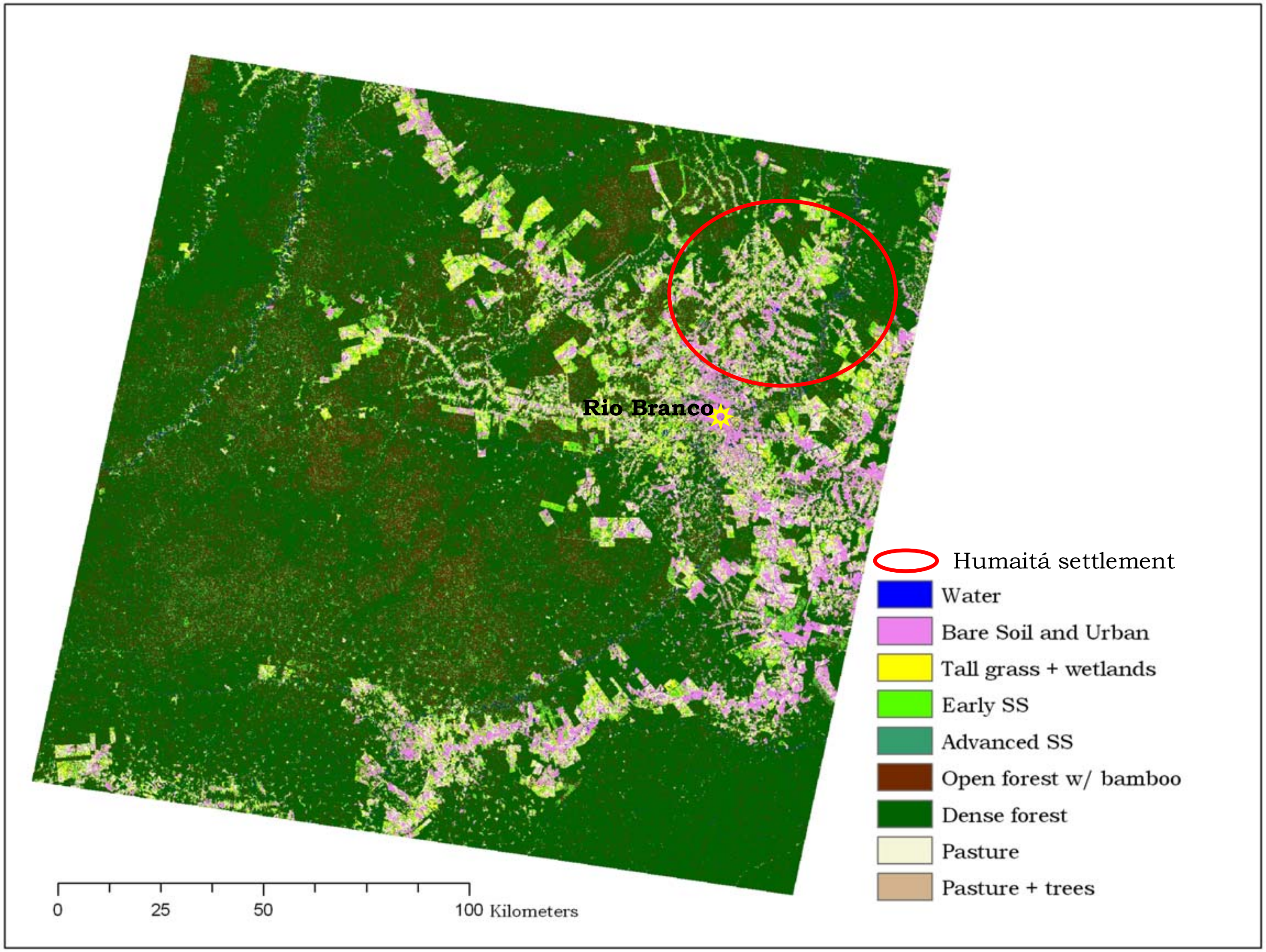


Table 2.1 – Land-cover classes for Landsat 2003 footprint:

Land-cover class	Area (km^2)	Percentage of the scene
Dense forest	20130.5	60.4
Open forest with bamboo	5015.9	14.9
Advanced SS	1102.6	3.3
Early SS	1943.1	5.8
Pasture + trees	621.8	1.9
Tall grass and wetlands	948.1	2.8
Pasture	1848.5	5.5
Bare soil and urban	1623.2	4.8
Water	187.6	0.6
Total	33601.4	100

2.3.1 – Land-cover classification errors and problems

Problems encountered during classification include technical problems with images and problems with spectral signature separability. Problems with images include cloudiness of 15% of the scene in the TM 1992 image (but not over P.C. Humaitá nor RESEX Chico Mendes study areas), intense haze in the 1996 TM image and less intense haze in the 1986 scene; and intense striping in the MSS 1975 scene (but not over P.C. Humaitá). To deal with these problems, we used the following procedures:

a) Cloudiness – Identification of clouds and shadows was done early in the classification process (in the 100 class stage of classification), by grouping clouds and shadows into different classes, and eliminating thus the possibility of misclassification. However, depending on the size and location of clouds and shadows, important information could be lost (but this was not the case for the study area).

b) Haze – Haze is composed by the presence of scattered light reflecting off the surface as well as light reemitted directly back toward the sensor from the atmosphere

(Lillesand et al, 2000). Haze affects brightness values of surface bodies in a non-uniform way across the scene, causing confusion across spectral signatures. Careful atmospheric correction is needed in a hazy image, but it often fixes only partially the problem, due to internal variation in a scene. Thus, besides a careful atmospheric correction, we had to fix manually mis-classification problems in our 1996 and 1982 images, by using neighborhood filtering.

c) Stripes – Stripes represent errors in the scanning devices of the satellite sensor, and were left unclassified in most of the MSS 1975 scene. One particular area falling within P.C. Humaitá, however, was filled with class "Forest" after certification that a minimum area comprising a 100 meters buffer surrounding the "stripped" area was covered with forest. I did this to allow transition matrices to be calculated in this area.

Spectral separability problems - The most difficult classification problem was to distinguish between shades of advanced secondary succession and types of Open Forest with bamboo (or *taboca*, as called locally). Homogeneous bamboo stands (Open Forest with dominating bamboo) and Open Forest with dominated bamboo and palms are typically present in the Southwest of the Amazon Basin, especially in the State of Acre

[36]. Bamboo stands of different sizes and compositions are intermingled within forest stands in many localities in Acre, characterizing a *continuous* bamboo – forest. The spatial distribution of Open tropical forests dominated by bamboo is probably related to soil moisture and nutrient availability, but is not known in detail so far.

This mixed forest-bamboo *continuous* land-cover type renders it difficult to establish discrete categories for Dense tropical forests and Open forests with bamboo. Therefore, we cannot claim that our classification scheme corresponds to the same types of forests

[36] See section 1.9.2.3 - Vegetation (Chapter 1) for details

described in the Ecologic-Economic Zoning of Acre (ZEE, 2000). Spectrally, bamboo is very similar to advanced secondary succession, which represents a methodological problem for LUCC studies in the area: how to distinguish areas that have been cleared for agro-pastoral uses in the last 20 – 30 years from areas *naturally* covered (not influenced by human activities during the last 20-30 years) with patches of bamboo intermingled with forests? This differentiation is important to address the question on the area of forest converted to agro-pastoral uses. As with the haze problem mentioned above, we could not find a definitive solution to this problem. Rather, we used a palliative approach to mitigate the amount of error deriving from mis-classification of open forests with bamboo as advanced secondary succession[37].

Another source of uncertainty in our classification regards differences between classes (1) Dense Forest and (2) Open Forest across the image dataset. Since the regional climate is subject to El Nino cycles, and some years are substantially drier than others, proportions between classes (1) and (2) varied substantially across the image dataset. Other sources of variation include radiometric calibration and haze. For all years where training data is not available (all years except 2003), it is virtually impossible to determine the level of correspondence, in the ground, to spectral signatures used for class description, without being arbitrary.

[37] Much of the open forests with bamboo, considered here as the problematic areas for land-cover classification are found within the Chico Mendes Extractive Reserve (no significant area under mixed forest/bamboo vegetation is found within P.C. Humaitá). Given the land-use characteristics in Extractive Reserves, it can be observed that most agricultural land is neighbored by secondary succession vegetation. This vegetation corresponds normally to land cleared in earlier years for different purposes. Thus, we used a post-classification neighborhood filter (3 x 3 filter) that used the following rule: all pixels previously classified under class (4) – Advanced Secondary Succession, and neighboring pixels previously classified under classes (5), (6), or (8) were maintained under class (4). Otherwise, pixels under class (4) were re-classified as Open forests with bamboo. However, this introduces another source of error, which is the mis-classification of secondary succession areas with *natural* occurrence (due to continuous forest renovation) as forests. This is why we used this procedure only for the purpose of deforestation estimation in the Extractive Reserve Chico Mendes (dissertations of Jackie Vadjunec and Valerio Gomes) area.

2.4 – Land-use and land-cover change from 1975 to 2003

I start this section by complementing the initial description given in the introductory chapter on the social groups of farmers (local ex-rubber tappers, colonist farmers and land investors) living or owning land in Humaitá settlement. This is supported with some descriptive statistics on the socio-economic characteristics of each group and of the lots they own. Biophysical characteristics of the lots for each group are then discussed. I start by presenting descriptive information on soil types in lots belonging to each group of farmer. Last, I discuss some of the differences found in availability of water.

Local rubber tapper farmers own smaller properties when compared to colonist farmers and to land investors (Table 2.2). They are, by definition, the ones living for a longer period of time in the area (34.5 years), while the average time of colonist farmers living in the area is 15.8 years. Thus, that many colonist farmers arrived in the site after the initial colonization period (when *pioneer* families were first settled in Humaitá). They are considered colonist farmers because of the multiple migration events they have experienced (before buying land in Humaitá, they were mostly colonist farmers in other colonization projects). Land investors began buying land in the late 1980s (1989 in average). Land investors own 4 Incra lots in average. This corresponds to properties that are 2.6 times larger than properties owned by local farmers and 2.2 times larger than properties owned by colonist farmers.

Table 2.2 – Average size, number of lots per farmer and time on the lot:

Mean lot size, number of lots and time on the lot	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	Mean	St.dev	Mean	St.dev	Mean	St.dev
Property size (hectares)	68	7.7	81.8	7.8	178	49.3
Number of lots	1.01	0.09	1.54	0.18	4	1.07
Number of years owning the lot	34.5	4.14	15.8	1.02	14.2	1.4

Colonist farmers, who are better represented in the sample (n = 37), have been living in average 1.6 years more than land investors in the settlement area. 73% of the colonist farmers of the sample come from the Northeast and North regions of Brazil (Table 2.3), while 27% come from other regions. Yet land investors present in the sample are all from either the North or Northeast regions.

Table 2.3 – Region of origin by farmer group:

Region of Brazil	Colonist farmers	%	Land investors	%
North	13	35.1	9	69.2
Northeast	14	37.8	4	30.8
Center-West	2	5.4	0	0.0
Southeast	3	8.1	0	0.0
South	5	13.5	0	0
Total	37	100.0	13	100

Most colonist farmer families arrived as young couples in their early stages of the household lifecycle. The second generation is almost entirely born in the region. Household size is shown in Table 2.4. It includes only members of the household who live or work on the lot. Households of rubber tappers are the most numerous, followed closely by households of colonist farmers. Land investors were sometimes defensive on providing me with personal information, so information on household composition of land investors is incomplete (I included only members working on the lot).

Table 2.4 – Household size (family members living or working on the lot):

	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	Mean	St.dev	Mean	St.dev	Mean	St.dev
Household size	4.8	0.54	4.13	0.3	1.4*	0.18

*includes only members of the family that live and/or work in the lot

Most members of local and colonist farmer households are used to doing some type of work on the lot. Boys help normally their fathers to milk cows in the mornings, or on performing cattle related activities (such as vaccination and pest control for example). Girls help on domestic activities and on taking care of the youngsters. Some tasks are more labor intensive and require inputs of the entire household during peak seasons, according to the agricultural calendar. Examples include the harvest of annual and perennial crops, and the making of cassava flour. In some cases, the whole family participates on the commercialization of agricultural products, especially when some type of processing is involved, as for example pastry made out of products from the farm. Labor allocation by age/sex in the study area seems to follow a similar pattern as reported by Siqueira et al (2003) for the Transamazon region.

The great majority of children in school age and teenagers (about 95%) attend regularly to school, although frequencies of attendance vary considerably depending on road conditions, especially during the rainy season. In the early stages of settlement development, schools used to have a more even geographic distribution, and were present even in the most remote areas. With investments on settlement infra-structure, and urbanization processes taking place in Humaitá, distribution of schools changed to more centralized locations, to be concentrated in the villages Vila do Incra and Vila do V. Two factors contribute to the trend observed on the centralization of public services: 1 – Growing demand for better quality services, requiring higher investments on school infra-structure; and 2 – lot consolidation made it less important to maintain schools operating in remote areas.

Public transportation is also deficient on some roads, with no bus lines operating on a regular basis or with very scattered schedules. In the early stages of settlement development, public transportation used to be more regular. INCRA staff was constantly moving in and out the settlement area, providing substantial transportation help to farmers (including agricultural products). The Reduced supply of transportation services might be related to a probable drop in demand in some areas, due to lot consolidation into large cattle-ranches and to changing land-use practices. As annual and perennial crop cultivation dropped significantly over the years, so has the demand for transportation of these products[38]. On the other hand, dairy production has been increasing and provides a reasonable means of transportation for settlers who do not possess their own transportation means. Daily, the dairy processing industry sends a truck to pick milk production, which gives "rides" to settlers on its way back to the processing plant.

Differences in levels of education between local farmers, colonist farmers and land investors are substantial (Table 2.5). While some 86 % of local farmers (averaging across female and male education levels) have not completed elementary school, this percentage

[38] However, one of the main reasons leading to the drastic reduction observed in agricultural cultivation is precisely the lack of transportation networks.

drops to 47% for colonist farmers and to some 15% for land investors, who have achieved high school or higher degrees.

Table 2.5 - Education of male and female heads of household:

Education		Local farmers (n=13)*		Colonist farmers (n=37)		Land investors (n=13)	
		Freq.	%	Freq.	%	Freq.	%
Male Head of Household	Illiterate	5	41.7	5	13.5	-	-
	Elementary incomplete	6	50.0	16	43.2	2	15.4
	Elementary complete	-		11	29.7	2	15.4
	8th grade	1	8.3	3	8.1	-	-
	High school	-	-	2	5.4	4	30.8
	College degree	-	-	-	-	3	23.1
	Graduate degree	-	-	-	-	2	15.4
Total		12	100	37	100	13	100
Female Head of Household	Illiterate	3	25	6	17.1	missing data**	
	Elementary incomplete	7	58.3	7	20.0		
	Elementary complete	2	16.7	15	42.9		
	8th grade	2	16.7	4	11.4		
	High school	-	-	1	2.9		
	missing data	-	-	2	5.7		
Total		12	100	33	100		

* Some households have only one head (either male or female)
** Due to time constraints, many female heads of household belonging to this group could not be interviewed

Education is probably one of the most important mechanisms to provide opportunities of social ascent. Limited education opportunities for less endowed families might connect to theories on the political economy of agrarian change (Ellis, 1993), which state that disparities in farmers' access to resources reinforce income and wealth gaps leading to uneven development.

2.4.1 – Soil types by groups of farmers

Lots belonging to local farmers seem to contain a slightly higher percentage of fertile soils, when compared to lots belonging to colonist farmers and land investors (Table 2.6). This data was obtained from field surveys with farmers, based on their own estimation of percentages of fertile soils in their lots. Lots belonging to colonist farmers come in second place, and land investors' lots possess, on average, the lowest percentage of fertile soils.

However, and according to the 1:250,000 soil map produced for Acre's Ecologic-economic Zoning (do Amaral et al, 2005), no differences in soil types are found across properties belonging to the three groups of farmers (Table 2.7).

Table 2.6 – Soil types based on descriptions given by farmers, according to percentages of fertile soil in their lots:

Portion of fertile soils in lot	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	Frequency	%	Frequency	%	Frequency	%
> 70% of lot good soils	6	46.2	20	54.1	6	46.2
40% < good soils < 70%	6	46.2	6	16.2	1	7.7
10% < good soils < 40%	0	0.0	7	18.9	1	7.7
< 10% of lot good soils	1	7.7	4	10.8	5	38.5
Total	13	100.0	37	100.0	13	100.0

Table 2.7 – Soil types according to Acre's Ecologic-Economic Zoning (ZEE) 1:250,000 soil map:

Soil class	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	Frequency	%	Frequency	%	Frequency	%
Alfisols	4	30.8	10	27.0	4	30.8
Aluvial soils	1	7.7	0	0.0	0	0.0
Ultisols	1	7.7	3	8.1	0	0.0
Plynthic Ultisols	7	53.8	24	64.9	9	69.2
Total	13	100.0	37	100.0	13	100.0

2.4.2 – Water availability in Humaitá

Water ponds are a very important source of water supply for cattle-ranching in the region, and are often used for other purposes, such as fish breeding and human use. Local farmers and colonist farmers build ponds for multiple uses, while land investors build ponds mostly to supply cattle with water. Other sources of access to water include creeks crossing the lots and the Acre River, where plenty of fish still exist (according to most *ribeirinhos* (river shore residents) the stock of fish in the Acre River has been steadily dropping).

While most local farmers have one to two ponds on their lots, most colonist farmers have more than 2 ponds and most land investors have more than 4 ponds (Table 2.8). These differences are probably related to the following factors: a) demand for new ponds increase with larger cattle herds; b) land investors have better financial conditions to invest in the construction of ponds.

Table 2.8 – Number of ponds per lot:

Number of ponds per lot	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	Frequency	%	Frequency	%	Frequency	%
0	1	7.7	4	10.8	0	0
1 to 2	10	76.9	16	43.2	2	15.4
3 to 4	2	15.4	11	29.7	3	23.1
5 to 7	0	0	5	13.5	4	30.8
more than 7	0	0	1	2.7	4	30.8
Total	13	100	37	100	13	100

Land investors possess not only a higher quantity of ponds on their properties, but also have substantially larger ponds. It should be noted, however, that local farmers have better access to natural sources of water (creeks, springs and the Acre River), since they were often free to choose where to live, at that time Humaitá was still part of four rubber farms or *seringais*. In Chapter 6, I explore the increase in the number of ponds along with the settlement's aging, and how it relates to changes observed on land-use strategies between farmers of different social groups.

2.5 – Land-use in Humaitá

This section begins by presenting land-use allocation at the farm level and by social group of farmers. This is based on land-use data from household surveys with farmers (n=63). Next, I present some of the land-use practices that are locally important, which were observed during fieldwork.

2.5.1 - Land-use allocation

When P.C. Humaitá was implemented in 1981, there was a considerable expectation among administrators of the public sector that it would turn into some kind of breadbasket of Rio Branco and supply it with staple foods such as rice, beans, manioc flour, corn and vegetables. This expectation was based on the strategic advantages brought of agricultural development, for example ending dependence on imports from Rondônia (neighbor State), or creating new opportunities in the rural sector thus reducing urban problems in Rio Branco caused by rural-urban migration. Some initiatives were taken by administrators to encourage production of annual crops in the settlement, including construction of grain stocking facilities, establishment of lines of agricultural credit at low interest rates (as for example the Procera/Incra credit line), and a detailed study on the agricultural potential of the settlement, promoted by INCRA in coordination with EMATER, the local rural extension agency, that included the participation of researchers and consultants from several other local governmental agencies (INCRA, 1990). Indeed, many farmers took the bait" and invested heavily in the production of annual crops. Contrary to most States in the Amazon, Acre has a substantial portion of fertile soils distributed in small patches of Alfisols in some parts of the State, rendering credibility to potential agricultural development projects. However, problems of transportation of agricultural produce to markets and low prices made many farmers abandon annual crops cultivation, and move towards cattle-ranching and/or mixed husbandry systems. More on land-use strategies is discussed in Chapter 3.

Land-use data from household surveys allowed me to analyze land allocation according to the most important land-use types in the settlement. Pasture for cattle-ranching and mixed husbandry systems (including dairy, sheep and horses) is the main land-use type in Humaitá, covering 45.9 % of lot areas in average (Figure 2.3). Forests come in second, with 36.5 % of lot area, followed by secondary succession with 10.8%, annual crops with 3.3%, perennial crops with 1.9% and ponds with 1.7%.

Looking into detail for land-use differences across farmer groups (Figure 2.4), colonist farmers have the highest amount of pasture (52.6%), followed by land investors (45.2%) and local farmers (27.5%). Local farmers maintain the highest percentage of land-covered with forests, secondary succession and annual crops. Percentages of perennial crops are higher in lots belonging to colonist farmers, while percentages of ponds are higher in lots belonging to land investors.

Figure 2.3 – Land use in P.C. Humaitá: average percentages of total lot areas (based on survey data, n = 63 lots; average lot size = 98.8 hectares)

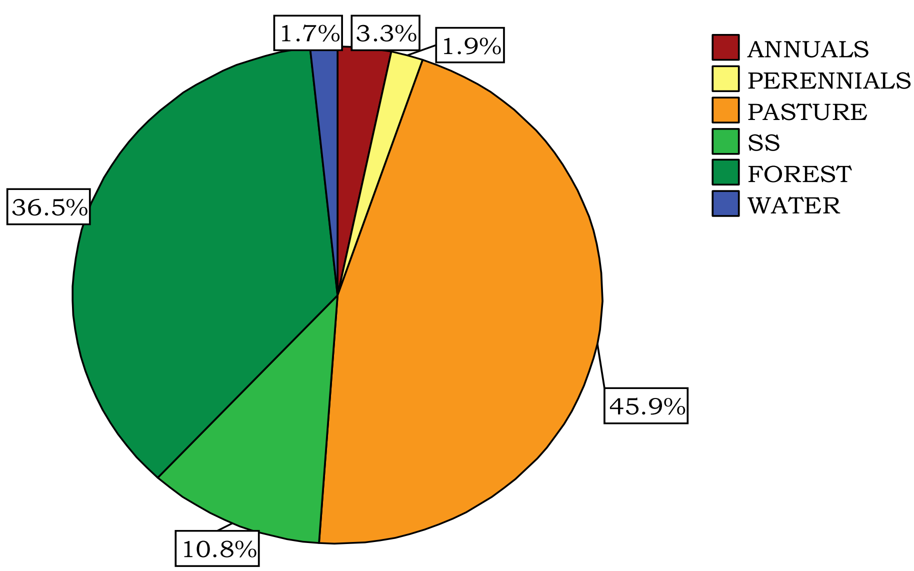
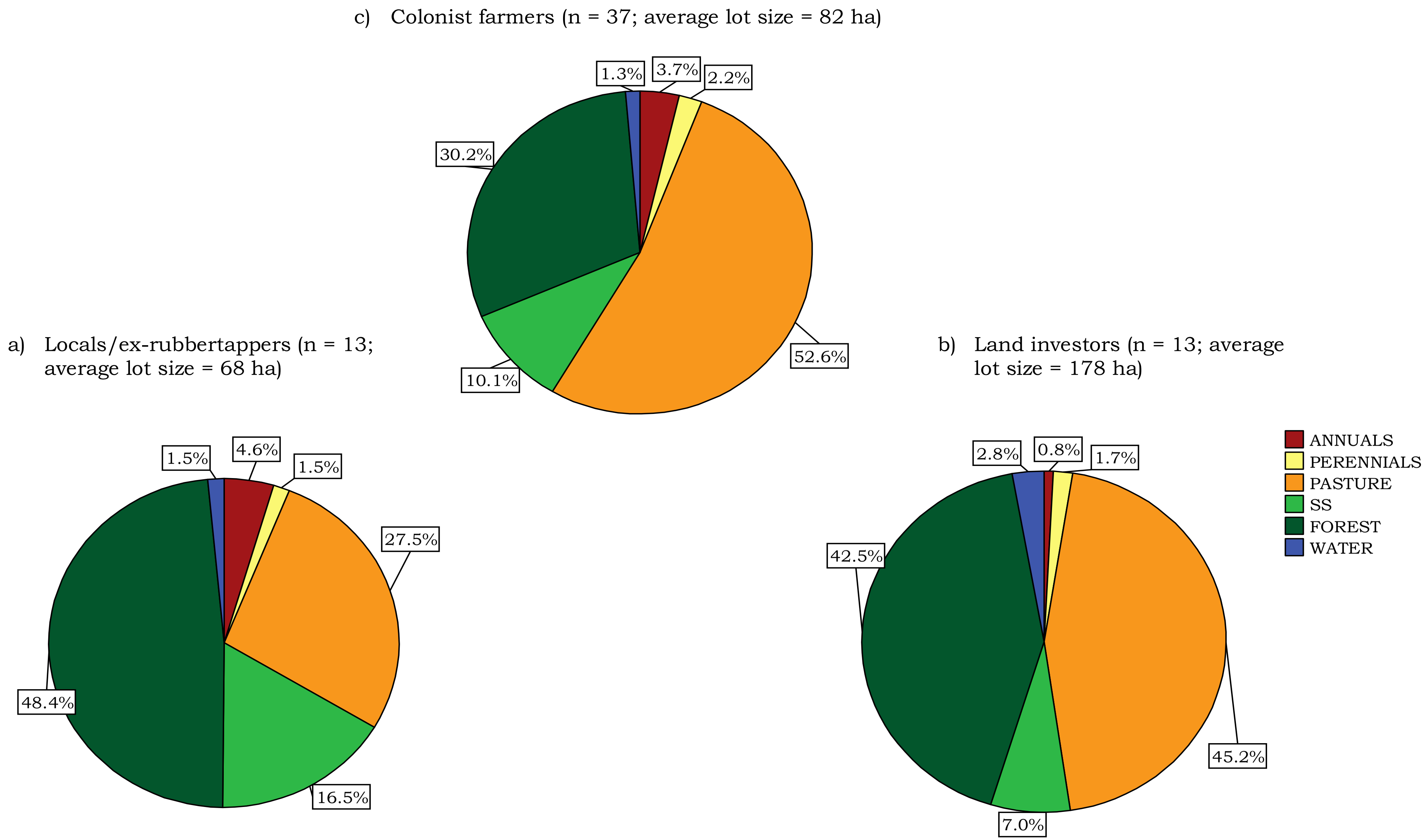


Figure 2.4 - a, b and c: Land use according to social group of farmers (average percentages of lot areas)



2.5.2 – Land-use practices

There are multiple forms of establishing pastures. Grass seeds can be directly sown in previously forested areas, after the burning of vegetation debris (most land investors). Pasture can also be established in areas previously cultivated with annual crops, mostly rice, cassava and corn, or sown between rows of crops by flowering time (most local and colonist farmers). Alternatively, pastures are established on fallow areas where previous pasture fields were populated with secondary succession. Direct establishment of pastures on land previously covered with primary forests is less common among local and colonist farmers. Even land investors, who are used to establishing larger pasture fields try to take advantage, whenever possible (and depending on labor supply availability), of the nutrients released by forest biomass burning to produce one harvest of rice or corn before sowing *Brachiaria brizantha* (locally known as *braquiarão*) seeds for pasture establishment.

Field preparation for annual crops usually begins early in the dry season (June-September) by clearing understory vegetation and smaller trees (*broca*), which is followed by cutting large trees (*derrubada*). Hardwood is eventually used for construction of houses or fences, but most of the woody vegetation is left to dry in the field, and later stacked manually into piles (*coivaras*) to be burned. A good burn is important for efficient release of nutrients, for weed and pest control, and for allowing field clearance of vegetation debris (Moran, 1993). No burning is often preferable to a poor burning. This allows future burns to happen during the short dry periods following the first rain. Poor burning consumes important fuel matter making future terrain clearance problematic.

Cassava is normally planted in September, after the first rain, while corn and rice are normally sown only after rain distribution is considered “regular” by farmers. This varies from year to year, constituting an important source of uncertainty to farmers. If farmers wait too long, fields are rapidly plagued with weeds making weed control more costly. Farmers exchange information about weather when meeting with neighbors. This information exchange takes place either through informal visits, through church, labor unions or market meetings. Short-term weather forecasts (forecasts of one to two days) are available from TV news, radio programs and newspapers at the national and regional level, but not at the local level. Their reliability is thus limited.

Land investors clear forests often using heavy machinery, which results in potentially greater ecological damage to the ecosystem when compared to manual clearings followed by fire (Buschbacher and Uhl, 1988). Depending on the type of technology, mechanical clearings allow for mechanization of pasture fields starting from its establishment, making the system more labor efficient. However, mechanization of Plintic Ultisols has been leading to disastrous consequences, because it accelerates the formation of an impediment layer causing drainage problems and erosion. Moreover, several pastures established over Plintic Ultisols (locally known as *tabatinga*) have been experiencing the so-called "death of pastures" (*morte das pastagens*) due to water-clogging impeding respiration of *B. brizantha* roots. This problem is not limited to Humaitá, it has been extended to several settlements and cattle-ranching areas in Acre (Valentim, 2006).

Rice, corn, and less frequently planted crops, such as squashes and watermelons, are normally planted in previously forested areas, while cassava and beans are normally planted in areas previously covered with secondary succession. The problem with planting cassava in previously forested areas is that the dense root network makes cassava harvesting difficult. Beans, which are planted only in April, are not supposed to be planted in these areas because of problems with a fungus disease (*Rhizoctonia solani*, locally known as *mela*). Several farmers consider that areas previously covered with secondary succession are better for planting corn as well. This depends a lot on the soil fertility, which is extremely variable in Humaitá, as discussed in Chapter 1.

Fertile Alfisols allow for continuous soil cultivation with nutrient-demanding crops such as corn, for up to four annual cycles without chemical inputs. Alternatively, such soils may be cultivated under traditional slash-and-burn cycles, which lead to better harvests. Acidic Ultisols and Plintic Ultisols cannot be cultivated continually with mono-crops and without fertilization and require typically longer follow cycles for sustained harvests. However, some farmers have been shown to sustain yields of multi-crop perennial systems established in Humaitá soils with low natural fertility (Peneireiro et al, 2000). Such systems, also known as agroforestry systems, allow for more efficient cycling of nutrients and use of water and light (Nair, 1989), and sustain nutrient supply to commercial crops by exploiting ecological synergisms between multiple species, combined with cultural practices such as mulching and pruning.

Agroforestry in Humaitá has been used by some farmers since they arrived in the settlement, while other farmers began experimenting with it after an on-farm participatory research project was started by the Arboreto Project, a team of researchers with the Federal University of Acre and Parque Zoobotânico (UFAC/PZ). Arboreto researchers/extensionists and Humaitá farmers started developing participatory activities in 1998, with the general goal of promoting diversified agroforestry systems and practices such as the use of legumes for green manure, multiple use of trees, living fences, and planting of contour trees. Experimentation with high density and diversified perennial systems, also known as

Successional Agroforestry Systems (with species arrangements and management inspired arrangements based on ecological succession principles) took place on 17 farm lots with Humaitá families. In 2000, these families formed the Humaitá Ecologic Farmers' Group (*Grupo de Agricultores Ecológicos do Humaitá*), which is oriented toward promoting organic farming and aggregation of value to agricultural products by processing of foods. By 2003/2004, nine of these farmers were maintaining their agroforestry systems active, plus other seven farmers had recently joined the group and were implanting systems with banana and pineapple as the main commercial crops. The group acquired a processing plant for "dry" banana and pineapple production (with financial and technical support from the government of Acre), which was ready to begin small-scale operations. Another positive outcome was that the group joined organic farmers (from other settlements) and requested a spot in the central market of Rio Branco from the city authorities. The spot was granted, and by 2003/2004 commercialization of organic products in the market fair was contributing to a significant increase in farmers' income. Independent of the outcome of these activities and projects, they represented an important source of individual and social learning for farmers.

Other important land-use types include mixed husbandry and perennial crops. The first one includes dairy production (milk and cheese), which is very important locally given the existence of a dairy processing plant in the settlement. Dairy production is part of a hybrid cattle-breeding system, which is used for both dairy and beef production. Mixed husbandry systems also include fish breeding in ponds, which is economically important, and mixed commercial/subsistence husbandry including pork, fowl, goats and sheep.

The most important perennial crop is coffee (*Coffea canephora*

[39] and *Coffea arabica*), but coffee production has dropped significantly due to the 1998-2002 price crisis. Coffee plants are normally established by intercropping seedlings with annual crops. Later, coffee might be left alone in the system (sun-grown coffee) or cultivated as part of agroforestry systems shade-grown with other species, including *Inga edulis* which also provides nutrients to coffee plants. Banana and pineapple cultivation was stimulated in the neighborhood of the new fruit processing plant acquired by the Ecological Farmers Group. Banana has been traditionally grown by *ribeirinho* farmers; however, many farmers have been experiencing difficulties due to infestation of *Sigatoka negra*, a fungus disease affecting most banana varieties. But new resistant varieties have been developed by Embrapa, and were being tested by the time fieldwork was conducted. Pineapple crops have guaranteed markets, but have been plagued by gomose (*Fusarium moniliforme*) which is difficult to control. Other important perennial crops include pupunha (*Bactris gasipaes*) and cupuaçu (*Theobroma grandiflorum*), two native fruit species of the Amazon which have already reached important status on local, regional and even national markets. Passion fruit (maracujá, *Passiflora edulis*) and papaya (*Carica papaya*) are very well adapted to local conditions. These crops produce all year long and are highly perishable, thus requiring good road conditions throughout the year. Prices of passion fruit and papaya have been very good in the past, but increases in production have flooded the market.

2.6 – Land-cover change in Humaitá

In this section, I present the results of land-cover classification at the lot, social group, and settlement levels. This is based on transition matrices of land-cover obtained from remotely sensed imagery extracted at lot and settlement levels by combining them with the

[39] *C. conephora* is more adapted to the Amazon ecosystem and is thus cultivated more often than *C. arabica*

actual property grid into a GIS. The discussion of land-cover change at the level of farm lots is based on the dataset available for the entire settlement (n=739). The discussion on land-cover change at the social group level of farmers is based on both remotely sensed imagery and survey datasets (n=63). This limited sample size had to be used in the latter case because social group information is only available in the survey dataset.

Land-cover change is explored first by presenting the results for the deforestation transition matrix 1975 – 2003 for the three levels of analysis (farm lots, group of farmers and settlement). Next, I present and discuss a transition matrix for secondary succession during the 1986 – 2003 period. The third transition matrix is a combination between the two initial ones, showing two kinds of land-use transitions: a) cycles of fallow periods and b) land converted from forest to agro-pastoral uses and "kept under production" (no secondary re-growth observed). This third transition matrix is hereafter referred as the "land-use transition matrix".

2.6.1 – Deforestation rates at the farm-lot, social group and settlement levels

Figure 2.5 shows the deforestation trajectory for the 1975-2003 period. Forest clearing by 1975 was very limited in the settlement, and observed mostly in small patches along the Acre River and along AC-010, the main road connecting the settlement to Rio Branco. Areas deforested by 1975 correspond mostly to slash-and-burn agriculture plots established by rubber tappers living in the area. However, by 1986 all of the settlement was already occupied (all families had been already settled by INCRA), and deforestation was observed in 95% of the lots. Note that forest clearing starts closer to the roads and advances to the interior of lots as the settlement ages. Average deforestation rates per lot, measured in percentage of lot deforestation continued to increase for the 1987 – 1992 period, and then dropped slightly in the following 1993 – 1996 period (Figure 2.6). Deforestation rates continued to drop slightly in the 1997 – 1999 and 2000 – 2003 periods. However, it is important to note that this figure does not represent annual deforestation rates, once the temporal range between images is variable (1986-1992 period and 1997 - 1999 period). Thus, the distribution curve for annual deforestation rates is probably different from the one shown in Figure 2.6.

Figure 2.5 – Deforestation transition matrix 1975 – 2003:

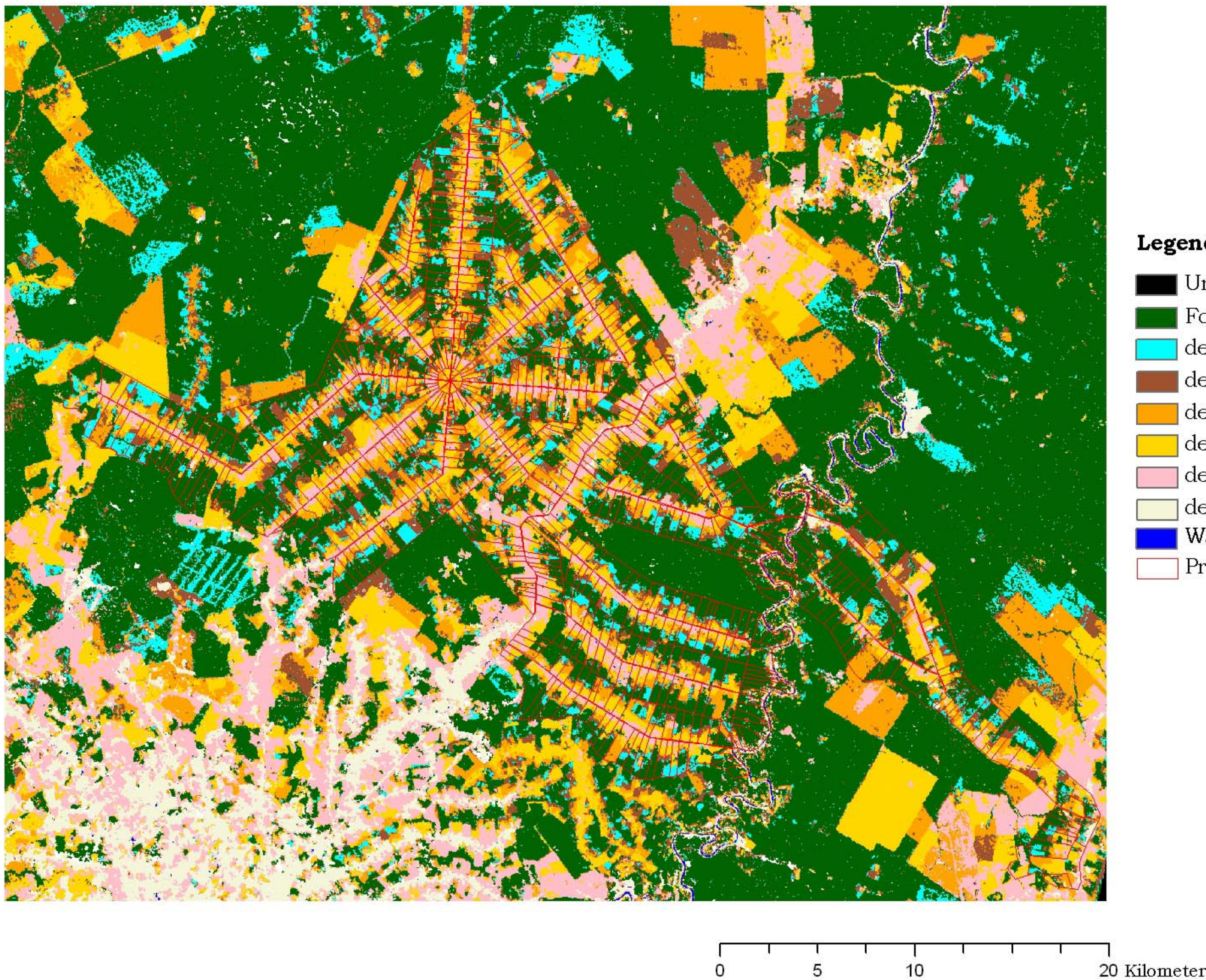
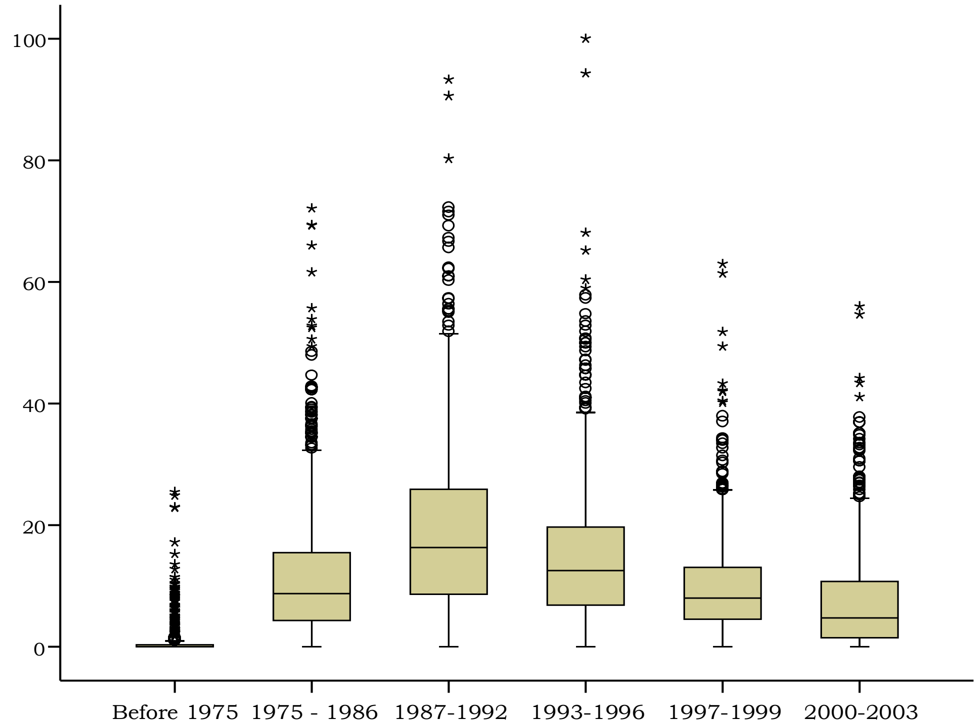


Figure 2.6 – Percentages of lot deforestation 1975 – 2003 (n = 739):



Most deforested land by 1975 took place in local farmers' lots (Table 2.9). By 1986, however, lots belonging to colonist farmers and to land investors exhibited deforestation rates twice as large as the ones in local farmers' lots. Colonist farmers continued deforesting at higher rates through 1996, and showed lower deforestation levels by 1999 and 2003, when compared to the other two groups. The lower deforestation rates observed for colonist farmers in the last two periods is probably influenced by the reduction in forested area that took place during the previous periods. Lots belonging to land investors were deforested at intermediary rates up to 1996, and

started showing the highest rates in 1999 and 2003. Given lot turnover events, however, it cannot be stated that actual owners belonging to the land investors group (and, to a lower extent, to the colonist farmer group), are responsible for deforestation rates observed in the late 1980s and early 1990s. The relationship between lot consolidation derived from lot turnover and deforestation, relates to the turnover hypothesis of deforestation mentioned earlier in this chapter, and will be addressed empirically in chapter 5.

Table 2.9 – Deforestation rates at the levels of lot, group of farmers and settlement:

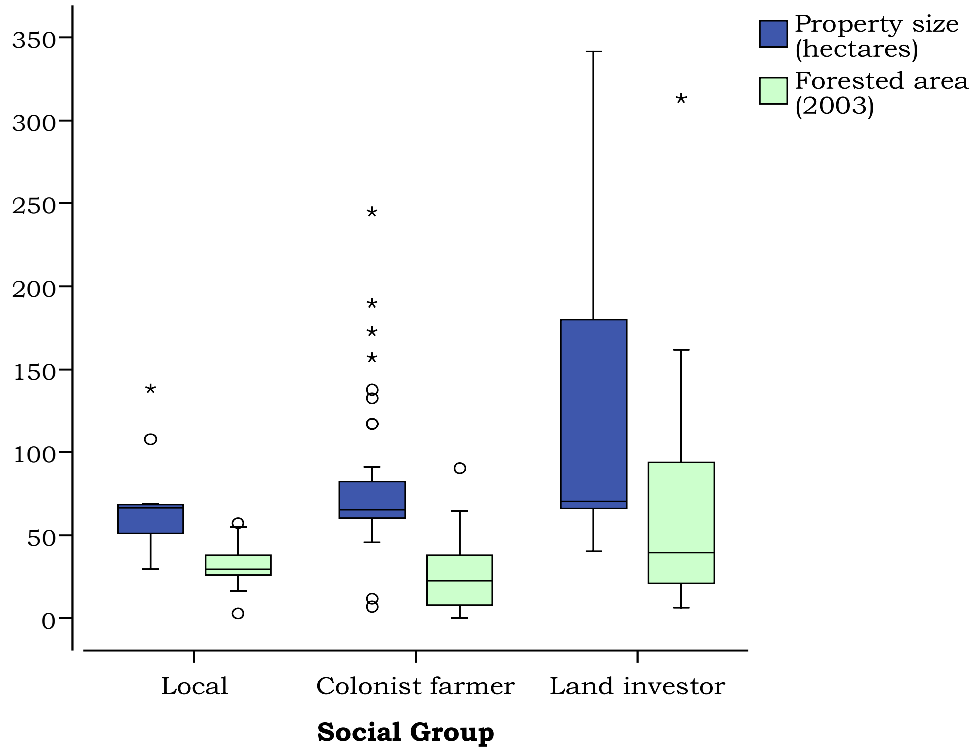
Levels of analysis		Deforestation before 1975		Deforestation 1975 - 1986		Deforestation 1987 - 1992		Deforestation 1993 - 1996		Deforestation 1997 - 1999		Deforestation 2000 - 2003		Remaining forest by 2003	
		%	stdev	%	stdev	%	stdev	%	stdev	%	stdev	%	stdev	%	stdev
Lot (n=739)		1.0	2.8	11.9	11.2	18.9	14.1	15.2	12.2	10.0	8.2	7.7	8.4	44.7	24.7
Group (n=63)	locals	1.9	2.8	7.1	4.8	13.9	7.3	14.9	8.7	10.9	5.0	7.9	4.6	54.3	14.9
	Colonists*	0.6	2.1	14.4	11.4	18.9	13.4	18.2	10.0	9.4	7.5	8.2	8.0	40.3	26.0
	Investors*	0.3	0.6	14.2	12.7	14.5	8.6	13.3	9.8	11.6	8.2	9.7	9.4	44.8	15.5
Settlement (%)		1		11.9		18.7		14.6		10.2		8.3		43.5	

* This analysis has a potential limitation which is that an important fraction of colonists and of land investors arrived only after 1986. Thus, differences across social groups are of limited analytical value for the initial periods of settlement (before 1992).

Figure 2.7 confirms that local farmers maintain more area of their lots covered with forest, followed closely by land investors, and colonist farmers show the lowest portion of forest on their lots. Variability on forested area of lots is much higher within the land investors group, when compared to the other two groups. Note that Figure 2.7 is based in absolute values for property sizes and forested areas (and not percentages as in the previous and following figures).

Licenses for forest clearing in P.C. Humaitá have been recently denied by IBAMA to several farmers, under the claim that deforestation limits per lot already had been exceeded. Under Brazil's Forest Code of 1964, rural properties located in Legal Amazônia are allowed to convert up to 50% of original forested area to agro-pastoral uses. However, in 2000, the federal government issued a decree under which this limit was reduced to 20% of the original forested area. Until the late 1990s, farmers in Humaitá were rarely fined for not observing the 50% limit. New political agendas in the early 2000s led to increased control over deforestation in Humaitá. Clearing licenses started to be neglected, and farmers clearing land without licenses were fined. Farmers with lots already over the 20% deforestation limit started to have problems securing approval for agricultural credit loans. Large properties over the 20% deforestation limit also have been facing difficulties when attempting to acquire definitive titles on land (*escritura pública*). Many farmers have complained about the current situation during field interviews.

Figure 2.7 – Forested area and property size by social group in 2003 (n = 63):



2.6.2 – Secondary succession at the settlement level

A transition matrix for secondary succession during the 1986 – 2003 period is shown in Figure 2.8. This transition includes all pixels classified as secondary succession (SS) in the image dataset, for the period when they were first classified. For example, if a pixel was classified as SS in 1986 but not in 1992, it remains classified as SS in the following images that compose the transition matrix up to 2003, the last year of the series. Thus, the secondary succession transition matrix shows a historic record for all pixels that have ever been classified as secondary succession, and labels them according to the year they were first classified.

Secondary succession re-growth is part of the cycle of slash-and-burn land preparation, which is frequently adopted by farmers in the Amazon. The biomass stored in fallows accumulates nutrients which are released to crops after cutting and burning the vegetation. Hence, farmers purposely allow secondary re-growth to take place in slash-and-burn systems, in conditions where other technologies are not available since it makes economic sense[40]. Secondary succession is also part of cattle-ranching land-use systems. However, in this case it usually indicates that farmers are having problems with managing their pastures, once invasive species reduce pasture productivity in the long term. The slash-and-burn systems with pastures are rarely adopted as a strategy to maintain pasture productivity in the long term[41]. In Humaitá, as elsewhere in Amazonia, farmers hire hourly labor to control secondary re-growth in pastures and use fire precisely to keep secondary succession from taking place.

[40] However, this depends on the ecologic and economic context in which farmers find themselves.
[41] However, fire is commonly used during the formative stages of pastures.

Figure 2.8 – Secondary succession transition matrix:

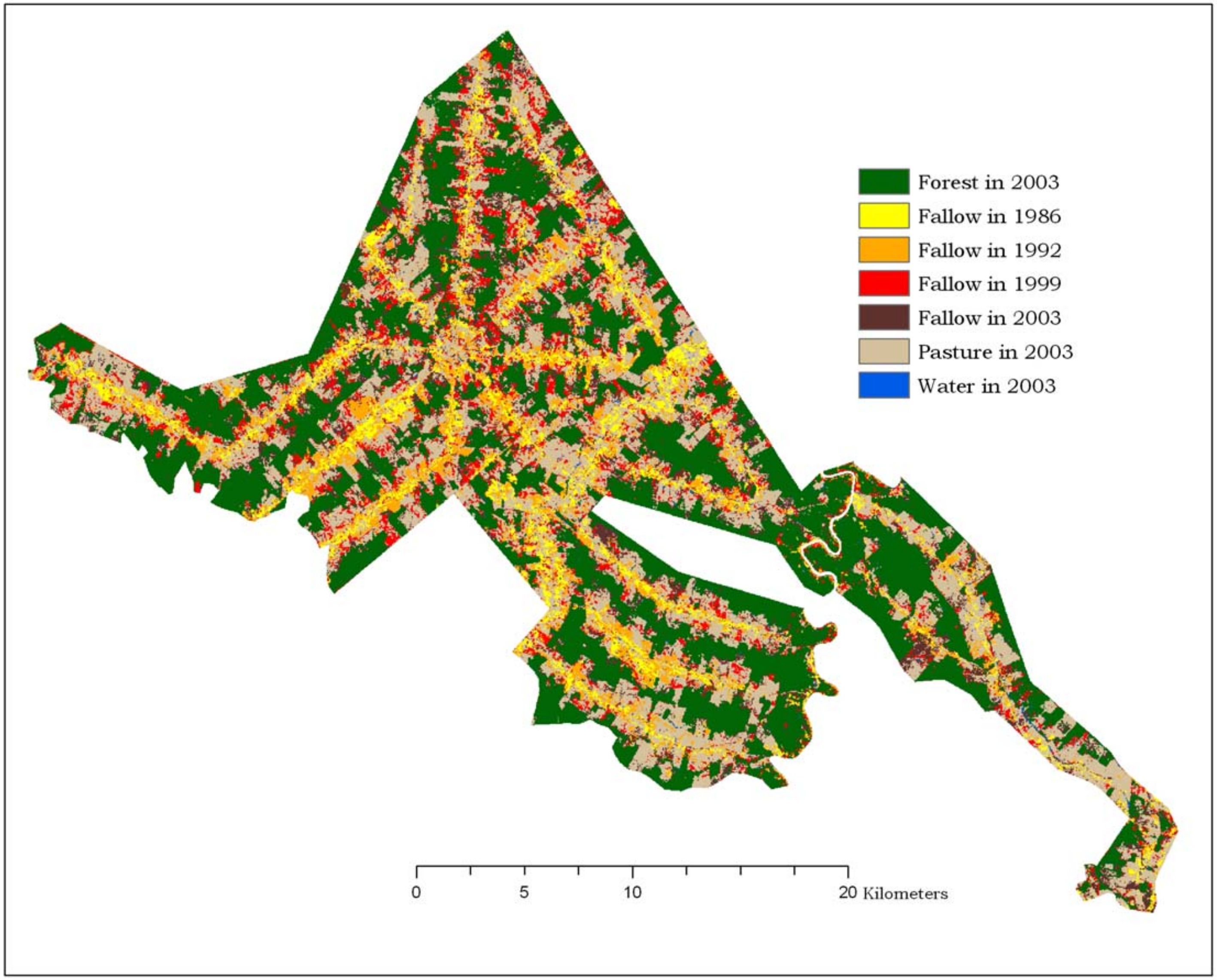


Table 2.10 shows that the area under secondary succession (SS) in Humaitá varied between 6.3% in 1986 and 9.3% in 1999. In 1992, there was an increase in the area under SS, which was reduced significantly by 1996[42] and increased again in 1999.

Table 2.10 – Fallow area from 1986 to 2003:

	Fallow in 1986	Fallow in 1992	Fallow in 1996	Fallow in 1999	Fallow in 2003
Settlement area (hectares)	3875	5071	4190	5692	5548
Percentage of settlement (%)	6.3	8.3	6.9	9.3	9.1

Based on the information that pasture was already the main land-use type in Humaitá by 1992, the trend shown in Table 2.10 indicates that farmers were more efficient in the 1993-1996 period at keeping SS from their pastures. This, in turn, points to overall financial conditions probably being better in the 1993-1996 period, when compared to other periods, allowing farmers to hire more personnel to invest in pasture maintenance. Better financial conditions during this period probably result from the effect of Plano Real established in 1994 in controlling inflation (Perz, 2002).

2.6.3 – Land-use transition matrix at farm-lots, group of farmers and settlement levels

A detailed land-cover transition map is shown on Figure 2.9, and is referred to as the land-use transition matrix, since the level detail of transition classes allows for inferences about land-use history. It combines information from the two previous trajectories into a

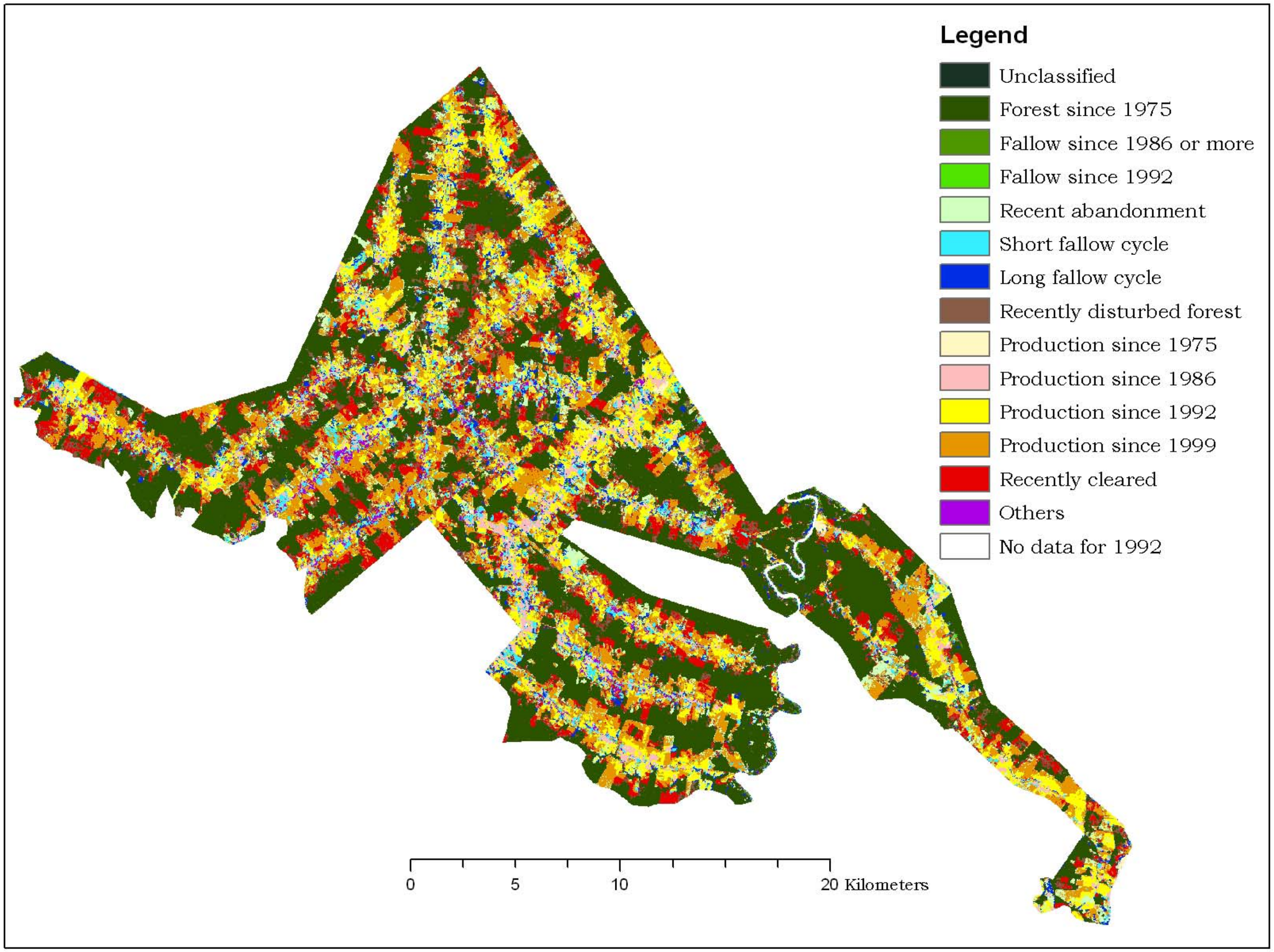
[42] The period of time between images in the SS transition matrix was intended to be as homogeneous as possible, to avoid large variation in number of years that could mask the “real” annual rates of change. Thus, the 1996 image was excluded from the 1986 – 2003 SS transition matrix.

single one. It shows two groups of land-cover classes: classes representing pixels that have been continuously classified as cleared area (pasture/agriculture/bare soil), after conversion from forests, and to here referred as “area under production since [..]”; and areas representing pixels that have been classified under different classes along the 1975 – 1986 – 1992 – 1999 – 2003 transition period. Each of these periods accounted for three classes (cleared, secondary succession, and forest). Pixels previously classified as water were included into the “cleared areas” class. Clouds and shadows in the 1992 image were left as unclassified. The “1999 and before – 2003” matrix, which is the last transition, had thus $3^5 = 243$ classes (3 classes, 5 images), which were combined according to similarities, resulting in the 15-class transition matrix shown in Figure 2.9. The “recent abandonment” class means pixels continuously classified as “cleared area” but under “secondary succession” in 2003. The “short fallow cycle” class means pixels continuously under transition between “cleared” and “fallow”[43] classifications, with only one “fallow” classification within “cleared” classifications;

The “long fallow cycle” means two consecutive classifications as “fallow” within “cleared” classifications. “Recently disturbed forest” applies to pixels continuously classified as “forest,” but under “fallow” in the most recent image (2003). The “recently cleared” class applies to pixels continuously classified as “forest,” but classified as “cleared” in 2003. Last, the “production since [..]” classes correspond to pixels continuously classified as “cleared” since the year of reference [..].

[43] The terms “fallow” and “secondary succession” are used inter-exchangeably here

Figure 2.9 – Land use transition matrix:



The next step was to extract the information from the land-cover transition matrix to the level of lots (as explained in section 2.2.4). Quantitative details in this last transition are presented on Figure 2.10 (at the farm-lot level with n = 739), Figures 2.11 and 2.12 (group of farmers, n = 63) and Table 2.11 (all three levels). Note a total of 36.9% of forest cover since 1975 (pixels classified as forest in all images of the 1975 to 2003 image dataset). This amount differs slightly from the total presented on Table 2.9, since it does not include re-growth of fallow areas in 1975 and 1986 into forests in 2003. 19.2% of the total area corresponds' to pixels currently under secondary succession, or short/long fallow cycles. 41.4% of the total settlement area has been continuously classified as cleared along a variable number of years. The last 2.5% represent all pixels that could not fit within these denominations (the "others" category).

Note that proportions of "forest cover since 1975" are apparently higher in lots belonging to local farmers, followed by lots belonging to land investors and then by lots belonging to colonist farmers, showing similar trends to Table 2.9 (which shows proportions of remaining forest in 2003). Local farmers also show lower proportions of land under short fallow cycles, which is probably connected to the lower rates of land allocated to pastures. Colonist farmers show higher proportions of recently abandoned land, when compared to local farmers and land investors. This might indicate they have been less efficient in maintaining their pastures "clean", or that they experieced more difficult economic conditions from 2000 to 2003, and could not hire wage labor for pasture maintenance operations. However, colonist farmers also have higher proportions of land under production since 1992 and 1999, which reflects higher conversion of forest to pasture during these years, and might also reflect that they were more efficient in keeping these areas under production than farmers from the two other groups. Colonist farmers also show lower proportions of recently disturbed forest, when compared to the other groups. Complementary data from the survey show that a higher proportion of colonist farmers have been exploring timber selectively since they arrived in the settlement, when compared to local farmers and land investors. Colonist farmers have probably exhausted their timber resources to a higher degree than local farmers and land investors. Land investors show higher proportions of land under production since 1986. This might reflect that by 1986 they were more efficient in keeping established pastures from undergoing secondary succession than colonist farmers (see Table 2.9 showing higher rates of deforestation by 1986 for colonist farmers), or that they experienced more stable financial conditions throughout the period (which makes sense since their annual income is much higher than colonists' income – see Chapter 4).

Figure 2.10: Land cover change in P.C. Humaitá – average proportions of lots (n = 739):

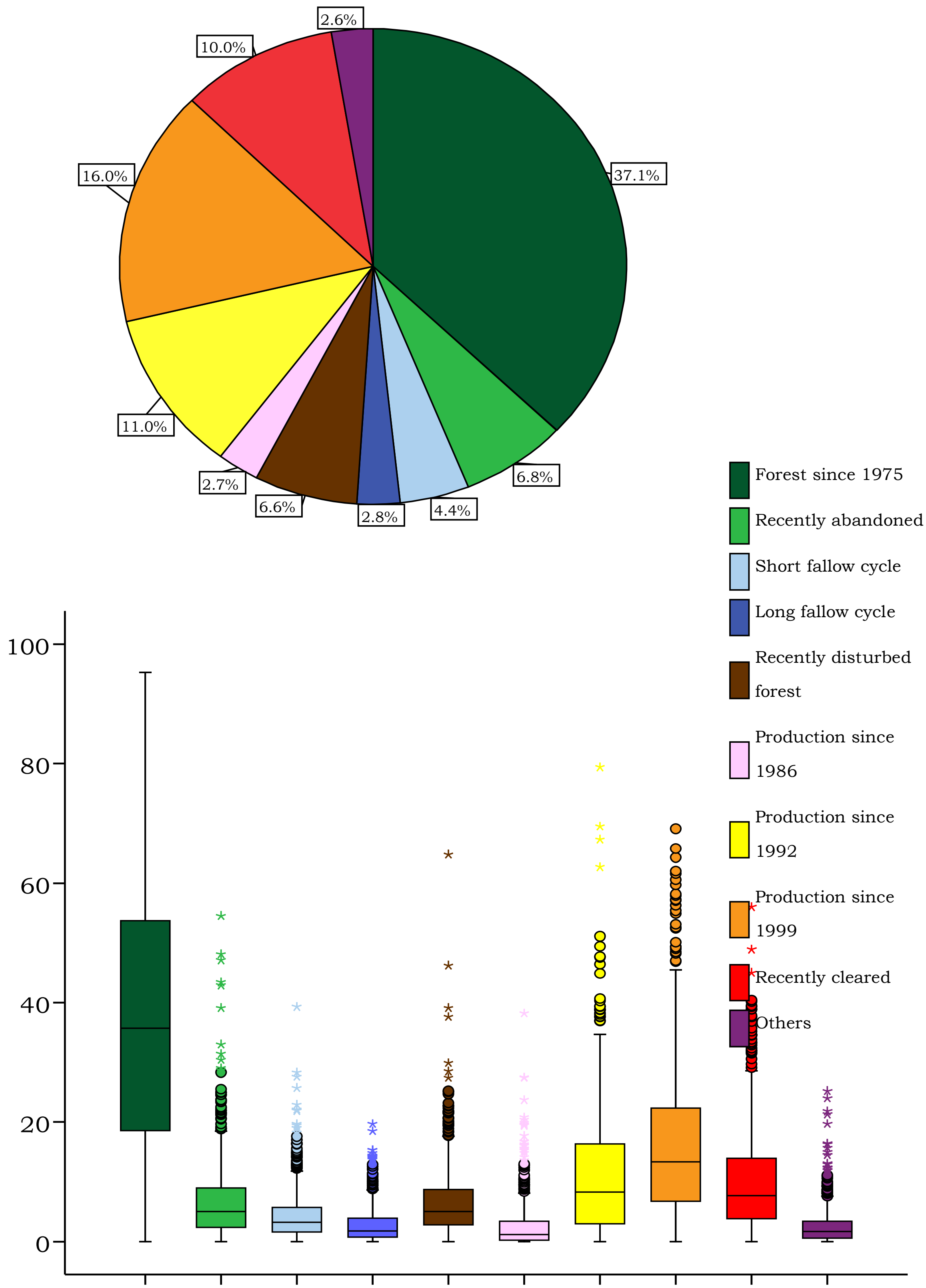


Figure 2.11: Land cover change in P.C. Humaitá – average proportions of lot areas by social group of farmer (n = 63):

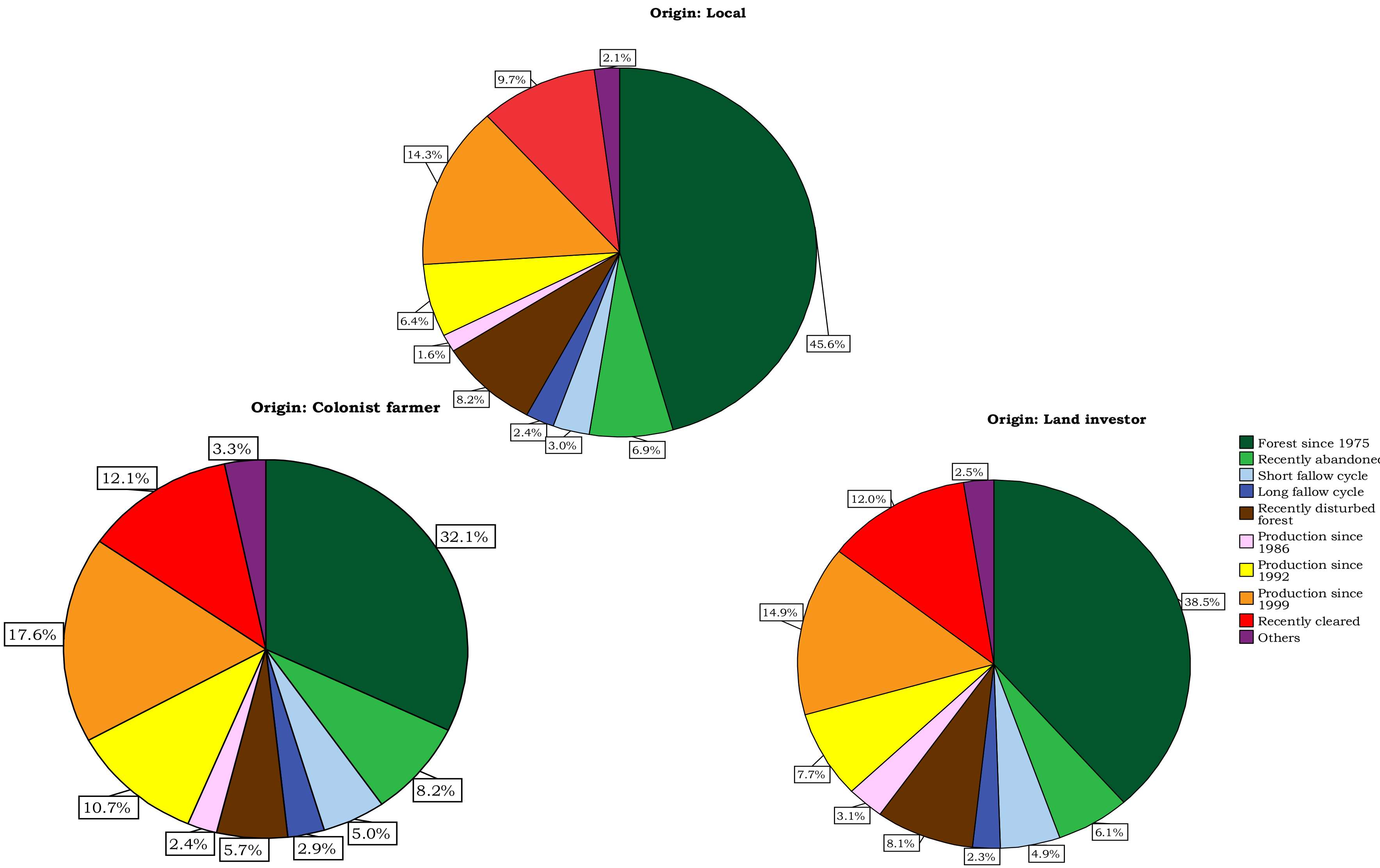


Figure 2.12: LUCC in P.C. Humaitá: percentage of lots by social group of farmers:

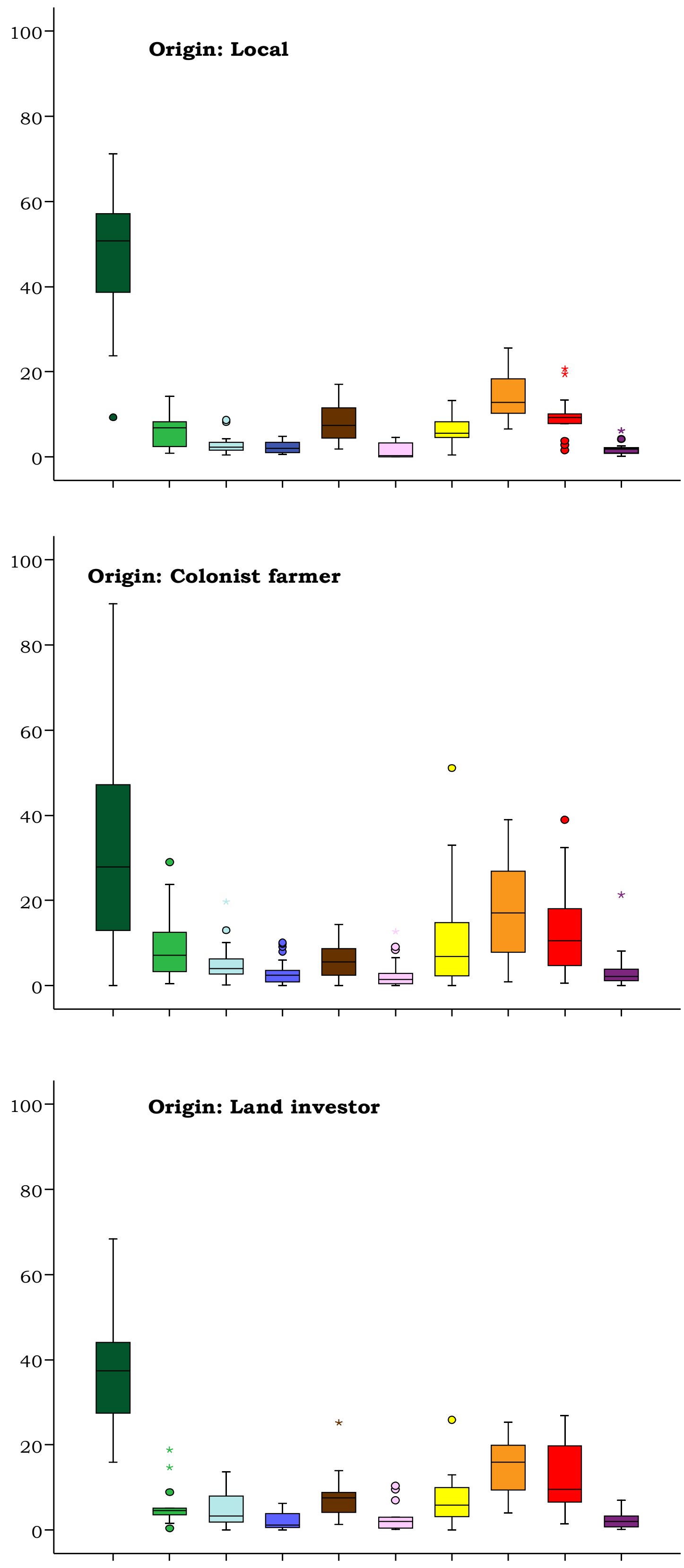


Table 2.11 – Rates for land-cover transitions at the farm lot, social group and settlement levels (%):

Land-cover types	Farm-lot level (n = 739)		Social group level (n = 63) Local farmers		Colonist farmers		Land investors		settle-ment level
	%	stdev	%	stdev	%	stdev	%	stdev	%
Forest since 1975	37.1	23.3	45.6	17.2	32.1	23.4	38.5	15.3	36.9
Recently abandoned	6.8	6.6	6.9	4.4	8.2	6.3	6.1	5.2	6.4
Short fallow cycle	4.4	4.3	3.0	2.7	5.0	3.9	4.9	4.7	4.2
Long fallow cycle	2.8	3.0	2.4	1.5	2.9	2.7	2.3	2.4	2.5
Recently disturbed forest	6.6	5.9	8.2	4.9	5.7	4.0	8.1	6.3	6.1
Production since 1986	2.7	4.1	1.6	1.8	2.4	2.9	3.1	3.6	2.9
Production since 1992	11.0	10.6	6.4	3.4	10.7	11.1	7.7	6.9	11.4
Production since 1999	16.0	12.7	14.3	6.0	17.6	11.0	14.9	7.0	16.8
Recently cleared	10.0	8.6	9.7	5.7	12.1	9.3	12.0	7.8	10.3
Others	2.6	3.1	2.1	1.6	3.3	3.7	2.5	2.3	2.5
Total (%)	100		100		100		100		100

2.7 – H1: Are differences across social groups of farmers statistically significant?

Normality tests for distribution of variances for land-cover transition classes observed at the group level revealed that none of them, with the exception of "Forest cover in 2003" and "Forest cover since 1975"[44], is normally distributed. Thus, neither the one-way analysis of variance test for the comparison of means (ANOVA) nor Multivariate General Linear Models could be used to test for differences across groups. Hence, the Kruskal-Wallis non-parametric test was used. Table 2.12 indicates that no significant differences were found across groups.

[44] I included the "Forest cover remaining in 2003" class from Table 2.9 in the statistical analysis because of the differences observed when compared to the "Forest since 1975" class.

A caution note is necessary at this point: while almost all ex-rubber tappers of my sample were already living in Humaitá by 1975, some 55% of colonist farmers and practically all land investors arrived only after 1986. This presents a potential limitation to the analysis of land-cover change, particularly when comparing social groups on earlier stages of colonization, for which no information on previous occupants is available.

Table 2.12 – Significance values for the Kruskal-Wallis (non-parametric) test for differences on proportions of land-cover transition classes between groups of farmers:

Land-cover types	Chi-Square	Asymptotic Significance
Forest cover in 2003 (%)	5.386	0.068
Forest cover since 1975 (%)	5.256	0.072
Recently abandoned (%)	1.254	0.534
Short fallow cycle (%)	4.280	0.118
Long fallow cycle (%)	1.247	0.536
Recently disturbed forest (%)	3.061	0.216
Production since 1986 (%)	1.865	0.394
Production since 1992 (%)	0.750	0.687
Production since 1999 (%)	0.657	0.720
Recently cleared (%)	0.409	0.815
Others (%)	1.247	0.536

This leads me to reject Hypothesis 1 (*Variation on rates of land-cover change between farmers belonging to different groups is larger than the same variations observed among farmers belonging to the same group, during the 1975 – 2003 period of analysis).* Note, however, that the p-values for forest cover in 2003 and for forest since 1975 are close to being statistically significant (Asymptotic significance = 0.068 and 0.072, respectively). In the first case, it can be observed that lots belonging to local farmers present average proportions of 2003 forest cover 14% higher than lots belonging to colonist farmers and 9.5% higher than lots belonging to land investors (Table 2.9). In the second case, these differences are of 13.5 % and 7.1%, respectively (Table 2.11). Later, in Chapter 5, it is shown that a highly significant negative correlation ($p<0.001$) exists at the farm-lot level ($n = 739$) between accumulated deforestation for 1975 and 2003. As discussed above, deforestation in 1975 took place almost entirely in lots belonging to local ex-rubber tapper farmers. This leads me to believe that lots belonging to local farmers maintain significant higher proportions of forest cover in 2003 when compared to lots belonging to the other two social groups, and that if my sample size were larger, these differences would probably have been captured in the comparison across social groups conducted here ($n = 63$).

Apparent differences between groups in the other eight land-cover transition classes discussed above (Table 2.11) are further away from being statistically significant (when compared to proportions of forest cover)[45], which leaves no room for the rejection of Hypothesis 1 to be questioned. However, do small differences (not statistically significant) matter? Depending on the context, and on what they represent in terms of land-use logic used by Humaitá farmers, I believe that yes, they do matter. Lower proportions of forest disturbance observed among colonist farmers, for example, are consistent with the long-term strategy of selective timber exploitation used by farmers of this group, which led them to exhaust their timber resources earlier than local farmers and land investors.

Thus, I conclude that despite the differences observed in agricultural (and cultural) background, education, time living on the lot, household size, and other differences across social groups not mentioned yet, but to be addressed in the following chapters (such as income, preferred land-use strategies, use of agricultural credit, goals, etc…) they all face

[45] It should be noted, however, that the Kruskal-Wallis non-parametrical test compares rankings for each variable across groups, instead of comparing the actual values of each variable, which makes it more robust (or less sensitive to detecting statistical significance) than most parametrical tests such as the one-way analysis of variance test for comparison of means (ANOVA) or Multivariate General Linear Models.

similar conditions common to the agrarian structure and formation of the settlement. The analysis above points to similar land-cover changes between social groups observed throughout the 1975-2003 study period. This might indicate similar land-use strategies (such as formation of pastures for cattle-ranching, and clearing land to increase land value, etc…) to cope with the challenges and constraints present in the settlement project, or that differences in land-use strategies across social groups could not be detected by the land-cover change analysis conducted, and with the sampling procedure and size of this analysis. Indeed, and as shown in the following chapters, differences in land-use strategies exist among social groups of farmers.

CHAPTER 3 – ACCESSIBILITY TO URBAN CENTERS AND TO AGRICULTURAL CREDIT AS DETERMINANTS OF LAND-USE STRATEGIES

3.1 – Roads, credit and land-use/land-cover change in the Amazon

Following precepts of neo-classical economic models, farmers are rational actors whose decisions are oriented toward income maximization. Others argue that risk minimization takes priority whenever farmers make land-use choices (Ortiz, 1967; Barlett, 1982). However, and as already discussed in Chapter 1, there are several situations under which land-use decision making processes cannot be conceptualized according to assumptions of complete information about the odds of outcomes. From a methodological perspective, environmental, infra-structure and market conditions render it difficult to estimate both income and risks whenever information about the behavior of these variables is uncertain. Thus, limited information on variables affecting land-use in agricultural settlements needs to be considered in two ways: it affects farmers' choices regarding land-use; and b) it affects analysts` capabilities to estimate the effect of these variables in land-use choices made by farmers.

In this chapter, I explore how farming families in P.C. Humaitá respond to two factors of income uncertainty in the choices they make regarding land-use. These two factors of uncertainty are: a) access to urban centers, measured in time-distances of lots to local urban centers (time-distances are estimated based on road network conditions throughout the year); and b) access to agricultural credit, measured by the number of bank loans modes to farmers in the five years preceding fieldwork. As later discussed, recent studies of proximate and distal causes of land-cover change in the Amazon, particularly deforestation, include both variables as extremely relevant to land-use decision making in the region. By analyzing the effect of access to urban centers and access to agricultural credit on land-use strategies employed by farmers, my goal is to discuss the effect of regional level processes in individual decisions made by farmers. These ideas are translated into the following question:

Research Question 2 - *How do differences in land-use strategies at the farm level reflect variation in the spatial context (time-distances to urban centers) and in access to agricultural credit?*

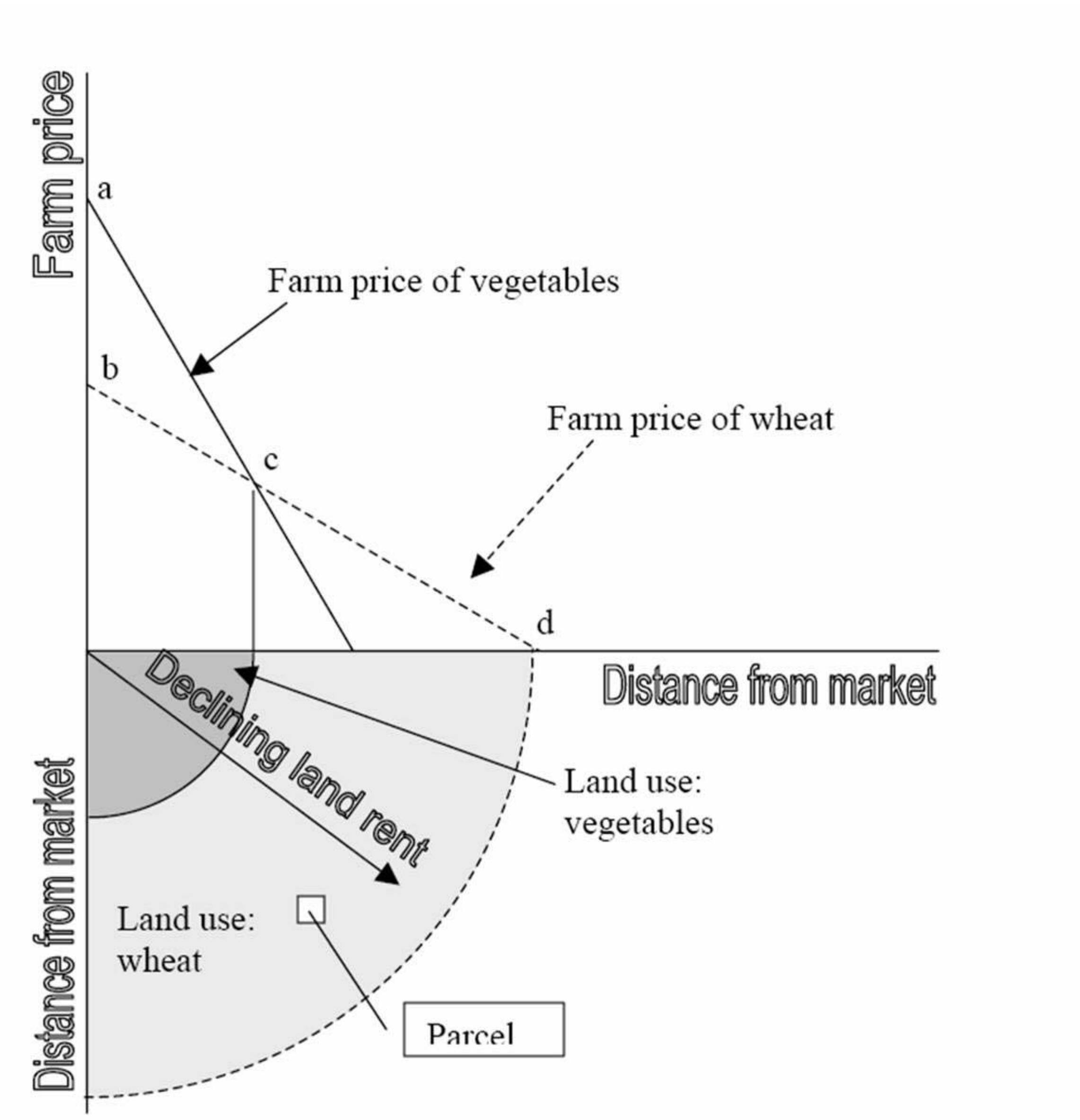
I will address this question in two parts, one for each relationship of interest between land-use strategies and time-distances to urban centers (Part I); and access to agricultural credit (Part II). Each part begins with a discussion on the approaches to study these relationships, including the role played by each one in explaining land-use change in the Amazon. What follows is the statement of the two working hypotheses. Next, I present the methods and the data sources, followed by a description of the statistical model used to test both hypothesis, and a discussion on the typologies used for the dependent variable land-use strategy. Then, I present some descriptive statistics for the variables included in the model. Last, I present and interpret the results in light of my field observations, of relevant feedbacks and interactions with other variables, and possible theoretical links.

3.2 – Part I - The von Thünen model: time-distances, land value and land-use

The von Thünen model of spatial distribution of agricultural land states that the rent values for land are directly related to agricultural net income per area, and to proximity to urban centers (Dunn, 1970). Empirical confirmation of von Thünen's model already has been shown in several studies worldwide (O'Kelly and Bryan, 1996; Chomitz and Gray, 1996;

Nelson, 2002). According to the classical work of Robert Netting (1993:209), for example, rent values for land, land-use intensity and predominance of smallholders have been all found to be positively correlated with proximity to urban areas in China and elsewhere, showing consistency with von Thünen's model. A schematic representation of von Thünen's model, prepared by Nelson (2002) is represented in Figure 3.1. It depicts a plain agricultural surface surrounding a central market, and planted with two crops: vegetables and wheat. All agricultural land has identical production characteristics, except transportation costs which are higher for vegetables when compared to wheat. Market prices for vegetables (a) are higher than for wheat (b), but farm prices of vegetables fall more quickly than farm prices for wheat as distance from the urban center increases. Beyond point (c), farm prices for wheat are higher. The result is a series of rings surrounding the central market, representing land-use choices in line with farm prices for different crops. As distance from centers increases, rent values for land decreases. Beyond point (d), there is no profit from planting either of the crops, and land is left undisturbed.

Figure 3.1 - The Von Thunen model:



Extracted from Nelson (2002), with permission of the author

The relevance of all-weather roads for successful colonization projects has been claimed for quite a long time (Nelson, 1973; Moran 1981 and 1984; Martine 1990). Crop commercialization and access to basic services such as health, education, and credit tend to be favored in areas closer to urban centers or that have year-round connection to it. Additionally, access to wage labor opportunities might be better, reducing income uncertainties for farmers living in such areas.

In the Brazilian Amazon, accelerated conversion of forests to pasture can be explained, to a great extent, by more stable and secure financial outcomes of cattle ranching, when compared to uncertain commercialization conditions of most agricultural products (Mertens et al, 2002; Veiga et al, 2001; Tourrand et al, 1999). Thus, cattle production systems may work as "insurance" against poor road conditions, and against fluctuations in the prices of crops and in the national economy (Hecht, 1993).

Rural areas well connected and closer to Amazonian urban centers might face, (and following von Thünen's model), commercial incentives to invest in land-use alternatives with higher return rates to area in use, such as most agricultural crops, when compared to cattle-ranching. Most cattle-ranching systems found in the Amazon might be considered 'extensive' systems, in the sense they provide very low return rates to area in use.

The Humaitá settlement project is well suited to test this hypothesis, once it is connected to Rio Branco, the capital of Acre, through a 35 km paved road. A significant portion of lots are served by paved roads, or by roads kept in good conditions throughout the year. Another portion of lots is located where road access to markets is poor or almost non-existent during the rainy season. H2A tests for accessibility to urban centers as a major explanatory factor for differences in land-use strategies found among farming families:

Hypothesis 2A (H2A) – *Time-distances from farm lots to local urban centers are significant for explaining variation in land-use strategies adopted by farmers.*

A description of the procedures used to calculate time-distances is presented below. There are three local urban centers that are important for Humaitá farmers for marketing their produce, and were therefore considered: two of them are villages located within settlement's boundaries (Vila do Incra and Vila do V) and the third is Rio Branco, which is also important as a regional market. Time-distances calculation was done among all lots (n=739) and each of these urban centers, and an averaging index[46] used in the statistical model was calculated afterwards.

The dependent variable of the model is land-use strategy, a categorical variable defined for analytical purposes and based on typologies for land-use variability found in the settlement. The criteria used for definition of typologies of land-use are discussed in the methods section of this chapter.

3.3 – Part II: Is access to agricultural credit important to explain land-use strategies in settlement projects in Acre?

There is a theoretical question concerning the likeliness of a farmer to engage in a risky/uncertain activity: if s/he is "risk indifferent," credit would be used to engage in activities that would maximize income, regardless of risk. A "risk sensitive" farmer, on the other hand, would either avoid taking loans, or use loans for less uncertain land-use forms, such as pasture for cattle-ranching. The Null Hypothesis 2B, outlined below, follows Ortiz (1967) argumentation of farmers seeking risk-averse strategies of livelihood. However, Hypothesis 2B considers also that credit program policies prioritize agricultural crops (and

[46] See explanation in section 3.4.2.1

oppose cattle-ranching[47]), which translates into differential treatment when credit applications for small farmers are submitted for approval (BASA, 2002). Thus, Hypothesis 2B assumes that these two opposing factors neutralize each other:

Hypothesis 2B (H2B) – *Enrollment in agricultural credit programs is not significant for explaining variation in land-use strategies adopted by farmers.*

3.4 – Methods

3.4.1 – Data: questionnaires, road network and property grid

There are three main sources of data used to address Research Question 2: a) household surveys; b) a GIS of the road network with an updated version of INCRA's property grid; c) meetings and interviews with INCRA representatives and farmers about investments and maintenance of the road network. General aspects of the household surveys have already been described on the previous chapter. Here, I will describe the "credit history" and "access to urban centers/markets" sections of the survey the GIS used to calculate time-distances and the interviews with INCRA representatives.

Credit history questions include allocation of credit (what was it used for?), date and value of the contract, the conditions of the contract (lending agency, interest rates, period for re-payment), if re-payment has been already realized, and if the farmer had ever defaulted on credit loan re-payments. Given that all this information might be difficult for the farmer to remember, I limited the credit history part of the questionnaire to the 5 years previous to fieldwork, except the question "if the farmer has ever defaulted," which considered the whole period of time living on the lot. Secondary information on the use of credit was additionally

[47] According to FNO (Fund for financing the North) agricultural credit policies, agriculture financing has been prioritized over cattle-ranching, since one of FNO guiding principles is that funds shall be used for sustainable development (and should not encourage forest conversion to pastures).

gathered with BASA (Bank of Amazônia) and SEATER (Governmental Extension Agency, responsible for intermediating credit contracts).

Questions on access to markets include the quality of the road passing in front of the lot, the time required to reach the two local village markets (Vila do V and Vila do Incra) and Rio Branco, transportation means, and transportation costs. This information refers to both dry and rainy seasons.

3.4.1.1 – The road network: mapping and assessing quality

P.C. Humaitá's road network is composed of a total of 17 roads, part of them organized in a radial pattern with a village (Vila do V) located in its center (Figure 3.1). From this total, three roads are paved with asphalt or "all-weather" roads, and passable throughout the year, regardless of weather. The paved road AC-010 connects Humaitá to Rio Branco and to Porto Acre, and is the most important road in the settlement. The other two paved roads are Linha-1 (Line 1) which links Vila do "V" to AC-010, and Ramal do Açaí, a secondary road. All of the remaining 14 roads are unpaved: four roads were considered of "good quality," four of "regular quality" and the remaining five of "poor quality". "Good quality" unpaved roads are graveled and passable throughout the whole year. "Regular quality" roads are unpaved and un-graveled, but are passable throughout most of the year, except after rainy days during the rainy season, when some parts of it are passable only by 4-wheel drive (4WD) vehicles. "Poor quality" roads are problematic in the dry season and completely unreliable during the rainy season; some are passable by 4WD vehicles when rain is moderate, others leave colonists isolated no matter what vehicle is used.

The limit between good, regular and poor quality unpaved roads is subtle and may vary with time and space. A “poor quality” road may become a “regular quality” or even a “good quality” one after it is temporarily “fixed” with heavy machinery and graveled (using *piçarra*[48] donated by local farmers). Also part of a “good quality” road may become of “poor quality” if rain is heavy. By the same token, a “poor quality” road might have several segments that are passable throughout the whole year.

Other components of the network are trails passable only by horse, motorcycle, or bicycle, and the Acre river, which is used by ex-rubber tapper *ribeirinhos* to go to Rio Branco by boat.

The road network dataset used during fieldwork was extracted from INCRA’s original road and property grid map (produced in 1981). During fieldwork I noticed that the road network would have to be updated at several locations, due to relocations of road segments to avoid poor drainage conditions. When Humaitá settlement was implemented in 1981, INCRA’s plan for road engineering at these locations did not take the natural drainage pattern of the terrain into consideration. This resulted in problematic traffic, especially during the rainy season. This was gradually fixed (often using palliative actions) moving sections of roads the surrounding terrain offering better drainage conditions.

All roads contained within the Humaitá settlement, and some of the roads surrounding it were digitized using a geographically registered ASTER remotely sensed image of 2001, with a spatial resolution of 15 m. This allowed for relatively good differentiation of built features from surrounding vegetation. RMS error from ASTER registration was of 0.42 pixels.

[48] Sedimentary rock used as gravelling material

3.4.2 - Calculating time-distances to urban centers

Distance measurements used on testing H2A were calculated through *network analysis*, a GIS technique based on a set of rules that regulate network flux through a vector-based surface (Burrough and McDonell, 1998). Time-distances or total travel time were calculated for each property within Humaitá settlement to three destinations: Rio Branco, Vila do Incra and Vila do V. Additionally, time-distances were calculated for both dry and rainy seasons. This calculation was based on the quality of roads at different segments of the transportation network, all digitized into a GIS shapefile, as of 2003-2004, when fieldwork was conducted on the site. By informing the GIS of the average speed determined for each segment of the road network, travel times were calculated for each of these segments, using the following formula:

$$t_i = S_i / As_i$$

where t_i represents the time-distance for road $segment_i$, in minutes; S_i represents the length of each segment[49]$_i$ in meters; and the average speed As_i was determined in locus for each road segment, and later transformed into meters per minute.

Determination of average speeds of road segments - All roads of the Humaitá settlement transportation network were sampled during fieldwork, with the help of a Global Positioning System (GPS), and using information collected during interviews with farmers, such as their views on road quality for both dry and rainy seasons and maintenance operation records in the years preceding fieldwork. Farmers were also asked about problematic road sections (during the rainy season) and their location. Often they provided specific answers about the nature of the problem (e.g. flooding caused by overflow of creeks or rivers, or impassable road sections due to muddy slippery *tabatinga* soil in steep terrain). Using additional criteria

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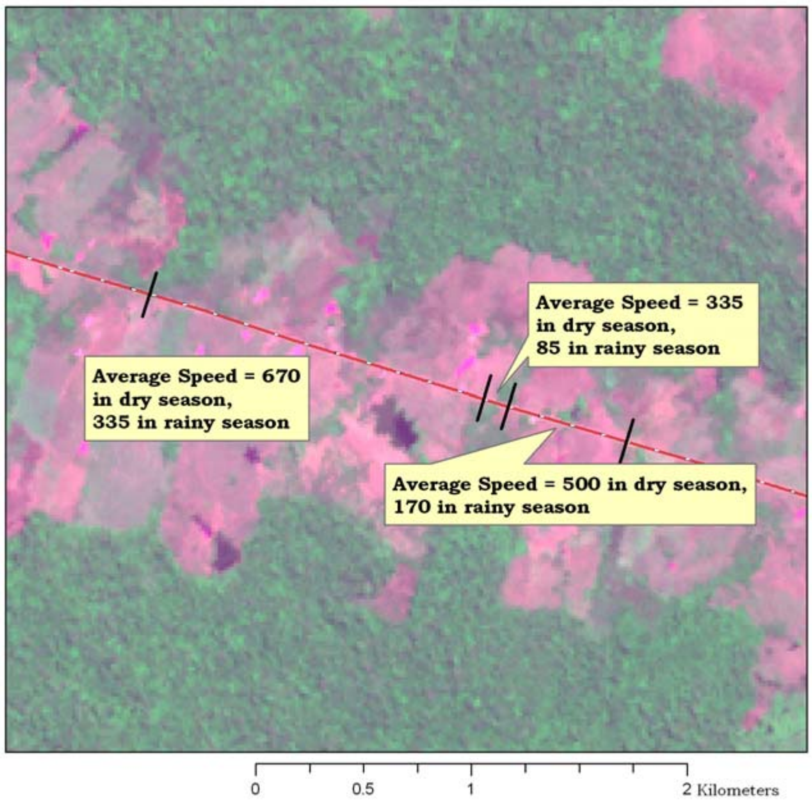
[49] lengths might be easily determined by any geo-referenced GIS

while driving through the road network, such as the presence and size of potholes, presence of gravels (indicating road maintenance), soil quality and the angle of steepness in road ramps, I was able to establish a relative scale for road traffic conditions for different segments in every road of the Humaitá network. A schematic representation of road segment conditions and of the average speed attributed to each segment is presented on Figure 3.2. It is difficult to determine average speeds based only on information provided by farmers and on training data for road quality without falling into arbitrary judgements. An additional source of control is needed. This control was obtained from the survey, using the travel time from each surveyed lot to the local urban centers Rio Branco, Vila do Incra and Vila do V (according to farmers, and considering individual means of transportation). It was used to calibrate the time-distance measurement obtained from the GIS network analysis procedure.

Figure 3.2 - Road segments with average speed limits (in minutes/hour) attributed according to trafficability:



3.4.2.1 - Establishing the Origin-Destination (OD) Cost Matrix

The Network Analyst extension of Arc GIS© - ESRI was used to determine the total time-distance from each property in the grid (origins) to the three local urban centers (destinations). Digitized line features representing roads were broken into 238 segments showing homogeneous "average speed" conditions. A field (or column) for "average speed" was created for each record (representing each road segment) of the shapefile. A second field contained the length of each segment, and a third one contained the time-distance calculated for each segment of the road network through the $t_i = S_i / As_i$ formula.

Next, the line shapefile (road segments) and two other point shapefiles, namely the *origins* (containing 739 records, one for each lot) and the *destinations* (containing 3 records, one for each urban center), were organized into a geodatabase. The creation of the origin shapefile was done according to the following procedure:

(1) Establishment of 80 meter buffers along roads;

(2) The property grid shapefile with 739 polygons was clipped by the buffers, generating smaller polygons representing each lot (and maintaining their unique identifier);

(3) Establishment of centroids[50] to each smaller polygon (creation of a point shapefile);

Later, after establishing the origin destination (OD) cost matrix, centroids keeping the unique identifiers to lots were snapped to the transportation network, and used as origins for the calculation of time-distances.

Building the transportation network dataset – Initially, a feature dataset was built into the geodatabase, using the road shapefile, all within the geodatabase. From this feature dataset, a new network dataset was created, composed by a road network, and a "ND" junction file. Junctions might be used to enforce traffic rules within the network, such as "no right turn," or "wait 15 seconds in this crossway" and so on. One-way traffic rules or barriers might be inserted within the "ND" road network. This was not the case for the network dataset established for the Humaitá settlement. One-way traffic rules do not apply in

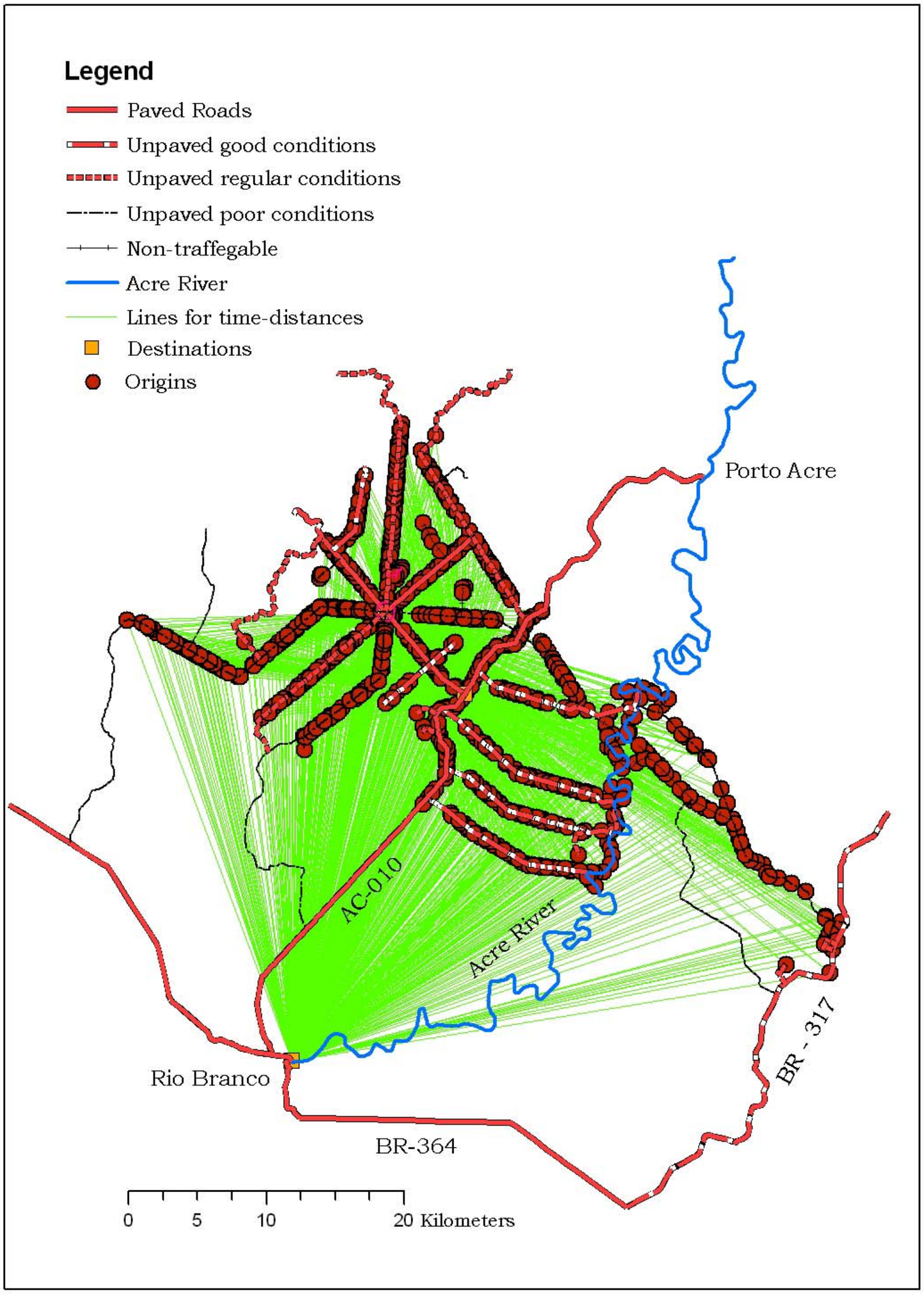
[50] Use of centroids of original lot polygons as origins was not be possible, because of consolidation and fragmentation processes the lots were re-created into properties of different shapes. These polygons would generate centroids that when snapped into the transportation network, would generate error in the virtual location of these origins.

Humaitá (nor in any other agricultural settlement of my knowledge). Impediments or barriers are frequent in the rainy season and do apply to many critical road segments. In Humaitá's case, there are hardly any alternatives to such barriers (such as detours), so I represented them instead by substantially reducing average speeds allowed for these segments, allowing for time-distances for all lots to be operable (possible to be calculated).

Establishing the OD cost matrix – Once the network dataset was created and loaded into the GIS, the OD cost matrix could be created through Network Analyst. Centroids of the clipped polygons (representing fractions of the lots) were loaded as *origins*, and virtually[51] located at the closest position of the road network from which time-distance values were computed. After loading the *destinations* into the system, lines connecting each origin to each destination could be generated. The final result of this operation is depicted in Figure 3.3. Two OD cost-matrices were established, one for the rainy season and another for the dry season. The attribute tables of the lines output of each OD cost-matrix was composed of 2,217 records, which is equivalent to 739 origins times 3 destinations, with the calculations of total time-distance, or travel time, from each lot to each local urban center.

[51] Snapped to the network by a software operation

Figure 3.3 – Origin – Destination Cost Matrix



For modeling purposes, I calculated an index for time-distance, collapsing all 6 measurements into a single one. The index is based on differential weights for *destinations* and for *seasons*. Rio Branco, as the main local urban center, has weight "2," while Vila do Incra and Vila do V were given both weight "1," since these are smaller markets. The rainy season corresponds to the harvesting time of most agricultural crops. Thus, the rainy season was also given weight "2," while the dry season was given weight "1". Thus, the index was calculated according to the following formula:

$$TD = ((tdd\_vi + tdd\_vv + 2*tdd\_rb)/4 + (tdr\_vi + tdr\_vv + 2*tdr\_rb)/2)/3$$

where TD is the indexed value for time-distance, tdd is the time-distance for the dry season, tdr is the time-distance for the rainy season, and vi, vv, and rb are time-distance specifications for the destinations Vila do Incra, Vila do V, and Rio Branco.

3.4.3 – The Multinomial Logistic Regression model of land-use strategies

Land-use strategy is a categorical variable that allows for the estimation of the effect of explanatory variables affecting land-use, which can be done through a Multinomial Logistic Regression (MLR) model (Walker et al, 2002). I built a typology for different land-use strategies used by farmers, in order to help with quantitative analysis.

3.4.3.1 – Typologies for land-use strategies

Typologies for land-use strategies were grouped based on the diversity of land-use types found during fieldwork, and on theoretical links of each strategy with the key explanatory variables explored in Question 2: a) time-distance to markets (H2A) and b) use of agricultural credit (H2B), as explained below:

a) Time-distance to markets (H2A) – According to von Thünen's model, transportation cost of agricultural products is one of the determinants of land-use choices. To be consistent with this model, and at the same time representative of the land-use options available in the region, a typology system shall thus include land-use options associated with a wide range of transportation costs. While cattle-ranching and subsistence agriculture are normally associated with low transportation costs, most agricultural produce (annual and perennial crops) and dairy production depend on good roads and often the farmer owning a vehicle, and are associated with higher transportation costs.

b) Use of agricultural credit (H2B) – As already discussed in the introductory chapter, credit support to cattle-ranching is acknowledged as one of the major factors driving forest conversion to pastures in Amazonia. This is true especially for the 1970s and 1980s, when agricultural subsidies given by the government to cattle-ranching were substantial. In the 1990s, these subsidies were dropped, and credit to cattle-ranching was reduced. However, technological advances such as the development of (*Brachiaria brizantha)* and low production costs made cattle-ranching much more profitable. A favorable domestic and global market helped to bring the cattle-ranching activity to the point where it is self-financed today (Faminow, 1998). On the other hand, actual FNO credit priorities for promotion of sustainable development include financing of agricultural produce rather than purchase of cattle or forest conversion to pastures. Most annual and perennial crops need inputs to be commercially competitive. This raises production costs and makes land-use alternatives focused on these products much more dependable on agricultural credit. Thus, we find land-use alternatives in Humaitá that are found to depend less (cattle-ranching) or more (agriculture) on the use of credit.

The typologies for land-use strategies are:

1 – Subsistence agriculture/extractivism: agricultural production is primarily oriented toward family consumption. It is mostly associated with farmers with low income, but also includes ex-rubber tappers who continue making economic use of forests (Brazil-nuts, game, timber/coal, other fruits, palms for thatching, fish,….) and farmers whose other sources of income (such as wage-salaries, pensions, remittance), are critical to their survival.

2 – Annual and perennial agriculture – includes farmers whose most important farm-related source of income comes from sales of agricultural products.

3 – Diversified husbandry– includes farmers whose most important farm-related source of income comes from the sales of diverse animal products (including dairy products, fish, chickens, eggs and pigs), not beef alone.

4 – Cattle-ranching – most important farm-related source of income comes from cattle-ranching oriented exclusively to beef production.

Frequencies for each category are presented in Figure 3.4. Cattle-ranching oriented to beef production is the main land-use strategy in the sample, accounting for almost 49.2% of all interviewed households. Mixed husbandry and subsistence/ extractivism both come in second, with 17.5 % each, and agriculture comes in fourth, with almost 15.9%. The preferential strategy used by local farmers is subsistence/extractivism, while colonist farmers and land investors concentrate on cattle-ranching for beef production. However, colonist farmers show more diversified land-use strategies than land investors.

3.4.3.2 - Back to the MLR model of land-use strategy

To test for the significance of the explanatory variables time-distance and use of credit, I used a Multinomial Logistic Regression model, with farmer land-use strategy (based on the typology presented above) as the dependent variable.

The land-use decisions of farmers are constrained by the biophysical environment (Moran et al 2000 and 2002). Better quality soils allow for a more diversified set of crops, while access to water reduces risks of crop failure. Therefore, in order to respond Question 2, these variables soil quality and access to water need to be and are included in the survey model. Farmers are asked to describe the predominant types of soil in their lot[52], as well as sources of water for agriculture and domestic use.

Time in the settlement and size of lots represent additional factors that might affect land-use allocation by farmers (Pichón, 2001; Kaimowitz and Angelsen, 1998), and were therefore included in the model. The survey instrument included questions on these variables. The model is thus determined by (in vector notation):

$$\mathbf{Y = X\beta + \varepsilon,}$$

where the land-use predominant strategy (categorical variable based on typology) in a lot (Y) is a function of the observed characteristics of the household/farm lot X and with the error terms of all households in the sample.

The explanatory variables used in the model, and from which the ßs will be estimated are: time distance index (in minutes), number of credit loans in the past 5 years, soil quality according to farmer, water availability (proxied by the number of ponds on the lot), lot area (measured in hectares, and time living on the lot (measured in number of years). Soil quality is a categorical variable that was divided as:

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[52] Time and funding constraints did not allow for detailed soil sampling.

(1) Good soils (for agriculture) are present in more than 70% of the lot area;

(2) Good soils are present in between 40% and 70% of the lot area;

(3) Good soils are present in between 10% and 40% of the lot area;

(4) Good soils are present in less than 10% of the lot area[53]

The error term "**ε**" follows standard assumptions (residuals are independent and normally distributed across households with mean zero and constant variance).

Hypothesis 2A and 2B were tested using STATA for Windows © version 9 by assessing the significance of the Multinomial Logistic Regression (MLR) estimators for: a) time-distance from lots to Rio Branco (H2A); enrollment in credit programs (H2B). The MLR model estimates coefficients of explanatory variables individually for each category of the dependent variable. These estimations are based on comparisons on the values of each category with a pre-determined reference category, to which all other categories are compared. The significant values represent the probabilities of explanatory variables in determining a specified category versus the reference category (for each comparison undertaken). Cattle-ranching was automatically elected as the reference category, since it has the highest number of observations. The variables "use of agricultural credit" and "soil type" are categorical variables and had to be broken into pairs of dummy variables to allow the estimation of coefficients. All other variables are either continuous (time-distance, lot area) or ordinal (number of ponds, time living on the lot).

[53] For the cases where the farmer could not provide this information (around 10% of the cases), I used the soil quality information provided by the 1:250,000 soil classification map produced by ZEE.

3.5 – Land-use strategies and the importance of access to markets and to credit

This section begins by describing farmers' access to urban centers and to agricultural credit, both by group of origin and by land-use strategy. I also describe membership in farmers' unions and cooperatives, since this variable is related to access to agricultural credit. Then, I present and discuss the results of the multinomial regression logistic model used to investigate the importance of time-distances and agricultural credit for explaining the land-use choices adopted by farmers.

3.5.1 – Access to urban centers by social group and land-use strategy

Local farmers and land investors own farm-lots located at higher time-distances from urban centers (Rio Branco and the two villages, Vila do Incra and Vila do V), when compared to colonist farmers (Table 3.3-a). Many local farmers (ex-rubber tapper families) are *ribeirinho* families living by the shore of the Acre River. Road access to the Acre River is limited in Humaitá, especially for lands situated to the East of the river (see Fig. 1.4). Many *ribeirinhos* travel by boat to Rio Branco, taking their agricultural produce (mostly bananas) and bringing back manufactured products. Other ex-rubber tapper families live along the last segment of Bujari road (far Southwest of Humaitá), where road access is also limited. It seems that most local families living close to paved roads or roads with better access sold their lots to colonist farmers and, to a minor extent, land investors, but this could not be corroborated with field data.

Properties belonging to land investors are also located at higher time-distances from urban centers when compared to colonist farmers. Prices of land are much lower in remote areas, allowing land investors to buy more land for the same amount they would pay if they were buying land in more accessible areas. Given that some 85% of land investors choose cattle-ranching as their main land-use strategy (Figure 3.4), buying more land in remote areas makes economic sense, since cattle-ranching requires large areas of pasture. Poor access to urban centers is not problematic as it is for the other land-use strategies, since cattle can walk to markets, and faces no problems for being "perishable" as most crops and dairy production.

Table 3.1 -a and -b – Average time distances from lots to urban centers (minutes):

a) By social group

Time distance from lots to urban centers	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	Mean	St.dev	Mean	St.dev	Mean	St.dev
Time distance dry season*	86.1	52.3	72.0	40.6	81.1	39.3
Time distance rainy season*	172.9	133.1	117.2	90.9	179.7	169.4
Time distance index**	134.7	32.8	86.2	13.9	133.1	39.0

b) By land-use strategy

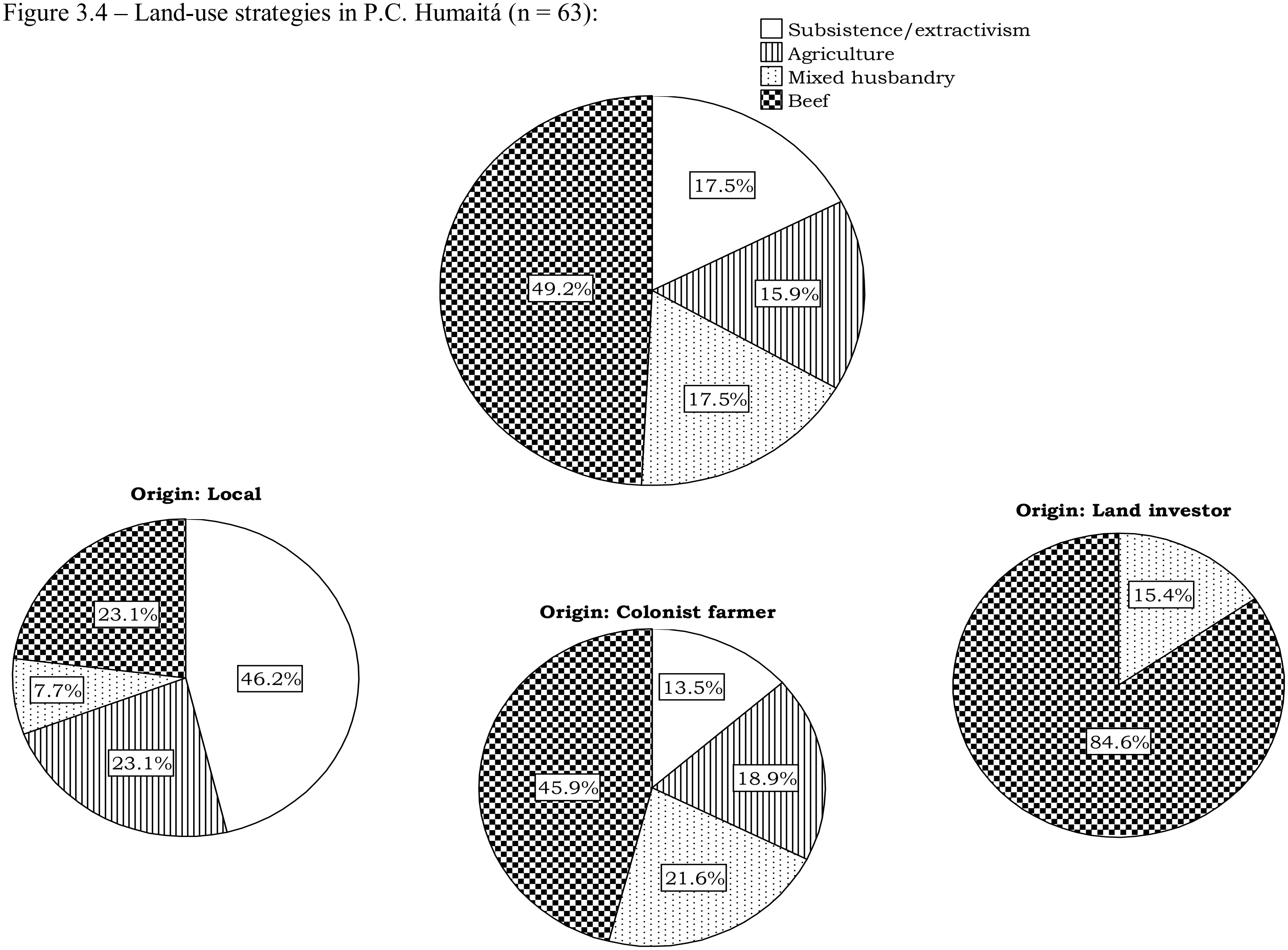
Time distance from lots to urban centers	Subsist/ Extract. (n=11)		Agriculture (n=10)		Mixed husbandry (n=11)		Cattle ranching (n=31)	
	Mean	St.dev	Mean	St.dev	Mean	St.dev	Mean	St.dev
Time distance dry season*	88.7	81.1	42.5	9.0	34.1	8.9	70	57.2
Time distance rainy season*	179.0	129.4	81.8	33.2	47.4	22.6	152.3	160.9
Time distance index**	149.0	112.6	68.7	24.9	43.0	17.7	124.9	125.3

*weighed average for three destinatons: Rio Branco, Vila do Incra and Vila do V

**weighed average for destinations and seasons

Subsistence/extractivism and cattle ranching oriented farmers own lots that are greater distances for urban centers (Table 3.4-b). This is consistent with Table 3.3-a, if we consider that subsistence/extractivism is the main land-use strategy for local farmers, and that 85% of land investors are oriented toward cattle-ranching (Figure 3.4). On the other hand, agriculture and mixed husbandry oriented farmers are located closer to urban centers, which is required for the type of economic activity in which they have been investing. Primarily, mixed husbandry includes year-round dairy production, which is highly perishable and requires farmers to be located on all-weather roads in order to be economically efficient. Even so, several milk producers complained to me about poor road conditions during the rainy season, which lead to considerable losses in income.

Figure 3.4 – Land-use strategies in P.C. Humaitá (n = 63):



3.5.2 – Access to agricultural credit by social group and land-use strategy

Colonist farmers borrow more agricultural credit when compared to local farmers or land investors (Table 3.4 –a). There are several possibilities on how to interpret this data. One is that local farmers are risk-averse when compared to risk-taker colonists, and capitalized land investors (not in need of credit to finance their cattle-ranching operations). Another possibility is that opportunities for loan approval to colonist farmers are far higher when compared to the other social groups. This will be further discussed.

As mentioned in the introductory section of this chapter, farmers respond in different ways to uncertainty in factors affecting their livelihood strategies. Agricultural credit might be seen by farmers not only as a risk alleviation factor, but also as a liability obligation, since capacity for loan repayment is often uncertain. In this sense, farmers have to learn to balance the pros and cons of each particular credit line before deciding whether to contract loans. Normally, farmers try to get as much information as possible about the characteristics of each credit line, such as: interest rates, collateral needed, types of liability involved (for instance, individual liability vs. group liability, when loans go to cooperatives or labor unions), flexibility on use of credit resources, grace period, repayment period and distribution of payments across parcels, etc. Such information is normally provided by extension agents, who are the operators of credit loans and intermediaries between lenders (banks) and borrowers. Extension agents are independently contracted to accrue the transaction costs involved in agricultural credit loans, and are paid with funds from FNO (Fund for the North Region), which is also the source of most agricultural credit in Amazonia (a detailed discussion on the origin and rules of FNO is provided in Chapter 4). Maximization on credit adoption rates is a policy goal that might be influenced by the extension agency's budget maximization interest. Thus, farmers often are unsure whether the information provided to them about credit lines is biased or not, which makes social networks sharing credit line information and social learning even more important in farming communities.

Table 3.2 -a and -b – Number of credit loans:

a) By social group

Number of credit loans	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	# of loans	%	# of loans	%	# of loans	%
No loans in the past 5 years	10	76.9	19	51.3	9	69.2
Credit once	2	15.4	11	29.8	2	15.4
Credit twice or more	1	7.7	7	18.9	2	15.4
Total	13	100	37	100	13	100

b) By land-use strategy:

Time distance from lots to urban centers	Subsist/ Extract. (n=11)		Agriculture (n=10)		Mixed husbandry (n=11)		Cattle ranching (n=31)	
	# of loans	%	# of loans	%	# of loans	%	# of loans	%
No loans in the past 5 years	10.0	90.9	2.0	20.0	7.0	63.6	19	61.3
Credit once	0.0	0.0	5.0	50.0	1.0	9.1	9	29
Credit twice or more	1.0	9.1	3.0	30.0	3.0	27.3	3	9.7

Agriculture oriented farmers took advantage of credit more often than farmers oriented toward other land-use strategies (Table 3.4-b). The strategy "mixed husbandry" comes in second, followed by "cattle-ranching," and subsistence/extractivism oriented farmers took credit less frequently, based on the survey data. This will be further discussed below, as I interpret the model results.

Several credit lines included in the FNO fund required that as of 2003, farmers should be affiliated with producers' associations (rural labor unions) or cooperatives, before being allowed to apply for agricultural credit loans. The rationale was to transfer part of the liability incurred on individual loans from farmers to the producers' association or cooperative with which they were affiliated. If a particular farmer defaulted on re-payment of a loan, the association or cooperative to which he/she was affiliated would lose eligibility for future loans. However, this mechanism did not work well in practice, since farmers belonging to non-eligible associations could easily get affiliated with other associations or create new ones, exclusively to make application for agricultural credit purposes.

On the other hand, a considerable number of associations and cooperatives were formed in Humaitá for reasons other than getting access to agricultural credit. The reasons included: increased negotiating power to request better road conditions, increased facilities for agricultural produce transportation and commercialization, and even a decision arena for issues such as public education available to the children of a community.

There are no apparent differences among the three main social groups of farmers (Table 3.5 – a) in their frequency of participation in producers' associations and cooperatives. When we analyze the question by land-use strategy, however, we see that 100% of the agriculture oriented farmers from the sample are associated with either a producer association or a cooperative, while for other land-use strategies, it barely reaches the 50% for land investors, 45% for animal husbandry and 36% for subsistence/extractivism (Table 3.5 – b). The higher rates of affiliation with associations/cooperatives found among agriculture oriented farmers is consistent with higher rates of credit use shown for farmers oriented toward this land-use strategy, and with the bank requirement to have farmers affiliated with producers' associations or cooperatives in order to be eligible for agricultural credit.

Table 3.3 -a and -b – Participation in producers' associations and cooperatives:

a) By social group:

Participation in producer's associations and cooperatives	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	Freq	%	Freq	%	Freq	%
Unionized	7	53.8	20	54.1	8	61.5
Non-unionized	6	46.2	17	45.9	5	38.5

b) By land-use strategy:

Participation in rural labor unions and cooperatives	Subsist/ Extract. (n=11)		Agriculture (n=10)		Mixed husbandry (n=11)		Cattle ranching (n=31)	
	Freq	%	Freq	%	Freq	%	Freq	%
Unionized	4.0	36.4	10.0	100.0	5.0	45.5	16	51.6
Non-unionized	7.0	63.6	0.0	0.0	6.0	54.5	15	48.4

Other relevant descriptive information on differences across land-use strategies is presented in Tables 3.6 and 3.7. The sample farmers oriented to subsistence/extractivism and agriculture strategies have lived longer on their lots than the mixed husbandry and cattle-ranching oriented farmers. This is consistent since the majority of farmers in this group are local farmers. The same cannot be said for farmers oriented toward agriculture (which cannot be explained at this point). Cattle-ranchers own larger herd (which is endogenous to having them under these categories). Farm-lot area and the number of ponds are also higher in lots oriented toward mixed husbandry and cattle-ranching, while forest cover is higher in lots oriented toward subsistence/ extractivism and agriculture strategies (Table 3.7).

Proportions of land under secondary succession are apparently highest in lots oriented toward cattle-ranching, and are similar across lots oriented toward the other three strategies. This might be connected to labor and/or capital shortages on hiring hourly labor to keep invasive weeds out of pastures. If cattle-ranchers face capital shortages when attempting to maintain their pastures, this could be a justification for them to engage more often in agricultural credit to promote pasture maintenance. However, as discussed in Chapter 4, there are some restrictions on FNO funds for cattle-ranching, which might lead to lower rates of agricultural credit adoption among cattle-ranchers (Table 3.4 –b) when compared to agriculture oriented farmers.

Proportions of pixels classified as water are highest in mixed husbandry oriented lots, probably due to more ponds for different types of husbandry (including fish). The use of ponds and their importance as a means of livelihood will be discussed in Chapter 6.

Table 3.4 – Time living on the lot, cattle herd size, number of ponds and lot area per land-use strategy:

	Subsist/ Extract. (n=11)		Agriculture (n=10)		Mixed husbandry (n=11)		Cattle ranching (n=31)	
	Mean	St.dev	Mean	St.dev	Mean	St.dev	Mean	St.dev
Time living on the lot (years)	30.0	18.6	22.1	3.1	16.9	6.8	15.5	8.8
Cattle herd size	37.5	37.3	52.6	41.2	85.5	61.7	161.3	168.1
Number of ponds	1.3	0.9	1.8	1.0	3.9	3.1	4	2.9
Farm-lot area (hectares)	62.9	19.2	67.0	7.1	76.7	48.6	129.6	127.6

Table 3.5 – Land-cover in 2003[54] per land-use strategy:

Land-cover in 2003 (% of lot)	Subsist/ Extract. (n=11)		Agriculture (n=10)		Mixed husbandry (n=11)		Cattle ranching (n=31)	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Forest cover (includes re-growth)	63.9	21.1	56.0	19.0	38.8	25.3	35.2	17.5
Secondary succession	9.3	6.8	8.7	2.9	8.8	7.3	12.4	6.7
Cleared area	26.4	16.6	34.8	17.9	51.5	23.4	51.9	16.1
Water	0.4	0.7	0.5	0.7	0.9	1.1	0.5	0.6
Total	100.0		100.0		100.0		100.0	

3.6 – MRL model results

Table 3.8 shows coefficients and significant values for six explanatory variables (time-distance, use of agricultural credit, number of ponds, lot area, time living on the lot, and soil type) and for three land-use strategies (Subsistence/extractivism, Agriculture, and Mixed Husbandry), all compared to the equivalent values of explanatory variables for cattle-ranching, the reference category.

[54] These values differ significantly from the ones presented in Chapter 2 because they were extracted from the classification of the 2003 image (and not from the transition matrices), and include a significant amount of forest re-growth.

Table 3.6 – Results for the MRL model (comparison with cattle-ranching):

LU strategies	Explanatory variable	Coefficient	Z	P > | z |
Subsistence/ Extractivism (LU strategy 1)	Time distance	0.0202082	1.25	0.212
	Credit once	-47.02613	0	1
	Credit more than once	-1.483438	-0.71	0.475
	Number of ponds	-1.636794	-2.44	0.015*
	Lot area	-0.0708791	-1.49	0.138
	Time living on the lot	0.215015	2.46	0.014*
	Soil type I	1.026406	0.62	0.536
	Soil type II	1.881645	0.99	0.322
Agriculture (LU strategy 2)	Constant	0.4477964	0.15	0.877
	Time distance	-0.0395412	-2.06	0.039*
	Credit once	2.695799	1.76	0.078
	Credit more than once	2.962402	1.57	0.115
	Number of ponds	-0.8373428	-1.63	0.102
	Lot area	-0.0316204	-1.15	0.252
	Time living on the lot	0.291396	2.71	0.007**
	Soil type I	1.713968	1.14	0.252
	Soil type II	1.276411	0.62	0.534
Mixed Husbandry (LU strategy 3)	Constant	-2.370319	-0.88	0.38
	Time distance	-0.0690168	-2.44	0.015*
	Credit once	-0.9085845	-0.67	0.505
	Credit more than once	1.391467	0.87	0.383
	Number of ponds	-0.0576778	-0.25	0.801
	Lot area	-0.0123687	-1.11	0.268
	Time living on the lot	0.1556745	1.61	0.107
	Soil type I	-0.1074773	-0.09	0.932
	Soil type II	-0.7305201	-0.41	0.679
	Constant	1.889053	0.74	0.461

Cattle-ranching (LU strategy 4) is the reference category
* Significant at the 0.05 level; ** significant at the 0.01 level

The explanatory variable "number of ponds" is shown by the model as having a significant effect on determining whether farmers choose land-use (LU) strategy subsistence/ extractivism (LU strategy 1) or LU strategy cattle-ranching (LU strategy 4), the reference category. Time living on the lot has also been shown to have a significant effect in determining whether farmers choose LU strategy 1 vs. LU strategy 4. It is important to note, that time living on the lot might be considered a proxy to an agricultural background. Local ex-rubber tappers are the Humaitá residents who live the longest time in their lots. They are more inclined to subsistence/extractivism activities, in contrast to land investors (who own their lots for less time), 85% of whom are cattle-ranchers.

Time-distance to urban centers is significant in determining whether the choice of land-use strategy is 2 (agriculture) or 4 (cattle-ranching). The negative value of the coefficient means that by increasing time-distances, chances of farmers adopting LU strategy 2 instead of 4 are reduced. Time living on the lot is significant for LU strategy 2 vs. LU strategy 4 comparisons. For comparisons between LU strategy 3 (mixed husbandry) vs LU strategy 4, the only significant effect found is for explanatory variable time-distance.

The significance of explanatory variables for comparisons other than those using cattle-ranching as the reference category are presented in Table 3.9. For each explanatory variable, 3 comparisons are shown: [subsistence/extractivism (1) vs. agriculture (2)], [subsistence/extractivism (1) vs. mixed husbandry (3)], and [agriculture (2) vs. mixed husbandry (3)]. Time-distance resulted in significance for (1) vs. (2) ($p<0.05$) and (1) vs. (3) ($p<0.01$) comparisons. Positive signs of the coefficients mean that by increasing time-distance, chances of farmers adopting LU strategy (1) instead of (2) or (3) also increase.

Use of agricultural credit once, as opposed to never securing contracted credit, resulted in significance for (2) vs. (3) comparisons. The positive sign means that credit adoption increases the chances of farmers choosing LU strategy (2) instead of (3). Another significant effect is the use of agricultural credit more than once, as opposed to never securing contracted credit, between (1) vs. (2) comparisons. The negative sign in this case means that the adoption of credit more than once decreases chances of farmers choosing LU strategy (1) instead of (2).

Table 3.7 – Results for the MRL model (comparison between subsistence, agriculture and mixed husbandry categories):

Explanatory variable	Odds comparing between strategies		Coefficient	Z	P > |z|	e^b
Time distance	1	-2	0.05975	2.402	0.016*	1.0616
	1	-3	0.08923	2.775	0.006**	1.0933
	2	-3	0.02948	0.923	0.356	1.0299
Credit once	1	-2	-49.72193	0	1	0
	1	-3	-46.11755	0	1	0
	2	-3	3.60438	2.123	0.034*	36.759
Credit more than once	1	-2	-4.44584	-2.253	0.024*	0.0117
	1	-3	-2.87491	-1.344	0.179	0.0564
	2	-3	1.57093	0.866	0.387	4.8111
Number of ponds	1	-2	-0.79945	-1.105	0.269	0.4496
	1	-3	-1.57912	-2.257	0.024*	0.2062
	2	-3	-0.77967	-1.506	0.132	0.4586
Lot area	1	-2	-0.03926	-0.811	0.417	0.9615
	1	-3	-0.05851	-1.236	0.217	0.9432
	2	-3	-0.01925	-0.69	0.49	0.9809
Time living on the lot	1	-2	-0.07638	-0.918	0.359	0.9265
	1	-3	0.05934	0.526	0.599	1.0611
	2	-3	0.13572	1.084	0.278	1.1454
Soil type I	1	-2	-0.68756	-0.331	0.741	0.5028
	1	-3	1.13388	0.601	0.548	3.1077
	2	-3	1.82145	1.115	0.265	6.1808
Soil type II	1	-2	0.60523	0.27	0.787	1.8317
	1	-3	2.61216	1.25	0.211	13.6285
	2	-3	2.00693	1.016	0.31	7.4405

* Significant at the 0.05 level; ** significant at the 0.01 level

Some comparisons between strategy (1) and others in relation to credit use could not be made because there were no representatives of credit-users within this strategy (subsistence/extractivism). Another significant difference comes from comparing (1) vs. (3) in relation to the number of ponds. The negative coefficient shows that by decreasing the number of ponds, the chances of a farmer choosing subsistence/ extractivism increases. No other significant comparison resulted between land-use strategies.

3.7 – Discussion

The Multinomial Regression Logistic model approach used to answer Question **2** (*How do differences in land-use strategies at the farm level reflect variation in the spatial context (time-distances to urban centers) and in access to agricultural credit, while controlling for time of settlement, type of soil and availability of water*) leads to the following outcomes:

3.7.1 – Hypothesis 2A

Hypothesis 2A (*Time-distances from farm lots to local urban centers are significant for explaining variation on land-use strategies adopted by farmers*) **is accepted**, since time-distance shows a significant effect in determining whether farmers choose LU strategy 1 (subsistence/extractivism) or LU strategy 4 (cattle-ranching) as opposed to LU strategies 2 (agriculture) or 3 (mixed husbandry). However, no significant effect of time-distance has been shown in determining LU strategy (1) vs. LU strategy (4), or LU strategy (2) vs. LU strategy (3). These results confirm the relevance of the von Thünen model on spatial allocation of land-use types according to transportation costs. Indeed, the land-use strategies of agriculture and mixed husbandry depend heavily on all-weather roads in the Humaitá region. Most agricultural products are commercialized during the rainy season, when conditions of non-paved roads are often poor. Mixed husbandry is composed mainly of dairy products and fish, and depends also on all-weather roads for economic viability. Several farmers reported having changed their preferred land-use strategy, after losing their crops or milk production, precisely because of poor access to urban centers and markets. Both agriculture and mixed husbandry strategies are also dependent on access to electricity (which

I have not tested for), but it is probably correlated to road network conditions. Cattle-ranching is less dependent on all-weather roads, as extractivism is of most local forest products (Brazil-nuts and timber). Lack of access to urban centers is probably the single most important factor keeping families under the "subsistence farming" category.

3.7.2 – Hypothesis 2B

Hypothesis 2B (*Enrollment in agricultural credit programs is not significant for explaining variation on land-use strategies adopted by farmers*) is **rejected**, since two significant relationships were found: having received credit once as opposed to not receiving credit, increases the chances of farmers choosing land-use strategy (2) (agriculture) as opposed to land-use strategy (3) (mixed husbandry); and having received credit more than once, as opposed to not receiving credit, decreases the odds of choosing subsistence/extractivism (1) as opposed to agriculture (2). Also, it should be noted that the MRL model could not produce coefficients for "having received credit once" under (1), since there was no farmer under this category. However, it might be reasonably assumed that if significant differences were found between agriculture (2) and mixed husbandry (3), the same should also be valid between agriculture (2) and subsistence/extractivism(1), since the differences in frequencies are even higher. Also, when comparing agriculture (2) and cattle-ranching (4), under both "receiving credit once" and "more than once" as opposed to "not receiving credit," both p values come substantially close to 0.05, meaning the level of significance had been almost reached.

To conclude, H2B is rejected because use of agricultural credit, or the existence of credit lines favoring specific land-use choices, has been shown to significantly affect land-use strategies chosen by farmers, specifically in favor of the land-use strategy agriculture (2) in relation to the other three land-use strategies. One explanation supporting this result might be found in the words of an agriculture oriented farmer:

> *"Many people complain about credit programs, probably because they don't go for the credit lines that are good; they often look for big loans and long re-payment periods, but are caught by "accumulating" interest rates… I have been planting corn and beans every year in the last five years, having taken credit four times during that period; I still regret the year I had not taken credit, since I could have made more money this year. Credit for annual crops under the PRONAF/FNO (National Program of Family Agriculture) credit line is really "good": small amounts, but cash money that is promptly available, no hassles, small interest rates and short re-payment period…this allows me to finance the inputs such as seeds and fertilizers, and often something remains for other uses…"*

Fieldwork experience and comparison across different agricultural credit lines confirm that the statement above translates into important differences on rates of agricultural credit adoption observed between agriculture oriented farmers and farmers oriented toward the other three land-use strategies.

A complementary explanation is the fact that, as already mentioned earlier in this chapter, agricultural development takes priority to cattle-ranching in FNO policies, because of the reduced ecological impacts of agriculture when compared to cattle-ranching. As a matter of fact, I learned from interviews with BASA and SEATER agents, that there is a BASA policy which explicitly restricts FNO use for forest conversion to pastures. This policy does not restrict FNO use for purchasing cattle, but the bureaucracy involved in cattle purchases with FNO funds (only certified cattle can be purchased, which increases cattle prices to above-market values) discourages many farmers from acquiring FNO loans to buy cattle. Given FNO restrictions on forest conversion to pastures, most farmers take loans not only for annual and perennial crops, but also for infra-structure investments (which includes fences and corrals) that might help them support investments in cattle-ranching.

Are agriculture-oriented farmers also risk-takers? I don't have a definitive answer to this question, but I am inclined to say that, for the conditions operating in P.C. Humaitá settlement and in many other settlements in the Amazon, the answer is yes. Land-use history in Humaitá shows clearly that many colonist farmers oriented toward cattle-ranching or mixed husbandry today were agriculture oriented in the past. A combination of factors, including difficult commercialization conditions, fluctuation of agricultural prices and environmental factors (such as uneven rain distribution, and high incidence of plagues and diseases), affecting agricultural crops more than other land-use options, has been probably the main reason for these changes. We need to consider infra-structure development and favorable credit lines for agriculture help to decrease the level of risk/uncertainty associated with agriculture as a land-use strategy. The expanding consumption market in Rio Branco opens several profit opportunities from commercialization of agricultural crops. Even so, environmental factors remain a considerable source of risk affecting cultivation of annual and perennial crops more than other land-use options, thus supporting the connection of agriculture oriented farmers with risk-takers.

CHAPTER 4 – USE OF AGRICULTURAL CREDIT BY COLONIST FARMERS

Whether for cattle ranching, family agriculture, or more recently for large-scale soybean plantations, agricultural credit incentives have shaped farmers' choices, institutions, and landscapes in the Brazilian Amazon. Most studies linking the use of credit to deforestation have focused on large cattle-ranching enterprises. Use of credit by smallholders and its implications for landscape transformation remains, however, poorly understood. Use of agricultural credit is a critical area of investigation for informing regional sustainable development and tropical forest conservation programs.

This chapter discusses relationships between the use of agricultural credit and land-use decisions:

Research Question 3 - *What is the role of farmer income, level of education, land titles and credit history on explaining credit adoption rates among farmers during the past 5 years?*

The use of agricultural credit involves uncertainty (e.g. capacity of repayment), but might also contribute to reduce risks of crop failure (e.g. purchase of fertilizers) (Chibnik, 1994). Chibnik noted that the use of credit was affected by land tenure, income, farm-lot size, size of the household, access to markets and farmers previous credit experiences. Credit might be ineffective to reduce risks associated with low levels of income (i.e., falling short of budget), if only better endowed households, or the ones possessing titles to land, have access to it. Farmers' previous credit experiences might also affect the likeliness they engage in credit programs. If re-payment of credit loans had been problematic in the past, or if the outcomes of engaging in such programs did not achieve the expected results, farmers might be unwilling to engage in future programs, even considering that credit policy is extremely variable, and that credit rules might be more favorable in the future. I propose to explore these questions by testing the following Null Hypothesis:

Null Hypothesis 3 – *Neither household income, level of education, land title, or credit history are significant on explaining actual credit enrollment variation across households from 1998 to 2004.*

Question 3 is approached by a Binary logistic model using a binary variable (adoption of credit). The survey instrument includes crop production and commercialization in 2003, plus questions on additional sources of income of the household (including salaries, retirement, commercial activities, remittance, etc), from which total income for 2003 has been estimated. Hypothesis 3 is tested by assessing the significance of the parameter estimates for the explanatory variables household income, level of education, possession of titles to land and if farmers have ever defaulted credit re-payment in the past. Deforestation rates as observed in 2003 might also affect who gets credit, and were therefore also included in the model. Several farmers mentioned to me they had not agreed with IBAMA (Environmental protection agency) on the "Behavior Adjustment Term" (*Termo de Ajustamento de Conduta* or *TAC*), which consists on the establishment of a forest reserve (*averbação de reserva florestal*) to make up for their excessive deforestation rates. Agreement on TAC is in some cases a prerogative to being eligible to agricultural credit, hence the inclusion of deforestation rates as observed in 2003 in the model. A discussion based on model results follows, including differences among farmers concerning adoption of agricultural credit and their behavior in relation to risk/uncertainty involving credit operations.

Following this introduction, an overview on theoretical developments on agricultural policies and tropical deforestation is presented. Next, it presents a brief historical background on agricultural credit policies in the Amazon from its inception in the early 1970s to more recent trends observed after the turn of the millennium. I pay particular attention to the relationships between credit, deforestation and agro-pastoral gross production. Following this regional contextualization, the chapter moves back to Acre, to focus on to the factors affecting adoption rates of agricultural credit (Question 3). It describes and discusses the socio-economic profile of Humaitá's credit-users and non-credit-users, and uses a Binary logistic model to investigate the "who gets credit?" question. I conclude the chapter by putting this case study in regional perspective. Humaitá data is compared to two settlements in the State of Pará (Transamazon BR-163).

Besides addressing question 3, this chapter presents an historical perspective on the evolution of credit programs in the Brazilian Amazon, and aims to contribute to the contemporary debate on agricultural credit, regional development, and tropical deforestation. I consider the regional context using data from the 1989–2003 Brazilian censuses and from Bank of Amazônia (BASA), a regional development bank in charge of several credit programs, for both small- and large-scale farming, commercial and industrial enterprises in the Amazon region. Agricultural credit distribution across user groups is then discussed, as well as its possible implications for regional development and LUCC.

4.1 – Agricultural credit, regional development and deforestation in Amazônia

According to a comparative study by Angelsen and Kaimowitz (2001), both positive and negative effects of credit-related policies impact tropical forests. Capital inputs can support the diffusion of technologies and crops with potentials for reducing pressure on forests, as has been observed in Ecuador (Wunder, 2001), and Côte d'Ivoire and Indonesia (Ruf, 2001). In other cases, credit can support expansion of cattle ranching or economies of scale (e.g. soybeans) with negative consequences on tropical forests (i.e. expansion of pastures and large agricultural operations) as experienced in Brazil, Bolivia (Angelsen and Kaimowitz, 2001, p. 387) and Ecuador (Pichón *et al.*, 2001). Despite its importance, credit is still one of the least studied topics in these geographic areas and in the Amazon.

As discussed in Chapter 1, farming in the Brazilian Amazon is considered risky, due to high chances of crop failure, infrastructure constraints, and fluctuations in market prices of most agricultural products. Nevertheless, the agricultural frontier has been permeated with opportunities for financial profit, such as land speculation, timber exploration, and extensive cattle ranching since the initial stages of large-scale expansion in the early 1970s. During the 1970s and 1980s, settlement and agropastoral activities have been promoted by subsidies from the Brazilian government as a means to boost regional colonization and development. Many researchers have questioned whether such policies are justifiable as expansion policies, because they have dubious social benefits and often accelerate tropical deforestation (Fearnside, 1985; Hecht, 1985, 1993). Moreover, given the apparent negligible effect of credit on boosting regional development in the Amazon, such policies have been labeled not only environmentally destructive, but inefficient from a cost-benefit perspective (Bunker, 1988; Mahar, 1989).

Agropastoral credit in the Amazon and across Brazil is allocated differentially between interest groups of farmers holding lots of different sizes (Helfand, 2001). Ethnographic data have shown that small-scale farmers' credit allocation and land-use strategies differ from those used by large-scale farmers (Brondízio, 2004). Hence, when credit policies in the Brazilian Amazon are evaluated, it is important to adopt an historical perspective and to take into account the characteristics of farmers targeted by the various credit policies.

Agricultural credit has been an important tool for governments to boost regional development and promote the expansion of agricultural frontiers worldwide. Unfortunately, most policies seek short-term returns, and governments pay little or no attention to the impact of credit policies on the maintenance of the natural resource base in the long term. The consequences of credit policies on tropical forests, for example, have been often overlooked or not considered during policy planning phases in several tropical countries (Reardon and Barrett, 2001). Even worse, the role played by governments is sometimes not only regulating the economic conditions for agricultural markets, but actively promoting deforestation through the distribution of credit funds.

Most smallholders in tropical forested areas operate with high discount rates, meaning that income alternatives with returns in the short term, such as annual agriculture and wage labor, become a priority versus the ones that require conservation of the resource base in the long term. In this sense, environmental externalities of credit programs tend to be much more significant in tropical areas, when compared to regions where discount rates are not as high. Additionally, farmers in tropical frontiers have low opportunity costs for their labor (Ozório de Almeida and Campari, 1995), so financial returns from clearing a forest might be the best alternative even if such returns are considered extremely low from an outsider's perspective.

In the case of Brazil, credit and tax relief programs were used by the military government in the 1970s and early 1980s to promote Amazon occupation and colonization

(Hecht, 1985; Moran, 1981). Credit policies provided incentives to large- and small-scale farmers to settle in and convert tropical forest into agropastoral use. During this stage, many credit programs directed to annual crops had actually been successful, but stories of farmers who lost their crops due to low prices or impassable roads are common. This heritage is still having an effect on how farmers relate to credit in frontier areas, where credit is often seen as a means to expand the area of pasture.

Other elements affecting the environmental impact of credit policies depend on factors such as tenure security and the nature of individual credit programs (including implementation and monitoring systems). Not only is credit frequently used for deforestation purposes, but deforestation itself might be a way to enforce informal rights to land (Hecht, 1985), thus increasing chances of later obtaining credit to further investments (Alston *et al.*, 1999). Land titles are often required as collaterals for bank loans (Tura and Costa, 2000). However, transaction costs for land titling are often prohibitive in Amazon frontier areas, leading many lenders to accept other forms of rights to land as collaterals for loans, such as informal rights acquired with conversion of forests to pastures. This represents an incentive for farmers to clear land in order to guarantee tenure over the property, and later obtain credit.

To examine the impact of credit policies on forests, it is important to look into how farmers make decisions under situations of risk and uncertainty. The risks associated with default on repaying credit loans acquired by small-scale farmers represent an incentive for them to adopt land-use choices with low risks of failure (Chibnik, 1994), such as cattle ranching, versus land-use alternatives with higher levels of risk, such as annual and perennial agriculture. Cattle ranching, usually extensive, requires large amounts of forest conversion to pasture, establishing a potential negative link between use of credit and deforestation.

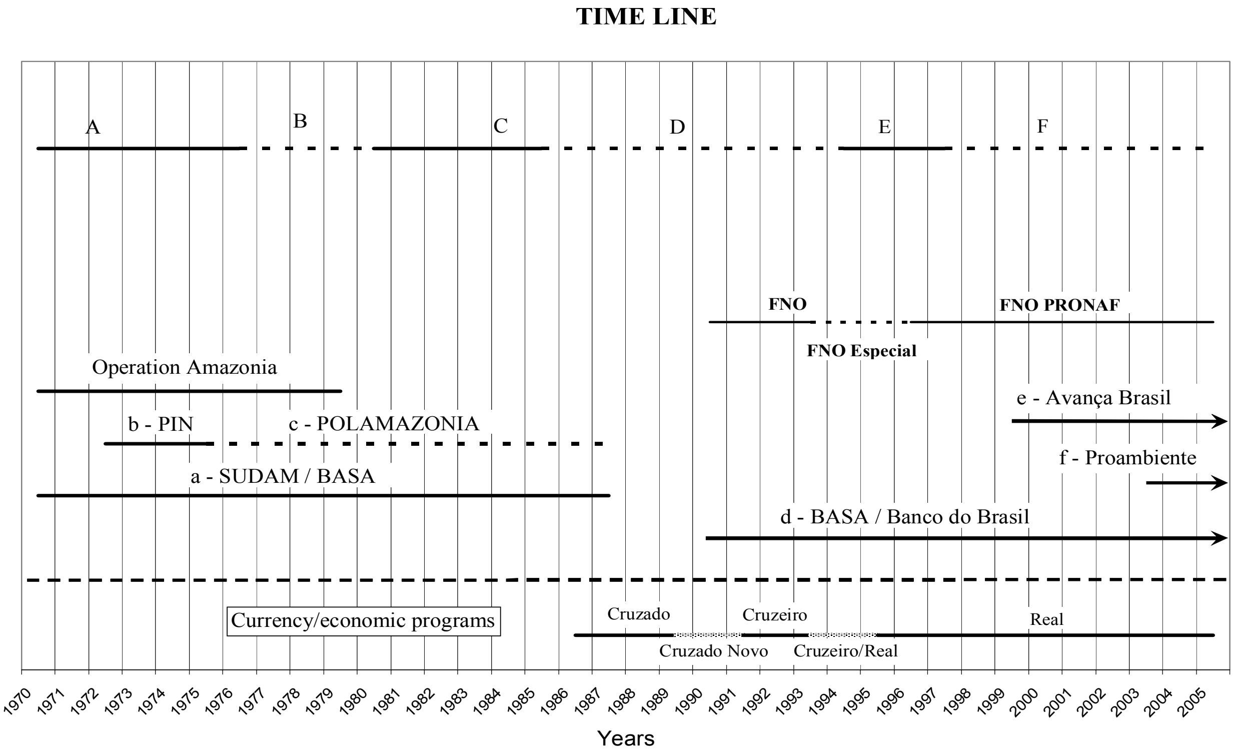
Most of Amazon deforestation is followed by the establishment of cattle ranches (Fearnside, 2005), which are also encouraged by the presence of market chains and the overall infrastructure context. Moreover, cattle ranching can often finance itself (Faminow, 1998), hence not having to depend on the acquisition of credit loans. Recent technological developments in the cattle-ranching sector, such as the use of new *Brachiaria brizantha* grass varieties, led to significant improves in cattle-ranching profitability in the Amazon. Under this specific context, evaluation of credit policies for small-scale farmers should aim at understanding not only if credit causes conversion of forests to pastures but whether farmers with access to credit loans convert larger areas of forest than they would without them.

4.2 – Historical background

From the onset of Operation Amazônia[55], credit policies and subsidies for the agricultural sector were the predominant incentives for migrant farmers and entrepreneurs to settle in the region. Allocation of such incentives and their impact on the environment differ broadly by period, geographic location, and interest groups, as widely discussed and recognized in the literature on Brazilian agricultural credit policies (Abreu *et al.*, 1996; Graham and Howard, 1987; Hecht, 1985, 1993; Helfand, 2001; Mahar, 1989). A time line of economic events and colonization policies for the Amazon region is presented in Figure 4.1.

[55] The colonization of the Brazilian Amazon region started in the second half of the 1960s after a series of legislative acts, known as Operation Amazônia, promoted by the military regime that came into power in 1964. The main concerns of the government were to ensure national sovereignty by occupying borders, to gain access to the natural resources of the area, and to rapidly resolve the demographic and socioeconomic problems of other parts of Brazil, particularly the northeast. These multiple goals were to be obtained through the occupation and development of the Amazon, with the construction of extensive road networks and establishment of colonization projects, based on agrarian settlements and an interconnected urban infrastructure (Mahar, 1989).

Figure 4.1 – Time line of economic events and agricultural credit policies in the Brazilian Amazon.



A - Increase of agricultural credit + credit as a colonization incentive
B - Constant agricultural credit + inflation growth
C - Currency devaluation + increase in interest rates
D - Hyperinflation + Plano Cruzado
E - Plano Real
F - Increase in land reform settlements

a - SUDAM/BASA attract private investment
b - Plan of National Integration INCRA
c - POLAMAZONIA
d - BASA and Banco do Brasil operate FNO funds
e - Launching of Avança Brasil infrastructure improvement program
f - Proambiente starts as a pilot program

Between the end of the 1960s and the first half of the 1970s, Brazil experienced an almost threefold increase of agricultural credit (Graham and Howard, 1987; Helfand, 2001). In the second half of the 1970s, the overall level of agricultural credit in Brazil remained constant. However, in Legal Amazônia[56], the level of credit increased almost tenfold during the 1970s (Mahar, 1989). This decade is characterized by a rapid expansion of the subsidized component of agricultural finance in Brazil.

This latest cycle of colonization along the Transamazon highway began in the early 1970s. The regional Agency for Development of the Amazon (SUDAM), in collaboration with BASA, was in charge of implementing five-year development plans. Taking into account existing and potential future populations, these plans attempted to aid the formation of stable and self-sufficient regional economic groups and to rationalize the exploitation of natural resources (Law 5.374/1967, cited by Browder, 1988). In the first phase, SUDAM/BASA development plans attracted private investment for the development of a broad range of economic areas, including the agricultural and livestock sectors (with particular attention to cattle ranching) and the industrial and forestry sectors (Moran, 1981).

Between 1970 and 1974, the Emilio G. Medici administration launched the Plan of National Integration (PIN), which entailed the massive construction of roads and settlement of farming families. The Brazilian Agency for Colonization and Agrarian Reform (INCRA) was in charge of regularizing the occupation of the land. The new farmers were expected to first produce food crops for local consumption, but eventually produce a surplus to be exported to southern Brazil. Farmers were offered benefits (land and a six-month salary) and access to bank loans. While BASA primarily offered loans for cattle operation, Banco do

[56] The Legal Amazon of Brazil is the largest sociogeographic division of Brazil and defined by law to include the states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Mato Grosso, Maranhão, and Tocantins (IBGE, 1991).

Brasil offered loans at 7% annual interest to pioneer farmers. By the end of the 1970s, only about 8,000 of the 70,000 planned families had settled, and of those, 40% came from northeastern Brazil (Mahar, 1989; Moran, 1981).

From a government perspective, the relative failure of the settlement plan, combined with a deep crisis in Brazil's balance-of- payment, led to the abandonment of PIN in 1975 in favor of the development of large-scale export-oriented projects, with a particular focus on cattle ranching, forestry, and mining (Browder, 1988). The new direction was principally promoted by the Association of Amazon Entrepreneurs, a São Paulo–based interest group mostly composed of large-scale farmers. In 1974, the federal government established the Polamazônia program to implement large-scale cattle-ranching projects. This program was abolished in 1987, in part due to reports pointing to its role in subsidizing deforestation, and to growing pressure from national and international organizations (Browder, 1988; Mahar, 1989).

As a response to the economic crisis of the late 1970s, the government under João Figueiredo (1979–1985) increased real interest rates in 1981 and devaluated the currency in 1983 (Abreu *et al.*, 1996). The impact of such policies on the agricultural sector was that the real value of credit declined by 55% (Graham and Howard, 1987). Repeated failures at stabilization, the Cruzado Plan in 1986, and the Collor Plans in 1990 and 1991 resulted in hyperinflation (Abreu *et al.*, 1996).

The Plano Real (Real Plan) established in 1994 was successful at achieving some stabilization in prices and an overall reduction in inflation rates. The stabilization of prices was associated with both a general increase in consumption levels and with the improvement of economic conditions for the lower-income strata of Brazil's population, which at that time had very limited buying power. The increased level of confidence in the economy brought by Plano Real contributed to the sharp increase in the demand for agricultural credit. Credit availability has been increasing in the Transamazon region since 1990, when the Fund for the North Region (FNO) was implemented.

FNO was established by the Brazilian Constitution of 1988 through the transfer of resources from industrial and commercial taxes to the Amazon region, in an effort to support its development (Tura and Costa, 2000). Thanks to the decentralization policies promoted by the Brazilian Constitution of 1988, the North Region (which corresponds to most of Legal Amazônia) had gained autonomy over regulating access to these resources for regional development. After auditing interested sectors of the society, such as farmers' unions and NGOs[57], BASA and SUDAM established the guiding principles for the use of FNO-related agricultural credit. The four principles were: (1) diminish intraregional development inequalities; (2) promote self-sufficiency in food supply; (3) promote regional sustainable development; and (4) provide incentives for family labor. The agricultural credit program was subdivided into three subprogram groups: small-, medium-, and large-scale farmers. Each of these subgroups was to be managed in accordance with specific sets of rules.

The initial implementation of FNO agricultural credit in 1989 was, however, an extension of previous programs, which traditionally had been biased toward primarily supporting large projects, such as extensive cattle ranching. According to Tura and Costa (2000), local upper-class landowners, dependent to some extent on ranching activities as a source of income, protested against poor economic performance and the waste of public

[57] These include the Federation of Agencies for Social and Educational Assistance, the Confederation of Workers in Agriculture, and the Pastoral Commission of the Earth (Catholic church).

funds on previous corporate initiatives in mega-ranching projects[58]. They claimed access to FNO sources under the premise that those funds should be used for their original intention—regional development. The result was that in 1992 a significant proportion of those funds were still being used to support large-scale cattle ranching, a policy that violated another general principle of FNO: the funds should be used for sustainable development, minimizing environmental damage (Tura and Costa, 2000). This situation changed in 1993, with the implementation of FNO Especial. This new program, basically a variation of the original FNO, changed the rules of access to agricultural credit and lowered interest rates for small loans, increasing the overall rates of credit acquisition among small-scale farmers.

FNO Especial operated at the regional level, but reflected an overall change in agricultural credit policies at the national level. The end of the 1990s brought the establishment of the National Program of Support for Family Agriculture (PRONAF), which is oriented toward rural smallholder families, especially the ones settled in agrarian reform projects. PRONAF has resulted in better access to agricultural credit for settlers throughout the Amazon region.

Regional integration within the Amazon and in the rest of the country has always been a problem. In 1999, the Brazilian government launched the Avança Brasil program. This program primarily focuses on infrastructure investments, reducing transportation costs, and connecting the Amazon region and its increasing agropastoral output to the rest of the

[58] Mega-ranching refers to large "development projects" owned by southern and transnational corporations who benefited from the tax-incentive policy; an important distinction is made here between large farms owned by local residents, who depended to some extent on their land as a source of income and position of power, and corporate *latifundio* investors, for whom land is merely part of their investment portfolios and whose decisions concerning production operations adhere strictly to financial criteria. Differences between these two general categories can be found also at the level of political influence: while the former lobbies more locally and informally, the later is constrained by formal institutions acting at broader national and even international levels (Tura and Costa, 2000).

country (Veríssimo and Barreto, 2004). However, seven years later, its impact on regional infrastructure remains limited and localized.

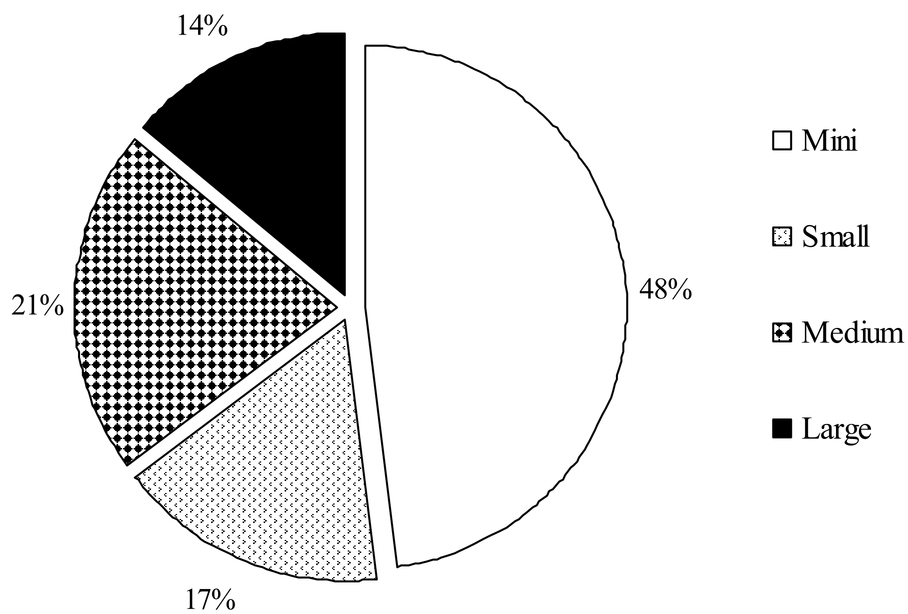
4.3 - Agricultural credit, development and deforestation at national and regional scales

Agricultural credit programs have been an important component for the expansion of the agricultural sector in Brazil. However, important fluctuations have occurred in the amount of resources made available throughout the last three and a half decades and in the distribution of resources across interest groups. According to Helfand (2001), interest groups vary in their power to lobby politicians for the approval of credit lines that benefit their own sectors. Thus, a large share of agricultural credit resources have been generally allocated to large-scale landowners while smallholders have received a significantly smaller share, during the 1970s and 1980s (Helfand, 2001). This bias produced the most perverse outcomes in the Amazon region as a whole. This includes an obvious impact on tropical deforestation, a questionable impact on bringing socioeconomic development to the region, and many highly publicized corruption scandals.

4.3.1 - Distribution of FNO resources to interest groups in the Amazon, from 1989 to 2003

According to the Bank of Amazônia's records, there was a substantial change in the allocation of funds across interest groups after the 1980s. Sixty-two percent of the US$1.86 billion of federal resources destined for FNO were transferred to mini- and small-scale beneficiaries in agricultural credit loans between 1989 and 2003, while medium- and large-scale farm enterprises received only 38% of the share (BASA, 2002, 2004; see also Figure 4.2).

Figure 4.2 - FNO agricultural resources by interest group, 1989–2003:



Note: Percentages are not relative to the number of receivers (US$/borrower)

These results might be linked to the ways farmers are categorized in census surveys. The typology used by BASA is based on the gross annual production (GAP) of farmers. The classification is as follows: (1) *mini-scale* farmers who make less than US$13,800/year; (2) *small-scale* farmers who make between US$13,800and US$27,600 per year; (3) *medium-scale* farmers who make between US$27,600 and US$ 172,400 per year; and (4) *large-scale* farmers who make more than US$172,400/year (BASA, 2004:55[59]). The arbitrary limits established for such classes affect the distribution of FNO resources to each interest group of different landowners and investors in the Amazon. Actually, it misrepresents the categories of small-scale farmers who largely fall under an income bracket for agropastoral commercialization lower than US$6,000/year (see income data for P.C. Humaitá on Tables 3.1-a, b, and c ahead in this chapter).

Another aspect to be considered is that there are other sources of agricultural credit in the Amazon besides FNO. This is especially true for large agricultural projects, which often obtain funding from commercial banks. Commercial credit operations require some kind of collateral to offset insolvency risks. While most large-scale cattle ranchers and soybean plantation owners have such collateral, smallholders in the Amazon do not meet this requirement and are rarely targeted by commercial banks.

4.3.2 - Relationship between agricultural credit and deforestation in Amazônia

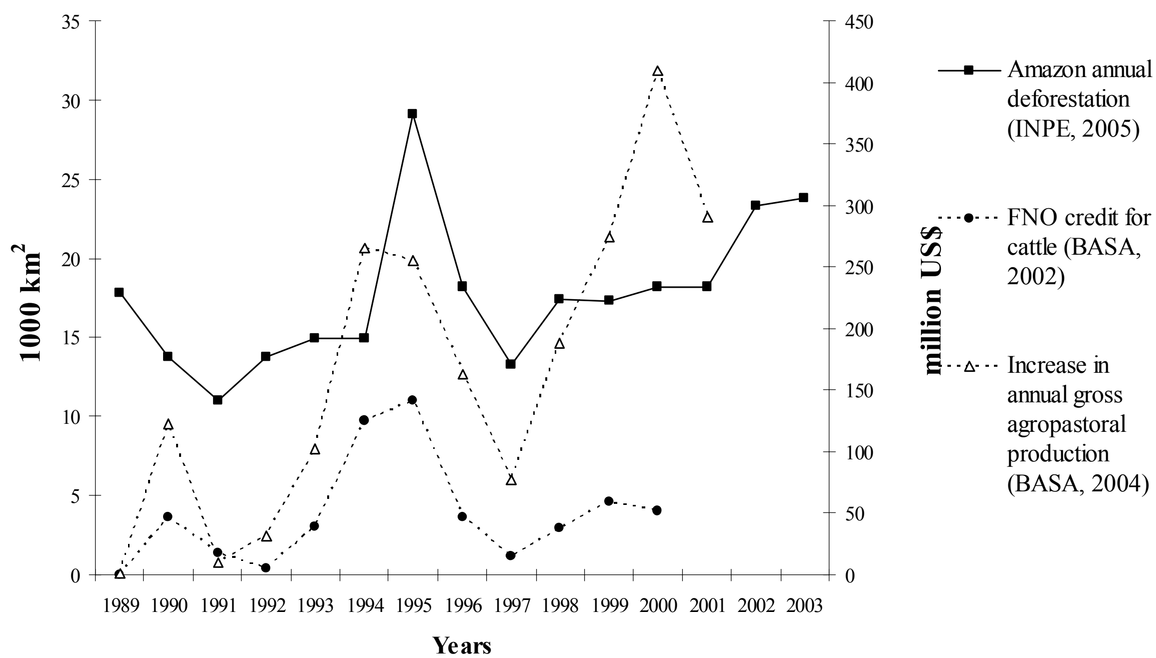
Greater availability of agricultural credit might promote deforestation by allowing farmers to expand their cropped area and pasture, as shown in studies from Brazil, Africa, and throughout the world (Angelsen and Kaimowitz, 2001; Kaimowitz and Angelsen, 1998). This also has been true in our study area. During the initial phases of colonization in the Brazilian Amazon, nearly 82% of credit received by individual settlers was used to clear forest (Moran, 1981).

In Figure 4.3, Amazon deforestation rates (INPE, 2006) are plotted against FNO credit for cattle ranching and against the increase in agropastoral GAP for 1989–2000 (BASA, 2002). Credit for cattle is correlated to the annual Amazon deforestation rate and to

[59] Using R$ to US$ conversion rates of 2.9 to 1.0.

the increase in agropastoral GAP (Pearson $\rho = 0.64$ and $\rho = 0.66$, respectively, for $\alpha = 0.05$). On the other hand, no significant relationship is found between the rate of annual Amazon deforestation and the increase in agropastoral GAP.

Figure 4.3 - Amazon deforestation vs. credit for cattle and agropastoral production, 1989–2000.

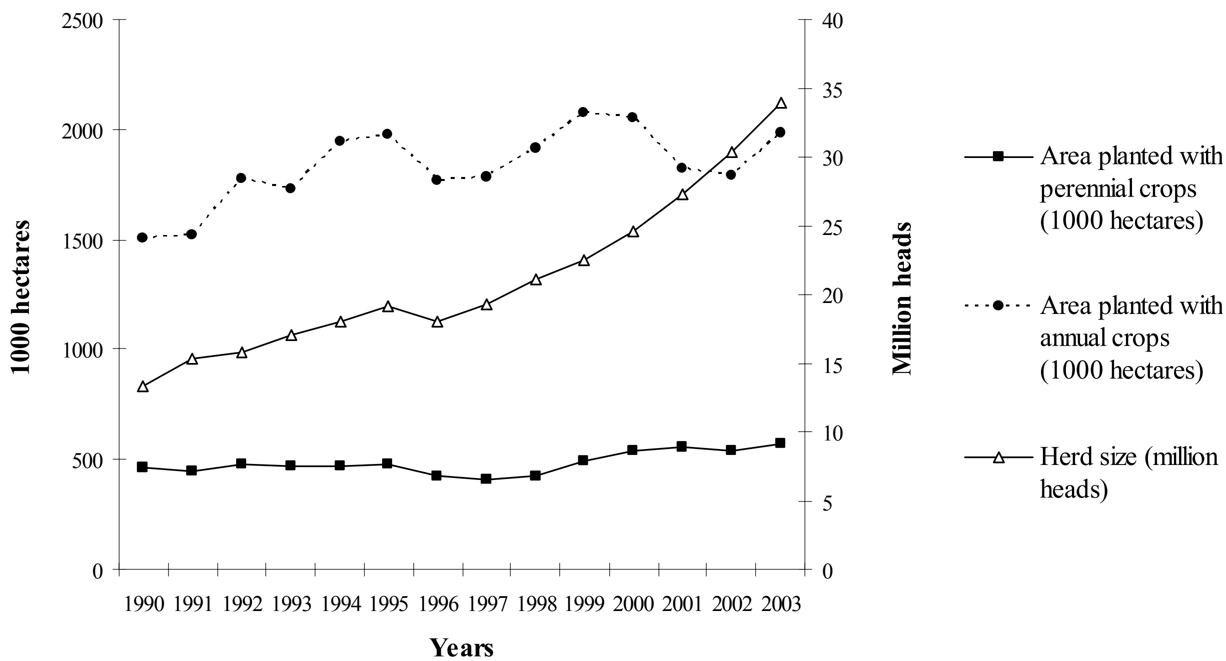


Due to data limitations, and despite the high correlation between deforestation and cattle ranching, potential correlations between annual deforestation rates in the Amazon and annual distribution of overall FNO credit (FNO for cattle + FNO for agriculture[60]) could not be addressed. However, data obtained from IBGE show that the total land area planted with

[60] Data for the FNO credit distribution to agriculture alone could not be found.

annual and perennial crops remained relatively stable throughout the 1989–2003 period[61] (IBGE, 2005; see also Figure 4.4). Nonetheless, the total cattle herd size in Amazônia increased by 155%, jumping from 13.3 to 33.9 million heads in 14 years. This leads us to conclude that if credit for annual and perennial crops is correlated with deforestation, this relationship is probably much weaker than the one found between credit for cattle and deforestation.

Figure 4.4 - Agricultural area and cattle herd size dynamics in Amazônia, 1989–2003.



These figures indicate that agricultural credit, at the regional level, has a positive impact on increasing overall agropastoral output, but at the expense of increasing deforestation rates. This result is in line with large-scale assessments of the impact of credit

[61] The increase was 32% and 24% for annual and perennial crops, respectively.

on deforestation, reported in LUCC literature, and on relationships between deforestation and cattle ranching (Fearnside, 2005; Pacheco, 2005) and soybean (McGrath and Diaz, 2006; Morton *et al.*, 2006; Pádua, 2004) expansion. At the same time, it does not correspond to what was observed at the local level among small-scale farmers in the Transamazon region (Ludewigs et al, under review-a). Thus, these findings provide useful insights on how policies aimed at the sustainable development of regions rich in biodiversity should be tailored to the characteristics of the targeted stakeholders.

4. 4 – Methods

4.4.1 – Data: Household data and regional contextualization data

The analysis in agricultural credit in Humaitá-Acre draws on characteristics of credit-users and non-users (e.g. income, time living in the lot), and on attributes from the lots they live in (e.g. lot area, land cover, time-distances), as well as on credit use and allocation by agropastoral activity, and loan repayment characteristics. All these variables are part of the survey instrument described in Chapter 1.

A regional contextualization of the use of agricultural credit is provided, by using the census database for agropastoral production by municipality from the Brazilian Institute of Geography and Statistics (IBGE). It provides information on the temporal variation of the acreage of annual and perennial crops planted in the 1989 - 2003 period for each state of Legal Amazônia. The same source was used for data on cattle herd size by state in that period (IBGE, 2006).

An analysis of FNO's performance for all Legal Amazônia states between 1989 and 2001 (BASA, 2002) and an annual report for the year 2003 (BASA, 2004), were obtained from BASA. These sources provided data on the amount of credit input available to different interest groups in the Amazon and to each sector of activity. They also provided data for evaluating the impact of credit policies on regional economic development. In addition, data on the annual rates of deforestation for Legal Amazônia were obtained from the PRODES program of the National Institute for Space Research in Brazil (INPE, 2006).

4.4.2 – The model

A Binary Logistic Regression (BLR) model including the explanatory variables mentioned on section 3.2 was run using STATA for Windows (version 9). The variables are:

- dependent variable: number of credit loans in the 5 years preceding fieldwork;
- independent variables:

a) Income in 2003 (estimated based on commercialization of agropastoral products and on extra-lot sources of income (salaries, wages, pensions);

b) Level of education (1 – Illiterate; 2 – Elementary; 3 – Higher than elementary);

c) Possession of titles to land (1 – titled; 0 – untitled);

d) Credit history (1 – history of default with bank loans; 0 – clear bank record);

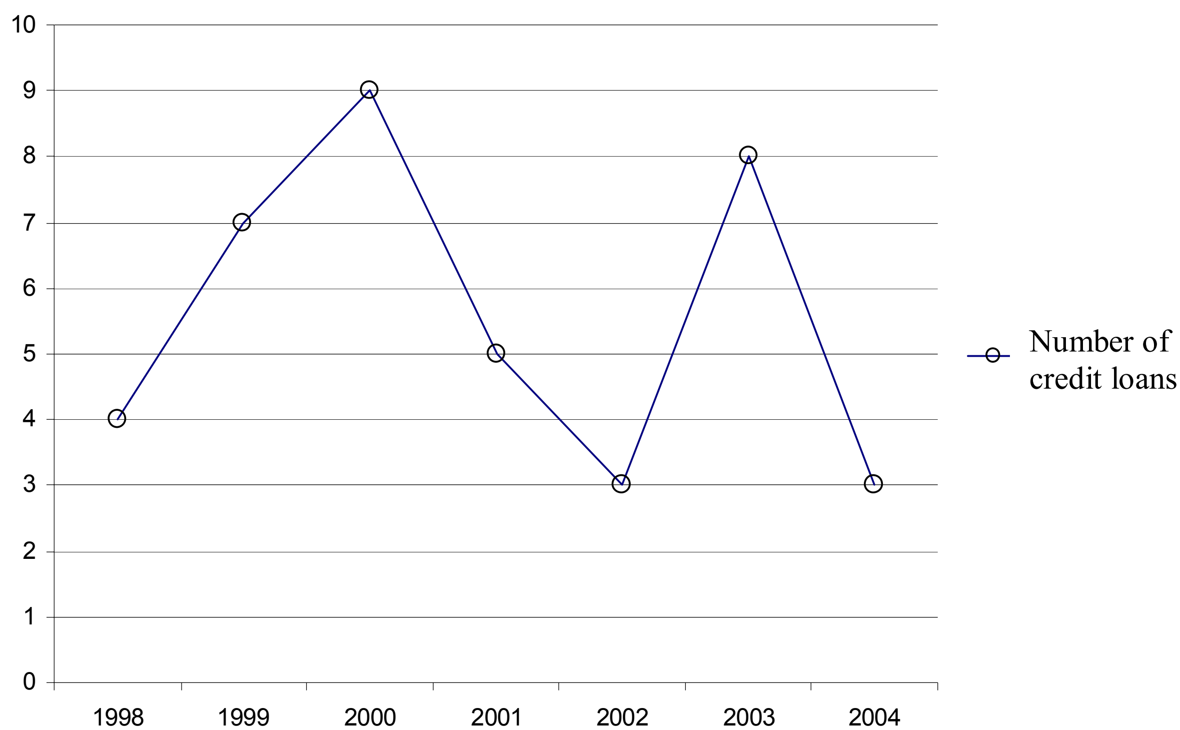
BLR models are useful when analysts want to predict an outcome based on values of explanatory variables. They are similar to linear regression models but better adapted to cases where the dependent variable is dichotomous. Coefficients obtained from BLR might be used to estimate odds ratios for the explanatory variables in the model (Menard, 2002).

4.5 – Use of agricultural credit in Humaitá settlement, Acre

4.5.1 - Rates of access to agricultural credit in Acre and in the Transamazon

There were a total of 39 credit loans, contracted by 25 out of 63 farmers within the surveyed sample and during the period January 1998 to June 2004, representing a rate of access to credit of 39.7% during the whole period. The peak year was 2000, with rates of 14%, and 2002 showed the lowest rates with 4.7% (Figure 4.5).

Figure 4.5 – Number of credit loans in the sample, from January 1998 to June 2004:



Agricultural credit in Acre has been part of INCRA colonization policies and began with the establishment of agrarian settlements, as was the case with many other frontier expansion fronts in the Amazon. In the Transamazon region, for example, migrant families arriving to colonize the area were eligible to receive subsidized credit for building their houses, buying agricultural tools and inputs, and clearing the forest (Moran, 1981). In fact, this early stage of settlement turned out to be the heyday of agricultural credit in the region. Perennial crops, particularly cacao, but also black pepper and rubber, received significant credit incentives from the mid-1970s to the early 1980s. The opening of several governmental agency for cacao research and promotion (CEPLAC) offices in the region and an attractive market contributed to high adoption rates of cacao credit among farmers with patches of alfisols (*terra roxa*) in their lots. The spread of witch's broom disease starting in the late 1980s contributed to the abandonment of many cacao plantations. With the implementation of FNO in 1989, rates of credit adoption increased sharply, rising to near 1970s' levels, with a peak of 12% in 1995 mostly allocated for cattle-ranching purposes. Thereafter, rates began a new downward cycle, most likely related to a combination of insolvency problems and a lack of confidence by farmers in credit loans, due to reasons discussed below. These reasons apply to many other areas in the Amazon.

During fieldwork in 2003/04, some farmers expressed a lack of confidence in credit loans and dissatisfaction with some aspects of credit transactions performed by technical assistance agents, who acted as intermediaries between the lending agencies (mostly BASA or Banco do Brasil) and the borrowers (farmers). For example, farmers complained about the lack of technical assistance during the implementation of projects financed by FNO, mandatory spending on agrochemical inputs, and their obligation to buy livestock from certified breeders who sold low-quality cattle at high prices. Another common complaint by farmers was the prescribed nature of FNO credit lines, which assigned particular crops and crop composition for a particular farm location and market, even if that crop was not the best fit.

4.5.2 - Allocation of credit by activity

The medium to high-fertility patches of Alfisol present in some parts of Acre might be almost considered equivalent to the ones in the Transamazon region, and also contrast to acidic low-fertility soils in most of the Amazon basin. Such above-average fertile soils have been nurturing expectations for successful agricultural development in Acre (INCRA, 1990). Crops such as corn, beans, coffee, and, more recently, peach palm (*Bactris gasipaes,* locally know as *pupunha*) have been receiving considerable support from government programs. Another "promoted" crop planted in some parts of Humaitá settlement is a *Piper* species locally know as *pimenta-longa*[62]. Following the example of settlement projects in the Transamazon region, most agricultural credit received by smallholders in Humaitá was for investment in annual and perennial crops during the 1980s, but cattle ranching has been the preferred activity of credit allocation for farmers in the early 1990s (SEATER staff, pers.comm.). This shift, observed also in the Transamazon region at the same time, may be related to the higher financial risk involved in planting most annual and perennial crops (Chibnik, 1994), and to the availability of new *Brachiaria brizantha* (or *braquiarão*) grass varieties, that proved to be well suited for the region and motivated farmers to reclaim areas of secondary succession for pasture formation. While chances of crop failure in the Amazon are high due to extreme precipitation and temperature conditions, the lack of all-weather

[62] "*Piper hispidinervum* (C. DC.), Piperaceae, is a promising source of sassafras oil, the source of safrol, currently derived from endangered plants of the Lauraceae such as *Ocotea pretios* Ness (Mez.), *Cinamomum petrophilum*, *C. mollissimum*, and *Sassafras albidum* Nutt. The essential oil of *P. hispidinervum* contains high levels (83–93%) of safrole in leaves which can be easily extracted by hydrodistillation" (Rocha and Ming, 1999).

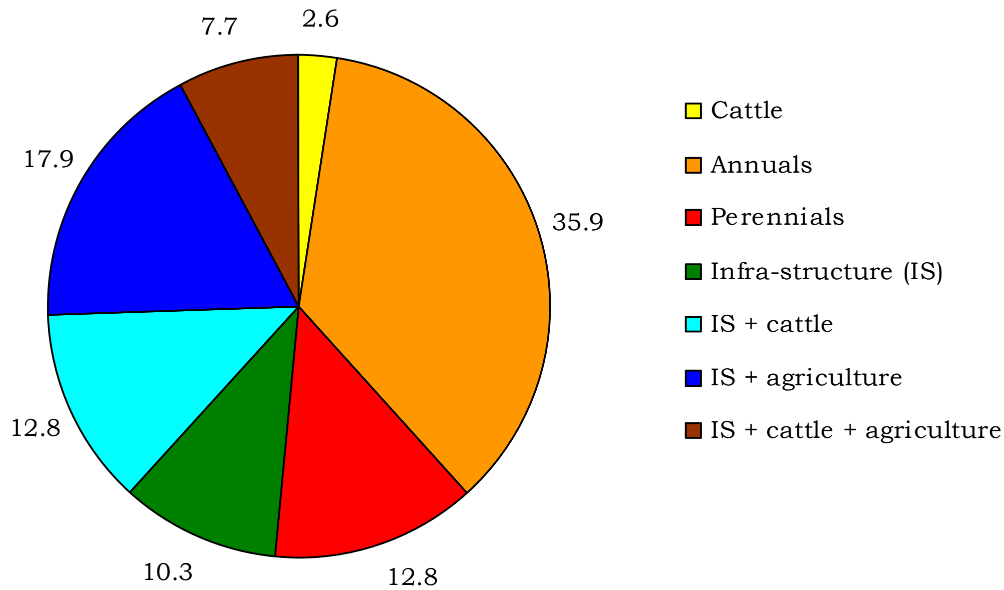
roads and substantial fluctuations in the prices of most agricultural products also make the commercialization of these products problematic. Cattle ranching, on the other hand, is considered a relatively safe income strategy given the lower chances of production failure, lower labor requirements, and its relative independence from the necessity for all-weather roads, as cattle do not need storage facilities and can walk to the market if necessary (Hecht, 1993; Mertens *et al.*, 2002). Moreover, due to strong local and regional markets, prices for cattle are less vulnerable to fluctuations than prices for agricultural products.

Despite preference for cattle-ranching as a land use alternative among Humaitá farmers, most credit loans have been allocated toward annual crops (Figure 4.6-a). Restrictions on FNO rules for financing forest conversion to pastures, and excessively bureaucratic rules for cattle financing are probably the most important reasons for fewer loans being allocated to cattle-ranching. This will be discussed into more detail further. Even so, higher average loans to cattle-ranching projects[63], when compared to average loans of US$ 2,753 across all categories and along the studied period, are responsible for concentrating some 42% of all credit financial resources into the categories “Infra-structure + cattle-ranching” and “cattle-ranching” (Figure 4.6-b). Infra-structure investments are composed mainly by construction of fences, corrals and other cattle-ranching related operations.

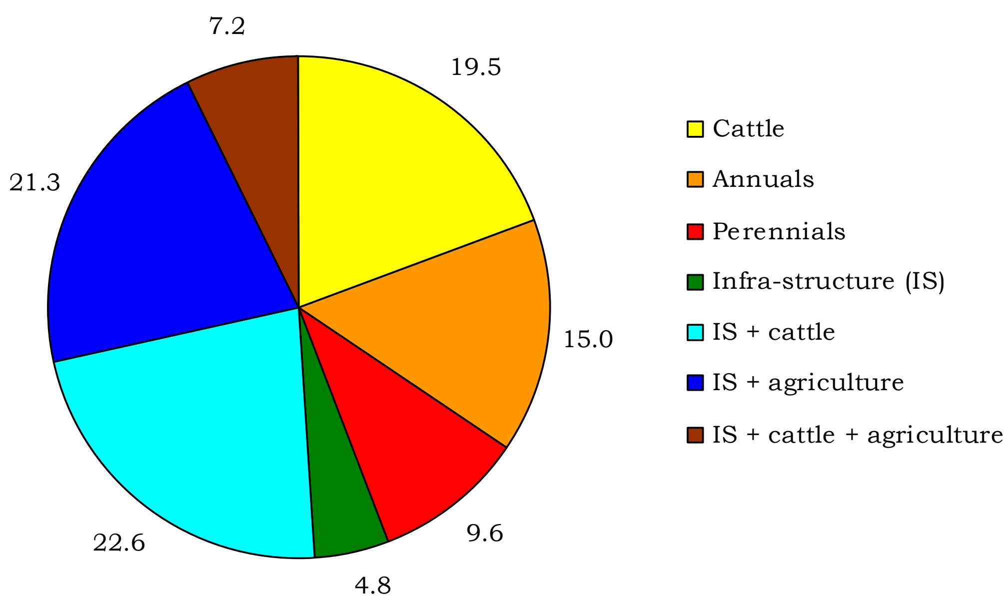
[63] A single loan of US$ 20,940 (the highest value observed in the period) was given to one interviewee for the purpose of buying cattle.

Figure 4.6 a and b – Rates of allocation of agricultural credit (%) in Humaitá settlement from 1998-2004 by:

a) Total of approved loans:



b) Total of financial resources:



4.5.3 – Household Income distribution

This section presents household income distribution by social group of farmers, by land use strategy and by users and non-users of agricultural credit. The objective is to describe income as an explanatory variable of credit use. Later in this chapter I present the results of the model. The different components of income are here only superficially explored. In Chapter 6, I discuss income partitioning into several components in detail.

Land investors' annual income is, in average, 3 times higher than local farmers' annual income, which is on average 27% higher than colonist farmers' income (Table 4.1a). The composition of income varies within groups: while 42.5% of total income comes from gross annual production (GAP - agropastoral production from the lot) for local farmer families, this figure rises to 55.2% for land-investors and 76.8% for colonist farmer families. Many local ex-rubber tapper families receive a special type of social security (or retirement pension), called *soldado-da-borracha* (rubber soldier) retirement pension, which is equivalent to two monthly minimal wages, whence most retired colonist farmers receive only one minimal wage per month[64]. The rubber-soldier policy represents a recognition from the federal government to their strategic role in the regional economy as rubber-tappers. It is also a financial compensation, since as rubber-tappers working under the patronage system, local farmers were systematically excluded from benefits related to labor rights during their productive lifetimes.

[64] Equivalent to R$250,00 or US$ 110 per month

Table 4.1 a, b and c – Average annual income in Humaitá (US$):

a) By social group

Income (in US$)	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	Mean	Stdev	Mean	Stdev	Mean	Stdev
Gross annual production (GAP)	3183	3627	4528	5353	12704	12311
Other sources of income	4309	10365	1844	3865	10290	11918
Total income	7492	10262	5899	6638	22994	18872

GAP: Gross annual production

Average R$ / US$ currency in 2003 = 3.2

b) By land use strategy

Income (in US$)	Subsist/ Extract. (n=11)		Agriculture (n=10)		Mixed husbandry (n=11)		Cattle ranching (n=31)	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Gross annual production (GAP)	619	688	3011	2551	6358	6429	8620	9446
Other sources of income	4761	11218	713	1028	695	710	6301	9346
Total income	5380	11275	3723	2361	7054	6532	14489	15408

Average R$ / US$ currency in 2003 = 3.2

c) By credit-users and non-credit-users:

Income (in US$)	Credit-users n = 25		Non-credit-users n = 37	
	Mean	Stdev	Mean	Stdev
Gross annual production (GAP)	5705	7165	6091	8287
Other sources of income	1548	4533	5877	9755
Total income	7253	8673	11550	14794

Average R$ / US$ currency in 2003 = 3.2

Given Humaitá's historical formation, in terms of social composition, and the actual stage of settlement's aging process, proportions of retired citizens within the local ex-rubber tappers group are also substantially higher when compared to the colonist farmers group, which explains the differences in income composition between these groups. All land investors have other sources of income (commerce, salaries, investments) besides the income earned from their lots. Large lots and large cattle herds lead to significant higher GAPs when compared to the other two groups.

Income differences observed by social group correspond partially to income differences observed by land use strategy (Table 4.1-b), if we consider that the subsistence/extractivism land use strategy is the most important for local farmers, and that most land investors fall within the cattle-ranching strategy (Figure 3.4). Subsistence-extractivism oriented households have annual incomes higher than households oriented toward agriculture, and cattle-ranching have the highest annual incomes, for the same reasons pointed above. However, income differences between mixed husbandry and agriculture land use strategies, and between these two strategies with subsistence/ extractivism and cattle-ranching, are related to social group categories alone. Mixed husbandry oriented households make twice as much money from the farm-lot when compared to agriculture oriented ones, which make in turn five times more money from the farm-lot when compared to subsistence/extractivism oriented ones[65]. Income derived from milk products and the selling of fish and calves tends to be substantially higher than the one derived from commercialization of agricultural products (annual and perennial crops), which accounts for most of the difference observed between mixed husbandry and agriculture.

Farmers who have been taking agricultural credit loans in the five years preceding fieldwork have on average lower annual incomes than farmers who have not been taking credit (Table 4.1-c). This is outcome follows the trend of higher credit use rates among

[65] This is far from implying extractivism is not important as a livelihood strategy. See Chapter 6 for details.

agriculture oriented farmers when compared to farmers oriented toward the other land-use strategies (Table 3.4-b), and lower annual incomes in households oriented toward agriculture (Table 4.1–b).

4.5.4 – Description of credit-users and non-credit-users

Differences in lot attributes between credit-users and non-credit-users are presented in Table 4.3. Note that credit-users have slightly larger lots than non-credit-users. This is rather surprising given the apparent relationship between cattle-ranching and larger farm-lots (Table 3.6), and between cattle-ranching and lower rates of credit acquisition (Table 3.4-b). However, credit-users falling under categories “cattle-ranchers” and “mixed husbandry” own larger lots than their non-credit-users counterparts (Figure 4.7), which helps to explain the lot area disparity observed in Table 4.3. An important point to be made is that since the unit of analysis used here is the farm-lot household, other properties belonging to the same farmer have not been included in this “lot area” measurement[66].

Non-credit-users own larger cattle herds, when compared to credit-users, which is in line with non-credit-users receiving higher income also. The largest variance in cattle herd size is observed within non-credit-user cattle-ranchers, followed by credit-user mixed husbandry oriented farmers (Figure 4.8). No apparent differences exist between both groups in relation to time-distances to urban centers, but credit-user cattle-ranchers show larger intra-group variance when compared to other groups (Figure 4.9). Non-credit users have been living a little longer in their lots when compared to credit-users, which is influenced by larger proportions of local farmers as non-credit-users, with larger intra-group variances as well

[66] In other words, the lot area variable (land area / lot) includes lot consolidation into a single property, but land concentration (land area/owner), including all lots regardless of sharing boundaries or not, is not considered here.

(Figure 4.10). No apparent differences between credit-users and non-credit-users are observed in land cover, but subsistence/extractivism oriented credit-users show clearly higher rates of forest cover (Figure 4.11) and fallow cover (4.12) when compared to other sub-groups.

Table 4.2 – Lot area, time in the lot, time-distance, herd size and land cover for credit-users and non-credit-users:

Diverse	Credit-users n = 25		Non-credit-users n = 37	
	Mean	Stdev	Mean	Stdev
Lot area (hectares)	108.7	97.1	92.3	96.6
Cattle herd size (# of cattle heads)	79.4	55.0	127.3	159.8
Time-distance (min)	104.5	123.6	106.8	94.3
Time in the lot (years)	17.4	10.1	20.6	12.3
Forest cover (%) in 2003	44.5	22.5	43.9	23.1
Fallow cover in 2003 (%)	16.8	9.6	14.8	9.2

Figure 4.7 – Lot areas by land use strategy and use of credit:

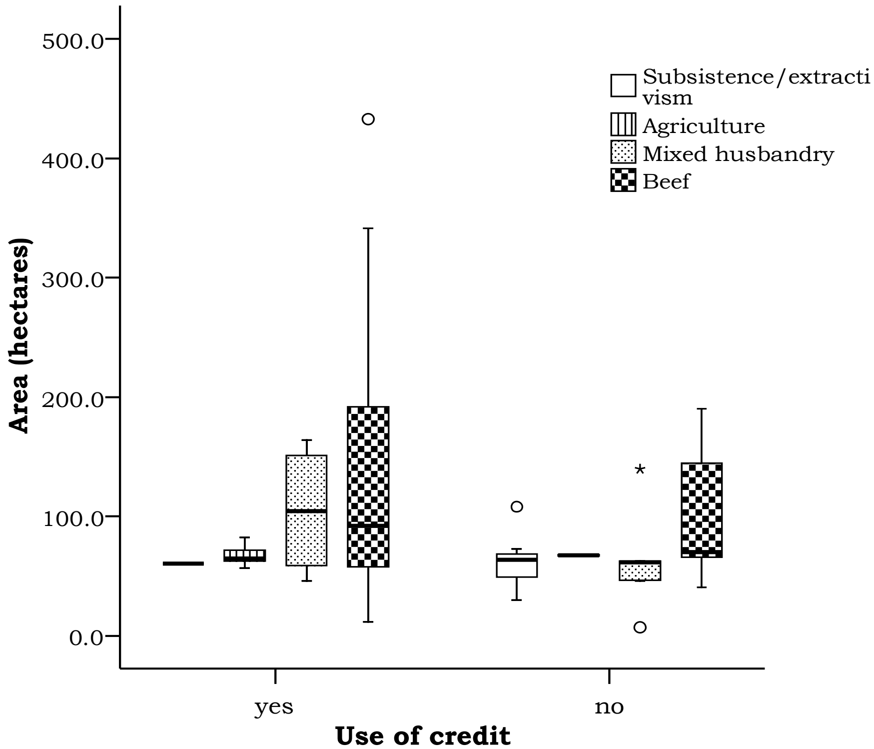


Figure 4.8 – Cattle herd size by land use strategy and use of credit:

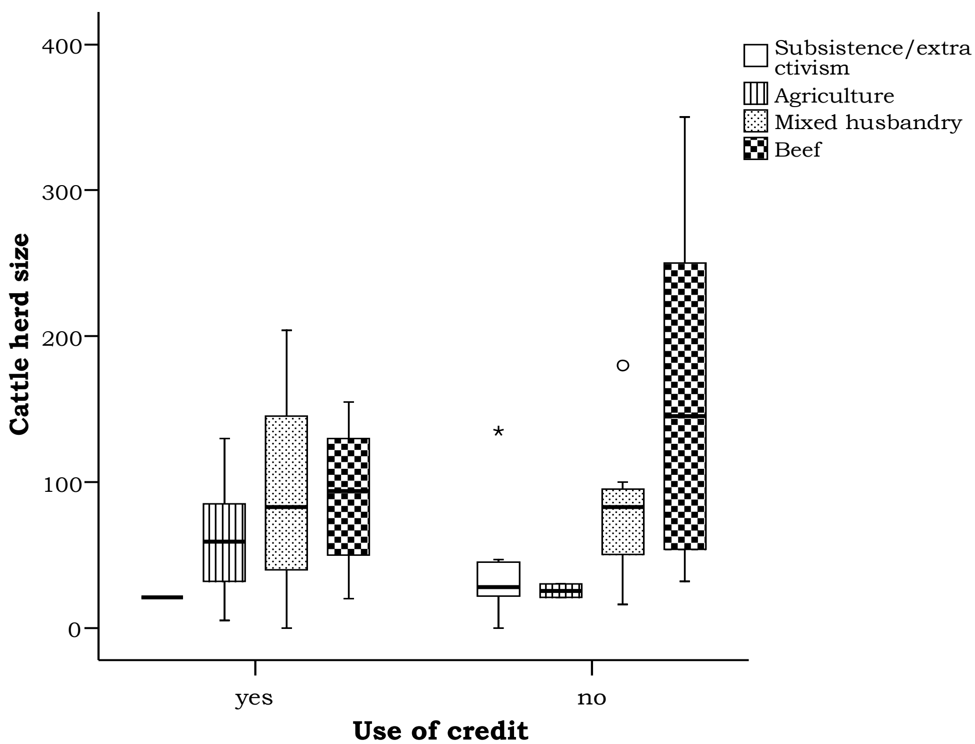


Figure 4.9 – Time-distances by land use strategy and use of credit:

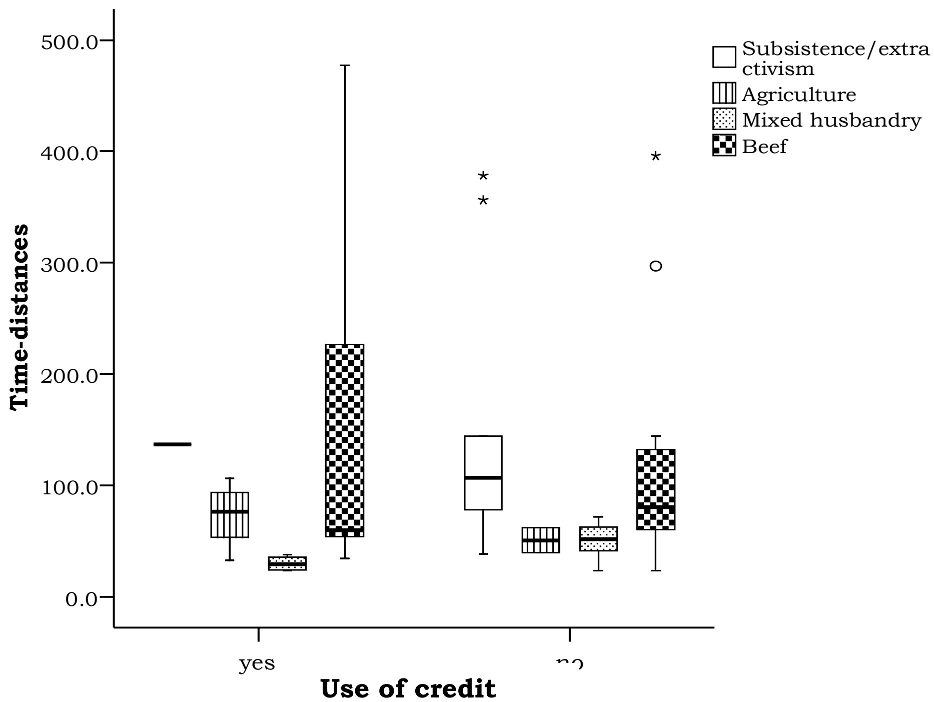


Figure 4.10 – Time living in the lot by land use strategy and use of credit:

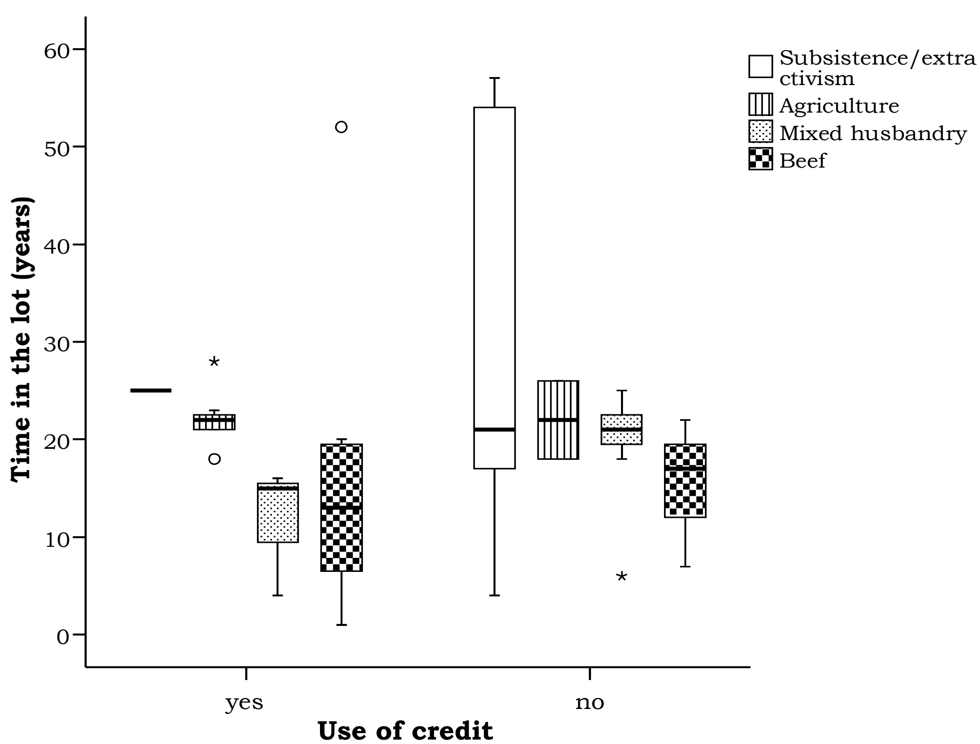


Figure 4.11 – Forest cover in 2003 by land use strategy and use of credit:

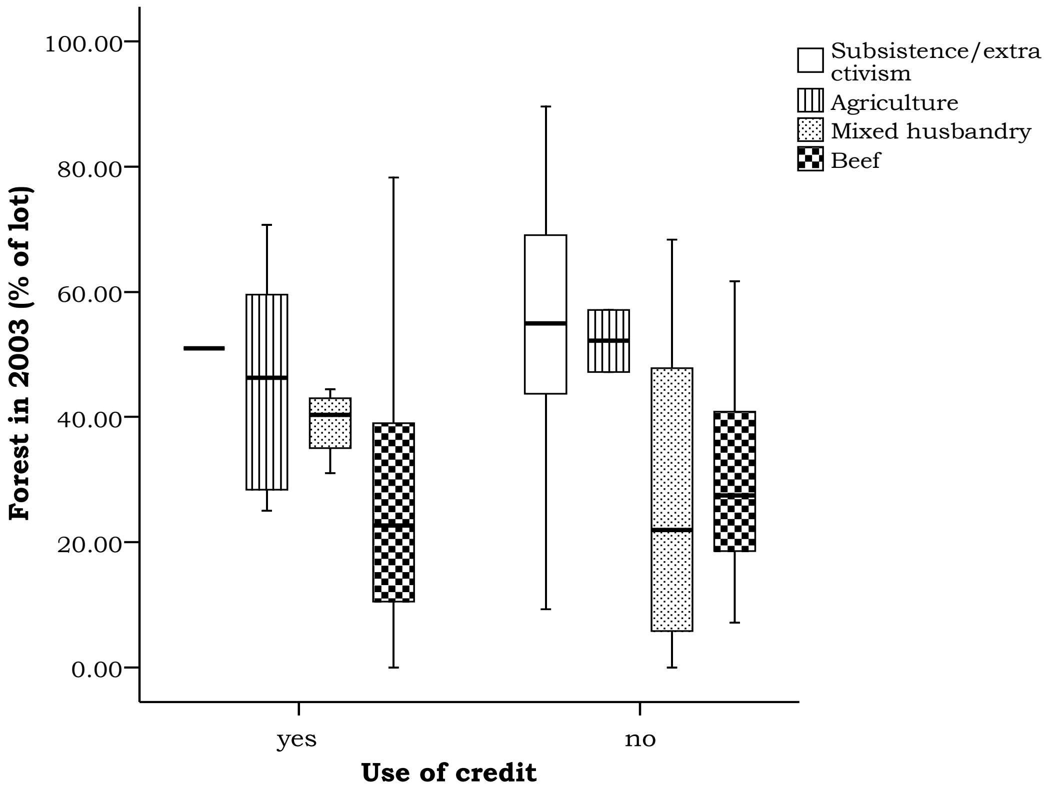
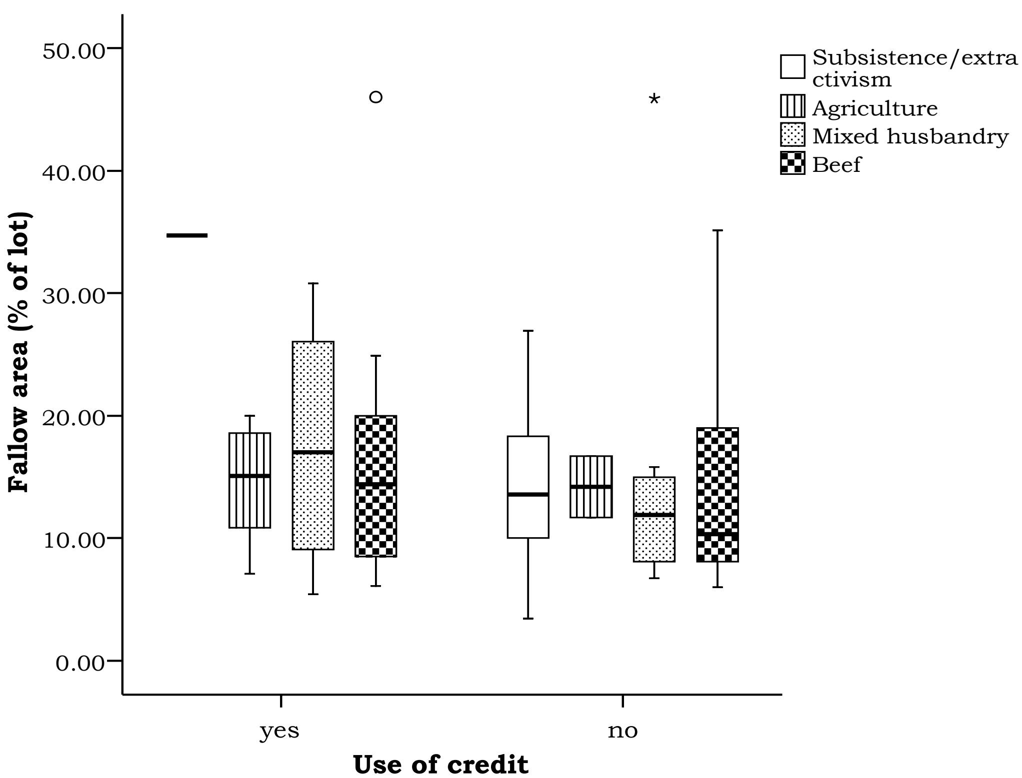


Figure 4.12 – Area under fallow by land use strategy and use of credit:



The sample does not show apparent differences in the possession of land titles between credit-users and non-credit-users (Table 4.4). This confirms the actual discourse of FNO proponents and SEATER agents on not discriminating farmers who do not possess title to land whenever credit loans are submitted to approval. Illiteracy levels are apparently higher within the non-credit-user group (Table 4.5), which is in line with the higher level of illiteracy observed within local farmers (Table 2.5), 77% of whom fall within the non-credit-user group (Table 3.4-b).

Table 4.3 – Possession of titles for credit-users and non-credit-users:

Possession of titles to land	Credit-takers (CTs)		Non-credit-takers (NCTs)	
	Freq	%	Freq	%
Titled	19	76	28	73.7
Non-titled	6	24	10	26.3
Total	25	100.0	38	100.0

Table 4.4 – Level of education for credit-users and non-credit-users:

Education	Credit-takers (CTs)		Non-credit-takers (NCTs)	
	Freq	%	Freq	%
Illiterate	1	4.0	6	15.8
Elementary	16	64.0	19	50.0
More than elementary	8	32.0	13	34.2
Total	25	100.0	38	100.0

Participation in labor unions has been a requirement for credit approval in several credit lines, and is thus clearly higher within the credit-user group (Table 4.6). Some farmer unions were created exclusively for purposes of applying for credit and did not "survive" after credit was granted. Other unions exist for a longer period and are rooted in a wider range of goals, such as enhancing negotiation power for better road conditions, schools or better commercial deals.

Table 4.5 – Participation in rural labor unions and cooperatives, for credit-takers and non-credit-takers:

Participation in labor unions or cooperatives	Credit-takers (CTs)		Non-credit-takers (NCTs)	
	Freq	%	Freq	%
Unionized	20	80.0	15	39.5
Non-unionized	5	20.0	23	60.5
Totals	25	100.0	38	100.0

4.6 - Model results and Hypothesis testing

There were no significant effects on explaining variation on credit acquisition for any explanatory variable included in the model (Table 4.7). However, the variable credit history could not be included in the model, since there were only two reported events of default in loan re-payment within the sampled households. Moreover, information on default in loan re-payment is considered sensitive and data accuracy might have been jeopardized. Hypothesis 3: "*Neither household income, level of education, land title, or credit history are significant on explaining actual credit enrollment variation across households from 1998 to 2004"* is thus accepted for three out of four explanatory variables and undetermined for credit history. The descriptive data presented shows, however, that average annual income for non-credit-users is 59% higher than for credit-users (Table 4.1-c), which points to some potential negative effect of income over the number of approved credit loans (not statistically significant though…). In the other hand, note that 42% of the total amount of financial resources put available to farmers through credit loans go to "Infra-structure + cattle-ranching" and "cattle-ranching" categories, which are typical of farmers with higher income (Figure 4.6-b). Differences on the level of education between credit-users and non-credit-users were also apparent from descriptive data on rates of illiteracy (Table 4.5). No apparent differences were observed, however, for the categories "complete elementary education" and "more than elementary education".

Table 4.6 – Binary regression model results:

Variables	B	S.E.	Wald	df	Significance	Exp (B)
Income	0.225	0.293	0.588	1	0.443	1.252
Possession of title	0.27	0.641	0.177	1	0.674	1.31
% of deforestation	-0.158	0.265	0.357	1	0.55	0.854
Education - illiterate			2.048	2	0.359	
Education - elementary	1.669	1.275	1.714	1	0.19	5.304
Education - > than elementary	0.54	0.713	0.006	1	0.939	1.056

4.7 – Agricultural credit lines influencing credit adoption

The lack of statistical significance of the explanatory variables included in the credit acquisition model might be given different interpretations. The first is that sample size limitations did not capture a potential negative effect of income over credit acquisition rates. This would be the case if we consider the following indirect relationship: FNO resources are preferentially allocated for loans focusing on annual and perennial crop projects, and agriculture as a land use strategy is associated with lower income farmers (Table 4.1-b); thus, lower income farmers focusing on annual and perennial crops would have higher chances of having their applications for agricultural credit approved. Alternatively, credit lines for annual and perennial crops offer better advantages to farmers (e.g., lower interest rates, more flexibility, less bureaucracy) when compared to credit lines for cattle-ranching and mixed husbandry, leading therefore to higher demand by farmers. My fieldwork experience leads me to believe that both mechanisms are probably important on explaining higher rates of loans allocated to annual and perennial crops within the surveyed sample, but there is more to it. Problematic experiences with inflexible credit loans (i.e. credit lines for which farmers are not allowed to choose how to manage and where to spend the money) have been driving many farmers away from agricultural credit.

A credit line designed to "incentive" the implantation of *pupunha* (peach palm) fields for heart-of-palm production might illustrate the case. With total loan limits up to US$ 9,000, grace periods of up to nine years and other seven years of re-payment period, and interest rates below the ones operating in the market, the peach palm credit line attracted the attention of several farmers in Humaitá. A group of peach palm farmers (*Grupo da pupunha*) was formed with members being granted loans for implanting monocrops of peach palms, after having all members required to join a labor union for co-liability reasons. Since agricultural background in peach palm was considered limited among farmers, proponents of the peach palm credit line and partners of agricultural research agencies established a technical protocol of peach palm including a recipe of inputs and operations to be strictly followed by the farmers. Since the projects were oriented toward heart-of-palm production, peach palm seedlings had to planted at spatial arrangements of 1 x 1 meters, and allocation of a considerable part of the budget for fertilizers, herbicides and pest control chemicals was mandatory from the onset[67]. Some farmers confessed to me they decided not to follow the

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[67] Actually, farmers had not even the choice on where to buy these inputs. A single provider was determined by the bank, who managed also to transfer financial resources from farmers' accounts straight to the provider

peach palm recipe, even after having been charged for all the chemicals (of which most were never used !), and managed to terminate the contract with the bank at some point. Others complained about the lack of technical assistance (which were also automatically charged from farmers' loan accounts) on crop implantation and management, which contributed to poor crop performance. The biggest problem, however, seemed to be the lack of processing plants for *pupunha* hearts-of-palm in Acre. By 2003, only one processing plant was operating in the State. The State government had to interfere and negotiate commercialization contracts so this firm would be buying heart-of-palm from farmers located at prohibitory distances from the plant. Farmers ended up having to share non-economical transportation costs, leading to considerable economic loss in most peach palm projects.

This example illustrates the type of agricultural credit line most farmers do not want to engage ever again. Some technical assistance agents to whom I spoke were fully aware of the problems caused by the kind of top-down approach assumed between farmers, technical assistants and bank employees implicit in credit lines such as the peach palm case. The rationale supporting this philosophy is that farmers' agricultural knowledge and decision-making capacity is limited and that farmers need therefore "help" on deciding how to manage their agricultural loans. Such paternalistic bias permeates the political discourse in several public programs of rural development in the Amazon (e.g. programs that educate farmers on how to conduct safe burns of their fallow fields – see Costa (2006) for a detailed treatment of the current political agenda on fire prevention and control). In many cases, the paternalistic discourse might be used as a mask to engage in rent seeking behavior (such as the *pupunha*

account. Such "policy" made farmers feel particularly uncomfortable about this credit line. More than that, it led many farmers to believe that bank and technical assistance employees responsible for this credit line were engaging in rent seeking behavior, especially because the prices charged by these inputs were believed to be above market values.

case or the case of certified cattle financing through agricultural credit), or as an excuse to enter and reclaim considerable shares of booming markets such as the *açaí* market (Brondizio, 2005).

Farmers, in the other hand, learn how to interpret signs and take advantage from governmental programs. There are credit lines that offer plenty of flexibility, such as most PRONAF lines for annual crops mentioned in the end of Chapter 3. Farmers benefit from such lines by often using them for alternative purposes, such as enhancing security against eventual agricultural losses, or converting forests to pastures, which is against credit rules. Electoral years are often good for negotiating road maintenance and construction of ponds, as mentioned in Chapter 2. Collective action theory and social learning might be helpful in addressing how farmers adapt to the political arena as active and self-determined actors. This will be further discussed in Chapter 7.

4.8 – Agricultural credit and deforestation in the Amazon

The regional-level contextualization shows that the overall patterns of agricultural credit availability correlate with tropical deforestation in Amazônia, for 1989–2003, supporting previous research on findings that credit is used, directly and indirectly, by small- and large-scale farmers for forest conversion to pastures. Generally speaking, years characterized by better macroeconomic conditions in Brazil, such as right after the implementation of Plano Real in 1994 and after the adoption of important economic measures in 1998, have had a positive impact on the opportunities for land-use investments, including availability of agricultural credit to farmers, and on the willingness of farmers to invest in resources for converting forest to other land-use types. However, the complexity of deforestation phenomena defies a simple causality explanation (Kaimowitz and Angelsen, 1998; Lambin *et al.*, 2001; Moran and Ostrom, 2005). We must consider that rules of credit programs change frequently, and that changes in agricultural credit policies affect farmers' land-use decision making differently, since farmers often make land-use decisions based on their perception of risk associated with enrollment in credit programs (Chibnik, 1994).

Previous research addressing land-use problems in the Amazon have revealed that regional-level analyses cannot capture the diverse mosaic of interactions regulating local-level processes (Brondízio, 2005, 2006; Brondízio *et al.*, 1994). In fact, local-level analysis does not reveal a significant relationship between credit and proportions of land covered by forest, when comparing land-use data between Humaitá farmers who obtained credit and farmers who did not. Similar outcomes were obtained after comparing deforestation rates between credit-users and non-credit-users in the Transamazon region (Ludewigs et al, under review-a). This outcome leads us to conclude that in agricultural colonization areas of established settlements (e.g. second-generation residents), credit might have no significant effect on deforestation. In both cases (Acre and Transamazon), samples were representative of a variety of mature households in a fairly mature settlement (McCracken *et al.*, 2002; Moran *et al.*, 2002). This contributes to a nuanced understanding of the development of the frontier and direct outcomes of credit policies. This would perhaps not be the case if our data were capturing an earlier phase, when families alternated expansion and consolidation of land-use activities, often driven by the need to establish the farm through clearing of forested areas during a time (1970s) when many credit programs were available for farmers to plant annual crops and selected perennials (Brondízio *et al.*, 2002).

However, it has been shown that the support provided by agricultural credit to small-scale farmers in the Transamazon was inconsistent during the last thirty years (Ludewigs et al, under review-a). Overall rates of acquisition were low, especially during the general crisis of the Brazilian economy in the 1980s when there was scarce availability of credit in the Amazon and in the country as a whole. This limited availability of agricultural credit during the 1980s did not affect the corporate cattle-ranching sector, which benefited immensely from government subsidies. However, there was little increase in agropastoral production and social integration in the region during that same period, as shown by an influential study produced by the Institute for Applied Economics Research (Gasquez and Yokomizo, 1990). Government subsidies also had disastrous environmental consequences, which have been broadly documented in the land-use literature (Fearnside, 1985; Hecht, 1985; Ozório de Almeida and Campari, 1995).

The implementation of FNO in 1989 reflected a significant change in the federal government's policy for agricultural subsidies. This led to changes in credit adoption rates among smallholders in the Transamazon area, as shown by both our data and others' (Tura and Costa, 2000). Equity issues in access to credit were not, however, immediately implemented with FNO. The social movement, led by the Federation of Agricultural Workers from the state of Pará and the Federation of Organizations for Social and Educational Assistance, had a critical role in implementing more equitable rules of access to credit, resulting in the reformed version of FNO, known as FNO Especial (Tura and Costa, 2000). Recent data (ACT's 2005 interviews) show that organized pressure by farmers' movements has influenced the type and ways credit has been distributed in recent years and will continue shaping new credit programs in the future. An example is the recent implementation of

Proambiente, a credit program initially proposed by Transamazon smallholder unions. Under *Proambiente*, interest rates are lower and loan repayment deductions are provided to farmers implementing long-term commitment to environmentally friendly agroforestry projects (FASE, 2006). *Proambiente* is being tested by the Brazilian government at pilot sites throughout the Amazon. One of these pilot sites is located in the Extractive Reserve Chico Mendes, State of Acre.

According to data obtained from BASA for 1989–2002, mini- and small-scale farmers appear to get half of the FNO resources in the Amazon, thus demonstrating that the new, equitable rules of access to agricultural credit in the Transamazon are working. However, the classification system used to categorize farmers into interest groups and size might not reflect farmers' real economic situation, which field data show at much lower levels of income. Moreover, medium- or large-scale farmers might declare a lower income to fall under the lower-sized categories of farmers, gaining access to loans at lower interest rates. It is not clear whether there are efficient monitoring mechanisms in place to control for such events. However, field data obtained for Humaitá and the Transamazon region indicate very low rates of credit acquisition among small-scale farmers, in contrast to what BASA data reveal for the whole Amazon region.

Farming in the Brazilian Amazon is considered risky. Currently, it appears that most farmers rely on cattle ranching as one of their main income-generating activities, associating it with better cost/benefit outcomes and lower levels of economic failure and/or risk. At the same time, advances in agricultural technology and growth in infrastructure networks have been promoting increases in productivity for both crops and cattle, reducing risks involved in crop production and allowing innovative land-use arrangements in some parts of the Amazon basin. As new land-use trends are being shaped, demand for agricultural credit is likely to increase.

An example of this new direction is the recent expansion of soybean fields along Central Amazônia's highways, such as along BR-163, which connects the north of Mato Grosso state to Santarém in the state of Pará, and the construction of large soybean storage plants. So far, the soybean expansion boom has been undertaken mainly by the private sector, namely by well-experienced large-scale soybean agriculturalists and ranchers from southern and central-west Brazil. These enterprises are also dependent on government subsidies through different forms of FNO credit. Expansion of these activities is based on buying smallholders' land and establishing farms in an expanding agricultural production area. Although government support has been important, financial support and incentives for soybean production have been primarily provided by favorable prices of soybean in the international market, especially during the early 2000s. However, the recent downward trend in soybean prices experienced in 2005 could lead to a reduction in the rate of soybean expansion and to considerable financial damage to important players of the agrobusiness sector. As a consequence, soybean farmers might step up their request for government help. Indiana University ACT's recent fieldwork in the Santarém region (Ludewigs et al, under review-b) found that local soybean farmers are increasingly accessing agricultural credit. This trend could lead to new disputes in the Amazonian political economy arena, with implications at national and international scales. Should soybean expansion be eligible for a larger share of government support in the form of subsidies such as low interest rates for agricultural credit? What would be the impact of such policies on regional deforestation levels, and on the displacement of families currently settled in future expansion areas?

In drawing any conclusions on this matter, we must consider the existing research on development versus conservation in Amazonia (Faminow, 1998; Nepstad *et al.*, 2002). Worldwide criticism on credit subsidies in the 1970s and 1980s had an important effect on the Brazilian government's strategies for developing the Amazon. Initial subsidy schemes were replaced by credit programs guided by social and environmental concerns. Part of this change was triggered by international funding agencies such as the World Bank, who, in the late 1980s questioned whether to continue funding Amazonian infrastructure projects that did not significantly address environmental issues. However, one of the fundamental shifts toward ensuring a more equitable distribution of agricultural credit resources, while also taking into account environmental responsibility and regional integration priorities, occurred at the domestic level through the framing of FNO in the 1988 Brazilian Constitution.

Soybean expansion might be important in bringing economic growth to Brazil's uppermost developing frontier. But so far, such development has been limited in its contribution to populations living in the region. While new jobs have been created and some regional integration has been achieved, historically, this soybean expansion process, and cattle ranching for that matter, has been connected with the displacement of countless farmers in other parts of the country and with considerable environmental damage from the conversion of millions of hectares of *cerrado* and forests.

CHAPTER 5 – LOT TURNOVER, ACCESS TO MARKETS AND LUCC: THE PROBLEM OF LAND REFORM IN ACRE AND IN BRAZIL

Lot turnover is at the core of several structural transformations in colonization areas in the Brazilian Amazon, including land distribution changes and land-use/land-cover change (LUCC). In Chapter 1, I discussed some of the factors that affect the rate of lot turnover, such as family adaptation problems (e.g., health, expectations), the lack of all-weather roads and overall supply of public services in the earlier stages of settlement development. Many families abandon their lots or sell them at lower prices to neighbor settlers or investors coming from the city, since land markets are only partially developed at this stage. As investments in infra-structure increase with settlement aging, land prices go up and settlers (who remain) are continuously facing incentives to sell their lots for better prices to newcomers (Ozório de Almeida and Campari, 1995; Alston et al, 1999). Some consequences of lot turnover include rural – urban migrations, a frequent driver of unemployment and of other social problems in cities, and migration to new agricultural frontiers, were new settlements might be later established to formalize informal land occupation.

Livelihood conditions are very difficult during early stages of settlement development. As agricultural families migrate to new colonization areas, following lifelong goals of working their own land as a pathway to prosperity, decisions on whether to stay and keep the lot or to sell it come often only after several years of endurance under the harsh conditions of the Amazon frontier. Frequently, families end up selling their lots after considerable investments have already been made, and when overall conditions of settlement development could allow household livelihood conditions to improve. The challenge and trade-offs of moving further to new colonization fronts to begin anew and go through all kinds of difficulties again is not a simple one, given the wide range of risks/uncertainties involved in the process. Many lives are put at risk, and substantial investments are left behind. From a policy perspective, the social price paid for failing land reform projects is often too high (Teófilo et al., 2003). Besides human exposure to difficult conditions and situations of land conflict, there is the issue of privatization of public land proposed initially by governments to promote social justice and agricultural development, but that has been ending with uncountable families leaving settlements and frequently with the replacement of land reform lots for corporate cattle-ranching farms. Moreover, the environmental cost paid by society is high because of the double pathway of deforestation and resource depletion (including erosion, wildlife decimation and impacts on the hydrological system) that takes place as lots consolidate into large properties: (1) at the consolidated farm and (2) at new frontiers, as a fraction of out-migrating settlers look for alternative livelihood options in new colonization fronts after selling their lots.

There are two particular relationships involving lot consolidation that compose the focus of this chapter: the first relationship addresses 'where' lot consolidation is happening, by looking into road quality and time-distances of lots to urban centers; the second relationship focuses on rates of deforestation as a consequence of consolidation processes, such as those pointed out by Campari (2002) when studying the turnover hypothesis of deforestation. Question 4 is thus formulated as:

Question (4) How do differences in access to urban centers and land-use/cover change reflect different rates of lot consolidation?

Lot turnover and consolidation processes might be approached based on the two main structural contexts conditioning their occurrence: the first takes place preferentially during the early stages of frontier development, and appears mainly as a consequence to the lack of infra-structure development. Settlers find themselves isolated from markets to commercialize their products, and are affected by the lack of access to public services. They either abandon their lots or sell them at low prices to investors. The second process happens typically during a more advanced stage of frontier development, when infra-structure improvements lead to the development of land markets. Farmers face capitalization incentives as competitive demand for land raise prices of land, allowing them also to better negotiate land prices. So, which of these two processes is more relevant on explaining actual lot consolidation status in Humaitá? This chapter addresses these issues by responding to the following hypothesis:

Hypothesis 4A (H4A) - *Lot consolidation is higher where time-distance to local urban centers is higher.*

The second relationship involving lot turnover that I will be exploring along this chapter, and that has been receiving considerable academic and political attention, addresses empirical correlations between lot consolidation and deforestation.

Hypothesis 4B (H4B) – *Deforestation rates are higher where lots are consolidated into larger properties.*

Hypothesis 4 is tested through a correlation analysis between indexes for lot consolidation and for time-distances. Lot consolidation was estimated at the farm-lot level, by estimating the number of lots owned by the owner of each lot. Farmers were asked to provide basic information on lot ownership at their neighborhood. Additional informants helped to fill gaps on lot ownership. The time-distance measurement is the same as used on

Chapter 4. The significance of the coefficient of correlation ρ was used as the outcome for **H4**.

To approach these goals, I present a background on land reform policies worldwide and some critiques focused on Latin American countries, especially Brazil. Next, I discuss the colonization process in Brazilian Amazônia, as part of the national Land Reform Program, focusing on the processes leading to lot turnover and those resulting from it. Data and methods are then briefly discussed. While presenting the results for Humaitá, I compare them to the ones obtained in Santarém and Altamira to enrich the discussion, and include some insights from incorporating land tenure issues into the correlation analysis[68]. Last, I summarize the findings and discuss how these relate to a broader policy agenda in land reform and agrarian change in Brazil and to common themes of this dissertation.

5.1 - Land reform from an historical perspective

Many different types of land reform have been implemented throughout the world. Political, socioeconomic, and biophysical factors that shape particular regions make land reform processes unique (Barraclough, 2001). While some resulted in effective changes in the agricultural sectors (e.g., Japan and Korea), others have been limited to the existent sociopolitical and institutional structures (most of Latin America) and produced only mediocre results from both redistributive and efficiency perspectives (Ranieri, 2003). Every land reform proposition, however, involves redefinition of roles and redistribution of power among political sectors in a society, and is marked by the polarization of debates.

[68] This part of the chapter builds on a comparative paper in lot turnover and LUCC in land reform areas in Acre, Santarém and Altamira, that I have been working in collaboration with Alvaro D'Antona, Eduardo Brondizio and Scott Hetrick.

Land reform and resettlement programs have been affecting human-environment interactions and economies for centuries (Sandwell, 1955). The impact of such programs on land-use and on land-cover change has long been debated, especially when participants migrate to regions they are not familiar with and use production systems not adapted to their local environment. In Indonesia, for example, unsuitable agricultural practices resulting from poorly planned resettlement programs were responsible for unprecedented deforestation and soil degradation (Whitten, 1987).

Centralized land reform programs implemented in Latin America in the last 40 to 50 years have been criticized for many reasons. According to de Janvry and Sadoulet (1989), they often lacked the political will to perform a de facto land distribution reform, and agricultural modernization policies in the 1970s and 1980s strengthened existing political and economic structures (e.g., favoring largeholders with agricultural subsidies) that prevented land reform policies from being effective. From an economic perspective, inflated costs of land purchases and redistribution have made land reform too expensive (Teófilo et al., 2003). Also, there was a lack of well-delineated agricultural production projects supported by investments in infrastructure and studies on markets and commercialization (Deininger, 1999). From an institutional standpoint, technical assistance and credit support to settled families have been offered only by governmental agencies, to the exclusion of the private sector. Such services are often doomed to ineffectiveness or nonexistence; also, excessive government control over land commercialization has inhibited the development of land markets (Deininger, 1999).

An alternative approach to government-centralized land reform programs is the negotiated, community-based land reform, implemented in some Latin American countries (including Colombia and Brazil), with the financial support of the World Bank (Deininger, 1999). Under this program, beneficiaries are trained and receive subsidized credit support to choose and purchase their own land. Municipalities are responsible for managing investment funds and for presenting productive projects, which are normally prepared by private agencies in collaboration with farmer unions.

In Brazil, land concentration dates from the colonial period, and land reform propositions have been part of government discourses for at least the last 60 years. Unequal access to land is connected to land conflict and to the emergence of social movements such as the Landless Rural Workers Movement (MST) (Comparato, 2003). While most analysts agree that something needs to be done to revert this historical inequality gap, there is much debate on what actions should be part of an effective land reform protocol. Considerable work has been done to address the philosophical and ideological issues at stake (Abramovay, 1996; Tura and Costa, 2000; Ranieri, 2003) and the socioeconomic outcomes of the existing land reform settlement projects (de Janvry and Sadoulet, 1989; Deininger, 1999; Sparovek, 2003). However, and as mentioned above, more studies addressing the linkages between land distribution and the environmental outcomes of land reform programs are needed.

5.2 - Lot turnover and deforestation in the Amazon

Brazilian policies of Amazon colonization have been heavily criticized for threatening the world's most valuable biodiversity realm (Hecht, 1985; Fearnside, 1993, 2001). Massive conversion of forests into cattle ranches was promoted by the government during the 1970s and 1980s through colonization initiatives and highly subsidized credit loans (Hecht, 1985). Colonization projects under the administration of the National

Integration Plan (PIN) aimed initially to settle up to 100,000 landless families along the Transamazon Highway. Families came mostly from the northeast, the poorest region of the country. Structural problems derived from poor planning, such as high turnover rates and implementation costs, led the government to replace PIN by colonization programs focused on the corporate cattle-ranching sector (Moran, 1981). Only 6,000 families were settled under PIN.

As frontiers develop, rents for land tend to be much higher than returns on labor, and settlers are encouraged to sell their land and move on (Ozório de Almeida and Campari, 1995). Campari (2002) believes that selling land might be the best economic option employed by many smallholders in the face of difficult conditions they experience in most Amazonian settlement projects, and he goes further to challenge the *Turnover Hypothesis of Deforestation* (THD), under which lot turnover in colonization settlements comprises the central mechanism for lot consolidation, which is followed by deforestation and frontier expansion. He argues that the frontier expansion process is much more complex than portrayed by the THD and supports his claims with data showing that consolidation of lots into large cattle ranches is frequently done by initial settlers rather than outside investors.

Deforestation is the primary mechanism of establishing informal rights to land in the Amazon frontier (Hecht, 1985; Alston *et al.*, 1999). Economic theory states that enforcement of formal property rights might be an effective way to reduce the uncertainty of returns on present investments. Schneider (1995) stresses that land titling policies in the Amazon can thus curb deforestation levels by reducing the need of land clearance as a land claim tool. Also, and according to Schneider, such policies would promote investments in agricultural production and more effective redistribution of wealth among the rural poor. Similar logic has been proposed as a fundamental development tool in Peru (de Soto, 2002) and Africa. Empirical evidence of land titling as an effective deforestation control strategy is rare and failed to materialize after Wood and Walker's (2001) detailed study in settlement projects in the Brazilian Amazon. However, one might argue that the theoretical linkage between property rights and deforestation is much more relevant in spontaneous colonization areas of the Amazon, where uncertainty over land claims is considerably higher than in settlement projects.

Several theoretical and methodological challenges remain to be addressed concerning the viability of future land reform programs. This is especially relevant if we consider that goals such as the promotion of agricultural development and the reduction of inequalities on access to land, which we understand as being important to land reform policies in Brazil, have been rarely met. From an environmental perspective, we know that forest and soil conservation are necessary for agricultural sustainability on land reform areas in the long term (Fearnside, 2001). The impact of lot turnover on deforestation in settlement projects cannot be understood through the existent models (such as the THD and the frontier expansion model proposed by Alston *et al.*, 1999), because these models have been developed in spontaneous frontier areas, where the institutional setting is different from the one existent in most INCRA-born agricultural settlements. From a socioeconomic viewpoint, neoclassical economic theory informs us that competitive farmers and efficient lot sizes are "naturally selected" by market forces. Empirical findings from agricultural frontiers point, however, to other factors, such as distribution of power and unfavorable institutional settings, being the determinants of land redistributive outcomes (mainly the reproduction of the inequality gap previously existent; see Borras, 2003, for a more detailed discussion of this topic). An alternative approach incorporating microlevel analysis, such as the HLT, might be able to contribute to a better understanding of the variables that determine changes in land-cover and in the agrarian structure of settlements, especially if integrative methods are included as part of research protocol.

5.3 – Data and methods

The analysis presented in this chapter uses land-cover data presented on Chapter 2, time-distance data presented on Chapter 4, and lot consolidation data from the field survey. Lot consolidation was estimated by asking farmers about lot ownership information for the entire settlement. This allowed me to update INCRA's property grid, from which total lot area was calculated (n = 739 lots).

The Gini[69] index is used as a measurement of changes in land distribution. *Gini* indexes of land concentration and lot fragmentation were obtained through an online *Gini* index calculator (Wessa, 2006), and were based on total land area by owner. Results were cross-checked according to the following formula:

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|x_i - x_j\right|}{2n^2\overline{x}} \qquad [1]$$

5.4 – Lot turnover and land distribution in P.C. Humaitá

Lot turnover rates in Humaitá are estimated as 65.1%, based on my survey sample, meaning 34.9 % of the owners were originally settled by INCRA, and the rest bought the land from previous settlers. These data show an active land market in the region. I do not

[69] The *Gini* index was originally conceived as a measurement of income equity, where the minimum value of zero (0) corresponds to a society with a perfectly equal distribution of wealth, whereas the maximum value of one (1) corresponds to all wealth owned by a single individual. The *Gini* index might also be used to assess equity in land distribution, as in the case mentioned in the text.

know how many times each lot was subjected to sale after the first turnover. Lot turnover was found to be also high in Altamira and Santarém, with rates of 76.3% and 74.2%, respectively (Ludewigs et al, under review). Higher rates were expected since these settlements were established more than a decade before Humaitá. Even with high lot turnover rates, most properties in P.C. Humaitá are still composed by a single lot (71.1%), while 11.3% of the properties result from fragmented lots (Table 5.1). Older settlement areas such as Altamira and Santarém show both higher rates of lot consolidation, with a larger proportion of properties composed by 2 lots and properties composed by more than 2 lots. While consolidation of lots is connected to cattle-ranching in Altamira, in Santarém it has been driven by the increased demand for land to expand soybean area plantation.

Lot fragmentation has been occurring at higher frequencies in the proximity of both Vila do V and Vila do Incra villages; lot fragmentation is also related to second-generation dynamics that develop as settlements mature (land is shared within members of the same family). Land fragmentation rates observed in older settlement areas might be much higher than the ones observed in Humaitá, as in Santarém, where 28% of the properties are fragmented.

Table 5.1 – Land distribution in Humaitá – number of lots/owner:

Land distribution in Humaitá (n = 739)	Fragmented	One lot	2 lots	More than 2 lots
Percent of properties	11.3	71.1	8.2	9.4

Several land investors in Humaitá buy lots located in a different areas (not sharing boundaries with each other), instead of consolidating lots into a single larger property. I refer to this process as land concentration. Lot concentration is thus a measurement of the number of original INCRA lots per owner, instead of number of lots per property. For instance, average property size in Humaitá is 83 hectares, and the average land area per owner is 85 hectares. Table 5.2 shows land distribution in Humaitá based on land concentration. Land concentration as estimated in 1997 (by Meireles, 1998) is also included in the table for comparison purposes. Note that while the proportion of one lot owners decreased by 14.5% during the studied period, two-lot owners increased by 6.4% and more than two-lot owners increased by some 8%. Owners of fragmented lots were excluded from this analysis, because of the difficulty of estimation. Figure 5.1-a and b gives an idea on the spatial patterns of land concentration in Humaitá[70]. Note the increase in more-than-three lot owners during the 1997-2004 period.

Figures 5.2 - a and b show proportions of land areas for each land concentration category. Note that proportions of land area across categories of land concentration changed substantially from 1997 to 2004. While some 70% of total settlement area was owned by single land owners in 1997, this proportion dropped to less than 50 % in 2004. Note also, however, that the 1997 figure does not include the "fragmented lots" category, due to data limitations.

Table 5.2 – Land distribution in Humaitá – percent of land owners of different categories:

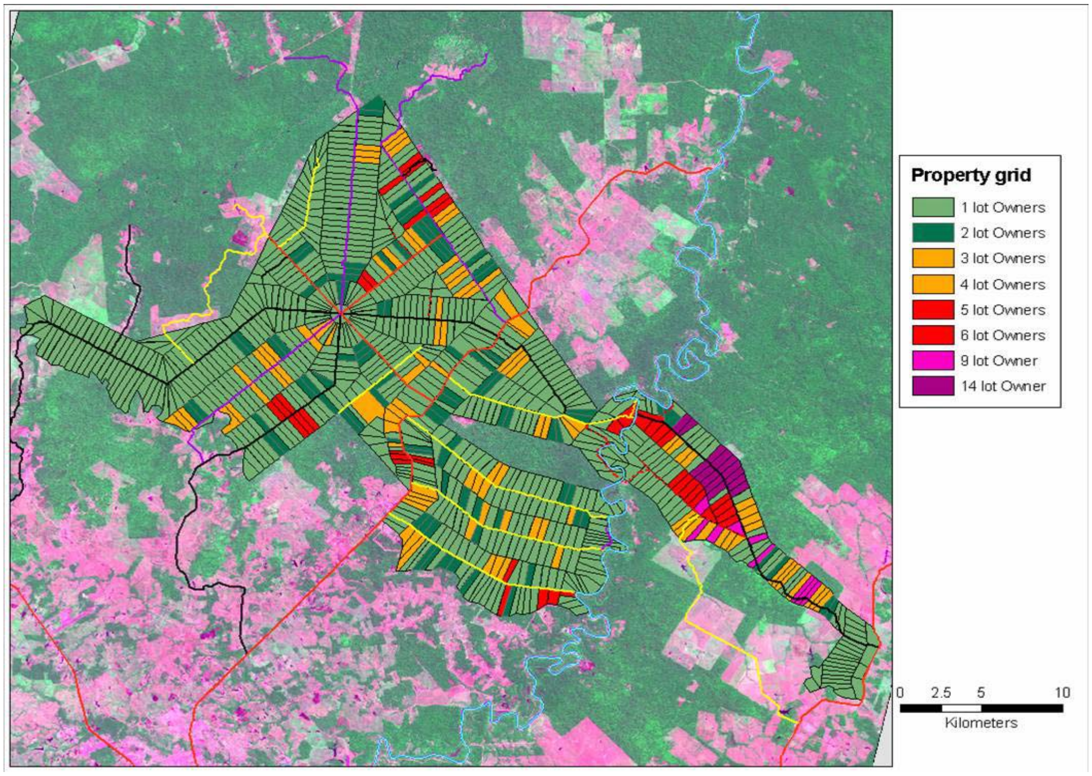
Land distribution in Humaitá (number of land owners)	One lot owners	2 lot owners	3 and 4 lot owners	≥5 lot owners	Total
Percent in 1997 (n = 764)*	88.4	6.8	3.5	1.3	100
Percent in 2004 (n = 574)*	73.9	13.2	8.9	4	100

* Does not include the number of owners of fragmented lots, which could not be estimated

[70] Spatial location of lots was changed for confidentiality purposes.

Figure 5.1 – a and b: Lot concentration in P.C. Humaitá in 1997 and in 2004 (spatial location of lots was changed for confidentiality purposes – proportionally by location along roads):

a)



b)

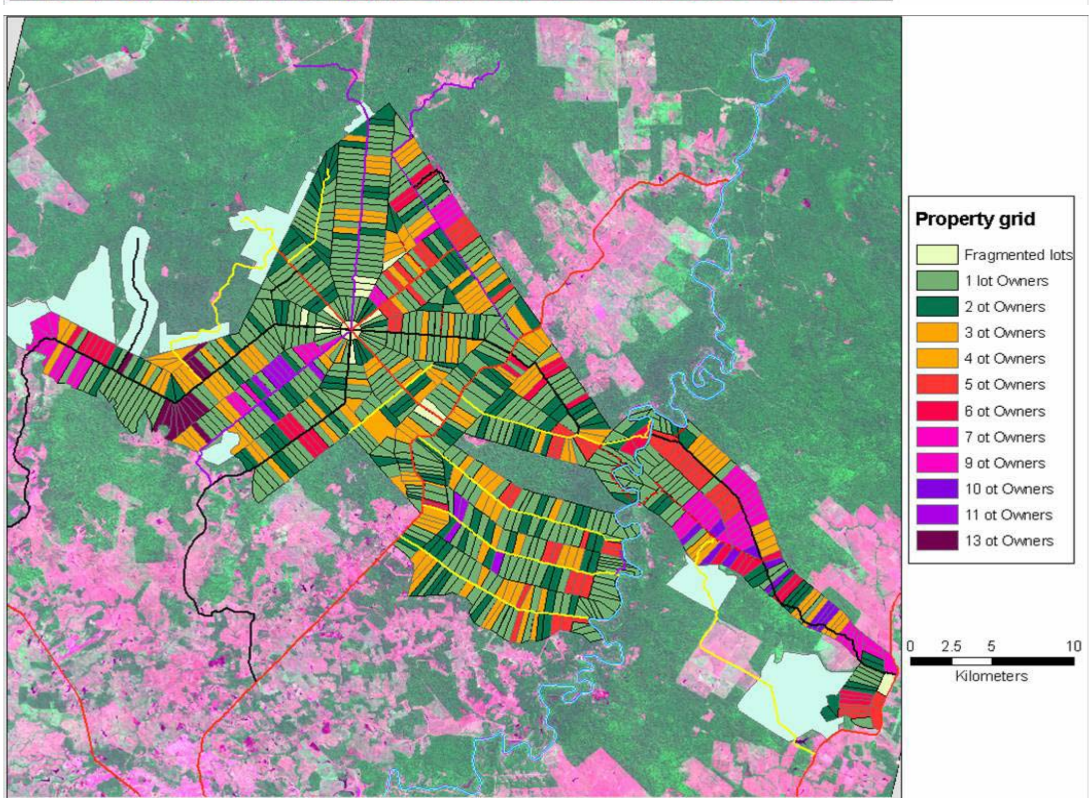
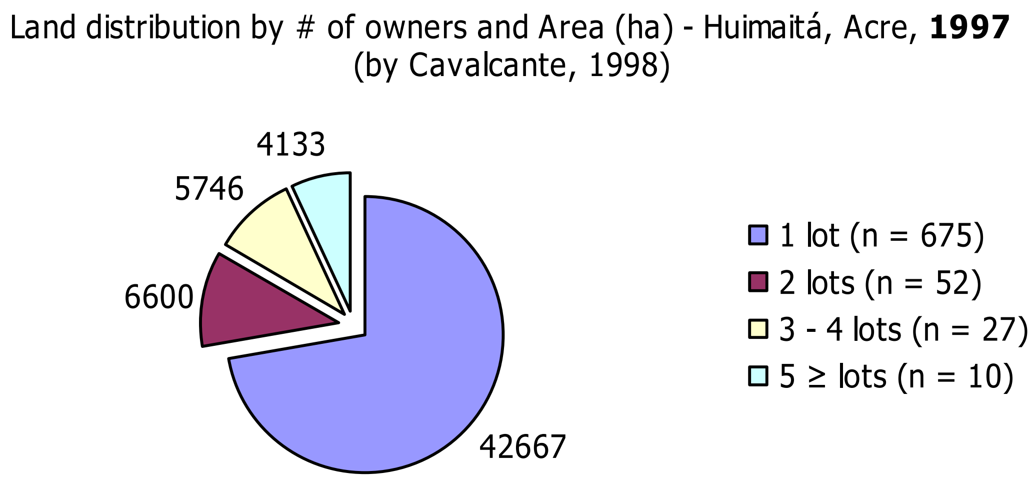
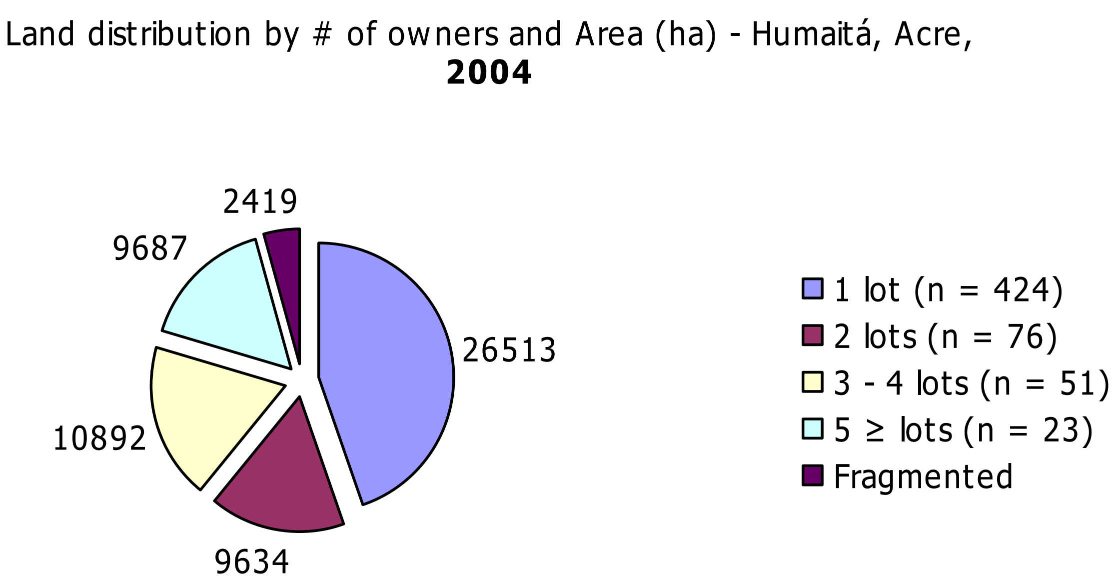


Figure 5.2 - a and b – Land distribution in P.C. Humaitá in 1997 (estimated by Cavalcante, 1998) and in 2004, by amount of land per category of owner (hectares/ category):

a)



b)



A third measurement of land distribution in Humaitá is shown by variations in *Gini* indexes from the establishment of settlements through fieldwork in 2003/2004 (Table 5.3). It shows growing rates of lot concentration since settlement formation, about three times larger in 2003/2004 than by 1981. Similarly to Humaitá, our research in Santarém and in Altamira shows that *Gini* indexes in Altamira increased almost fourfold between 1970 and 2005. Santarém also shows a continuous increase in land concentration. However, the range between smallholders and largeholders was already high by settlement regularization in the early 1970s (Ludewigs et al, under review).

Table 5.3 - Land distribution dynamics in P.C. Humaitá:

	Original INCRA settlement			Survey (2003/2004)			
	Average area per owner (ha)	St. dev.	*Gini*	Average area per owner (ha)	St dev	Gini	*D Gini*
Humaitá	63.5	15.3	0.12	93.8	91.6	0.39	0.27

5.5 – Hypothesis testing: Relationships between time-distances, area lot consolidation, and land-cover

Spearman's correlations between time-distances, total land area (proxy for lot consolidation) and land-cover are shown in Table 5.4. Note a highly significant positive correlation between time-distances and total land area ($p < 0.01$), showing higher rates of lot consolidation occurring at further distances of lots to urban centers. This result leads to the **acceptance** of Hypothesis 4A - *Lot consolidation is higher where time-distances to local urban centers are higher,* which confirms also that the von Thünen model is relevant to explain land-use allocation in the study area.

Table 5.4 – Spearman's correlations among time-distances, total land area, and land-cover (n = 739):

Percent of lot	Time-distances (minutes)	Total land area (hectares)	Deforestation in 1975
Forest in 2003	.391**	0.38	0.129**
Secondary Succession in 2003	-0.94*	-0.50	-0.114**
Pasture in 2003	-0.401**	-0.005	-0.118**
Deforestation in 1975	0.133**	0.078*	1
Time-distances	1	0.192**	0.133**

Note: * - significant at p< .05; ** - significant at p< .01

Time-distance is also correlated with all LUCC categories included in the analysis. Positive correlations are found between time-distance and forest cover in 2003 (as distances from lots to urban centers increase, so do proportions in forest cover at the lot level), and with rates of deforestation in 1975, and negative correlations are found between time-distance and both rates of secondary succession and pasture in 2003.

Besides a weak positive correlation between deforestation rates in 1975 and total land area, no other significant relationship was found between total land area (used in this analysis as a proxy to lot consolidation) and proportions of land-cover types across lots, including forest cover in 2003. This result leads me to **reject** Hypothesis 4B (H4B) – *Deforestation rates are higher where lots are consolidated into larger properties.* In the discussion section, I explore the implications of the results obtained for Hypothesis testing H4A and H4B.

Note also a significant positive correlation between deforestation rates in 1975 and forest cover in 2003. Given that spatial distribution of deforestation rates in 1975 was almost entirely limited to lots owned by local ex-rubber tapers (others arrived only after land reform implementation by INCRA in 1981), these results mean that local ex-rubber tapers observed at the whole settlement level (and not only in the 63 sample size) maintain a *de facto* different land-use allocation portfolio, at least in relation to conservation of forested land, when compared to the colonist farmers and land investors. Thus, a revisit to Hypothesis 1, which was rejected on the basis of lack of statistical differences between land-cover rates among the three social groups, leads me to counter-argument with settlement-level data which indicate that some differences in land-cover rates might exist indeed, at least in relation to conservation of forest cover.

5.6 - Land tenure, land-use and agrarian structure in Humaitá, Santarém and Altamira

This section compares land tenure, land-use and changes in the agrarian structure across Humaitá, Santarém, and Altamira. The objective is to illustrate variation across different settlement projects in the Amazon. I start by first describing the general pattern of land tenure arrangements adopted by INCRA for colonization projects in Brazil. Next, I present the distribution of titled land among households of the combined Humaitá, Santarém and Altamira datasets, followed by a brief description on land-use in these sites. Then, I discuss the relationship between possession of titles, land-use, and land distribution. These findings are then used to discuss the roles of markets (for both land and agropastoral products) and institutions in determining changes in the settlements' agrarian structure.

5.6.1 - Land tenure arrangements in settlement projects across the Amazon

Brazil's Land Statute (Law 4330 of 30 November 1964) is the legal framework within which agrarian reform programs in these areas have operated. Under this law, INCRA expropriates *latifundios* (landholdings larger than 10,000 ha) and redistributes them among landless families. Most of the settlement projects in Amazônia, however, are colonization projects on public lands. Requirements for landless families to participate in land reform programs have varied over time, but generally involve proof of low income and not having benefited from previous programs. Enforcement of the latter condition has been questionable (Fearnside, 2001), but there are signs that due to implementation of the new SIPRA (Land Reform Information Processing System) database this rule is finally being enforced (per. comm. from INCRA's Rio Branco office).

Lots in government-sponsored settlement projects are granted to settlers under favorable conditions, which have varied considerably through time and region. INCRA beneficiaries in my study area, for example, have not paid anything for their lots. In southern Pará State, however, and according to Fearnside (2001), lots were sold in the 1980s through subsidized loans with interest rates of around 6% (well under the inflation rate at that time) and a five-year grace period. Farm families are initially granted use rights by INCRA to lots averaging 100 ha (1970s' settlements) or 50–60 ha (1980s' settlements). Integral property rights to land are earned only after land titles are issued, which takes place normally after 7–10 years of settlement. Cadastral costs, however, are high, and land registration might not be affordable to INCRA. Commercialization of untitled land is prohibited by law, but is de facto active and dynamic.

Possession of titles in Humaitá by social groups is presented on Table 5.5. Note that local ex-rubber tapper farmers, who have been living longer in their lots when compared to farmers of the two other groups, hold titles to land in their own name more frequently than colonist farmers, and two times more frequently than land investors. On the other hand, land investors are associated to higher frequencies of titled land in name of others, which includes previous owners and relatives other than the spouse[71]. Note that while commercialization of

[71] Land buyers register lot acquisition frequently in the name of relatives to avoid paying taxes and for other fiscal/legal reasons.

untitled land is illegal, an informal market of untitled land is clearly established in Acre and elsewhere in the Amazon. Overall rates of titled land are higher in Humaitá when compared to Santarém and Altamira, where rates of 46% and 66% are found, respectively (Table 5.6). Other documentation of land includes receipts of purchase by previous owners, tax receipts, INCRA's "use authorization" and other forms of personal and public documentation.

Table 5.5 – Possession of land titles according to social group in P.C. Humaitá:

Possession of land titles	Local farmers (n=13)		Colonist farmers (n=37)		Land investors (n=13)	
	Frequency	%	Frequency	%	Frequency	%
Title in farmers' name	12	92.3	29	78.4	6	46.2
Title in the name of others	1	7.7	6	16.2	5	38.5
No title	0	0	2	5.4	2	15.4

Table 5.6 - Possession of titles in P.C. Humaitá, Santarém and in Altamira (% of cases)

Site	Possession of title		
	Title	Title in name of other person(s)	No title or other documentation
Humaitá	74.6	19.0	6.3
Santarém	45.8	7.4	46.8
Altamira	66.3	3.6	30.1

5.6.2 – Comparing Land-use in Humaitá to the regions of Santarém and in Altamira

I will start this section by presenting a brief revision on main land-use types observed in Humaitá, to facilitate comparison with Santarém and Altamira. P.C. Humaitá shows the highest shares of land devoted to pasture, which is present in 95% of the properties. Smallhold farmers raise cattle for both dairy and beef purposes, while largehold farmers concentrate on beef. Forty-eight percent of the Humaitá sample cultivates annual crops and 42% cultivate perennials.

Santarém shows the highest percentages of land under secondary regrowth, which is probably related to being the oldest area of occupation among the three areas, and where shifting cultivation is more important as a livelihood strategy, when compared to the other two sites. Annual crops are present in 77% of the sampled farms, and perennial agriculture is found in 36%. Cattle ranching is practiced by 46% of the farmers. Lower rates of cattle ranching, when compared to the other two sites, are probably related to the scarce water availability in most of the Santarém site. Smallhold farmers concentrate in manioc, rice and beans as cash crops, and largehold farmers focus mostly on cattle ranching and soybean agriculture.

Altamira presents the highest proportions of land devoted to perennial crops (mostly cacao, coffee and pepper), which are present on 72% of the farms. This is related to the higher percentages of fertile soils present in Altamira, and to several programs for promotion of crops such as cocoa and black pepper. Annual crops, mostly corn, manioc and rice are present in 53% of the farms. Cattle-ranching is practiced by 95% of the farmers in Altamira, with rates of land devoted to pasture varying directly with farm size.

5.6.3 – Comparing Land titles, land-use, and land distribution among Humaita, Santarem, and Altamira

The land tenure structure in Santarém shows most smallhold families with no official titles to their lands, while secondary sources point to the opposite condition among largeholders. This absence of legally recognized property rights among smallholders is believed to be a major condition facilitating lot purchase and consolidation by soybean farmers, who are typically associated with lower transaction costs of "acquiring" title to irregularly purchased land. Such a picture reveals a rule rather than an exception in Amazônia, and has been extensively depicted elsewhere (Ozório de Almeida and Campari, 1995; Alston *et al.*, 1999). Thus, land ownership, defined as land legally titled, has been found to be correlated to property size in both Santarém and Altamira.[72] In Humaitá, however, the data show an opposite relationship, with smallholders being more likely to hold titles to land. A possible explanation lies in a differential response in Humaitá to untitled land commercialization restrictions. This law is, however, hardly enforced, given that a large portion of the settling families suffer from poor infrastructure and overall living conditions, and want to leave before titling services begin to be offered. Local government agents tend to allow untitled land purchases, given that the state itself is hardly effective in keeping up with its responsibilities and promises of maintaining reasonable road conditions and supply of public services. Thus, land buyers in Humaitá might not care too much about owning titles to their land, if the unwritten norm says titles are not necessary for sales. Title emission for irregularly purchased lots also might be more expensive in Humaitá than in the other two sites. Another explanation lies, however, in the limited sample size for Humaitá, which also shows the highest percentage in titled land.

Titled possession of land is positively correlated to deforestation in Altamira, reflecting results found in nearby Uruará settlement (Wood and Walker, 2001). This contradicts the previous widespread assumption that possession of property rights is helpful to control deforestation (Alston *et al.*, 1999). However, as noted above, this assumption seems more relevant for spontaneous frontier colonization than for settlement projects.

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[72] Pearson correlation p values $< .05$ are "correlated" and p values $< .01$ are "highly correlated"

5.6.4 – Comparing Markets, Institutions, and Agrarian Structure among Humaita, Santarem, and Altamira

Land concentration has been occurring intensively in all three sites but is associated with different processes. In Santarém, soybean farmers have been attracted to the region due to improvements in infrastructure and good agricultural conditions for soybean plantations. Land valorization followed immediately, as well as land consolidation into large soybean farms, regardless of proximity to the main paved road. Yet in Humaitá and Altamira, it was observed that the main driving force of land concentration is the increasing demand for pasture land due to increases in herd sizes. Such a trend raises land prices,[73] creating incentives for settlers to sell their lots. Also, earlier attempts of the local government to make Humaitá the bread basket for Rio Branco, the local urban center, failed. Most farmers we interviewed identified the lack of infrastructure (roads, energy) and public services (schools, health centers) and the discontinuity of agricultural programs (credit and commercialization) as the main problems affecting their livelihood and success in the settlement. As a result, several farmers went bankrupt and sold their lots to urban-based cattle-ranching entrepreneurs. While some agriculture still remains, most cropland was transformed into pasture. Altamira has the best soils of all three sites. In the past, land allocation to cacao and annual agriculture was higher. Fluctuating prices for these crops led, however, to massive conversion of agricultural land to pasture, regardless of soil quality (Moran *et al.*, 2002). Additionally, field data show that many cacao and coffee producers in Altamira went

[73] While prices for pasture land rise as demand for pasture increases, forested land prices might not be affected. In Humaitá, for example, where recent enforcement of deforestation restrictions by the Environmental Protection Agency of Brazil have been somewhat effective on limiting local deforestation rates, we observed prices for deforested land up to seven times higher than for forested land.

bankrupt during the 1998–2002 price crises of these crops, which might have forced them to sell their lots.

Agricultural lots neighboring local villages experienced intensive fragmentation into smaller parcels, which contributed to the urbanization process observed in all three sites. Some lot fragmentation occurs, however, outside the villages, and is associated with intrafamily property divisions as newer generations take control over land decisions, especially in Santarém and Altamira. Major proportions of original and second-generation settlers are found, however, to have migrated to local urban centers or to neighboring settlements. Other families remained on their lots and were able to buy lots from neighbors to consolidate into larger properties; some maintain productivity of their lots but prefer to live in the local villages, which offer most public services and locally valued small businesses. The villages of Humaitá also attract significant migration from Rio Branco, since they provide some alleviation of that city's problems, such as violence, water supply, and noise pollution.

Implications of results from comparative analysis to the land reform program in the Amazon and in Brazil are presented in Chapter 7 – Conclusions.

5.7 – Discussion on Hypothesis 4A and 4B

5.7.1 - Hypothesis 4A: Lot turnover and time-distance

It was stated in the introductory section of this chapter that there are two main reaction chains, or processes, that might lead to lot turnover and to lot consolidation. The first process takes place during the early stages of frontier development, and responds to conditions of lack of infra-structure, more specifically to poor road conditions. The second process happens during a more advanced stage of frontier development, when land markets are already developed. Farmers face capitalization incentives as competitive demand for land raises land prices. The question proposed then is "Which of these two processes is more relevant on explaining lot consolidation rates in P.C. Humaitá study area? The analysis conduced in this Chapter leads to the conclusion that the first process, which has been taking place in remote areas of the settlement is more important on explaining the actual consolidation pattern being observed. However, given that much of the land ownership structure observed during fieldwork in these areas reflects a process that started during the earlier stages of the settlement, it cannot be implied from this analysis that the pattern of lot consolidation reflects a settlement in its early stages of frontier development. It points instead to the heterogeneity in infra-structure conditions that is present within Humaitá. These internal differences are not static. While some historically problematic roads remain non-passable during the rainy season, others are repaired and maintained temporarily under better conditions. The amount of time under which roads remain in good conditions is shaped by several factors. First, it depends on the quality of the service of road repair (if gravel stones (locally known as *piçarra*) have been used and how much of it, on the type of machinery used, etc…). Second, it depends on the intensity of the traffic of heavy log trucks. Log trucks have been causing considerable damage on local roads, as for example in Paulistas, which connects Humaitá to Tocantins settlement project, where intensive logging activity has been taking place in the past years. Third, it depends also on relief, soil type and on the drainage conditions of each road. Bujari road is one of the worst roads during the rainy season particularly because of poor drainage. Fourth, and as important as the above, it depends on the political organization and power of different groups of farmers and their pressure for road services.

Some parts of Humaitá settlement are virtually non-accessible during the rainy season. Agricultural families living in these areas have been facing uncountable challenges to make a living out of their agricultural lots and to survive during extreme events such as disease (including malaria and other tropical illnesses) and accidents (snake bites, work accidents among others). Many families either abandoned their lots or sold them for 'banana' prices during initial stages of settlement. Today, according to most farmers, road conditions are much better than 10 or 20 years ago, but some roads are still non-passable during most of the rainy season. The highest rates of lot consolidation were observed along problematic roads such as Bujari, Paulistas and the roads of Gleba G, which is the 'arm' of Humaitá across the southeast side of the river. Land investors have been taking advantage of settling families willing to leave these areas and have been often acquiring lots when no land markets had been developed. Hence, problematic road quality reflected on higher measurements of time-distances is clearly associated with higher rates of lot consolidation. On the other hand, lots better served by road conditions show much higher land values, which creates incentives to farmers to capitalize from selling them, and high rates of lot turnover have been observed in these areas as well. In these cases, however, other competitive land-use options attract a larger number of potential buyers, which makes lot consolidation into a single larger property much more difficult than in remote areas.

5.7.2 - Hypothesis 4B: lot consolidation and land-cover change

There are no indications, from the correlation analysis conducted in this chapter, that rates of lot consolidation, expressed by lot area, might be statistically correlated to rates of deforestation at the farm-lot level, which led me to **reject** Hypothesis 4B (H4B) – *Deforestation rates are higher where lots are consolidated into larger properties.*

This analysis used a sample size of n = 739, which corresponds to all properties contained within the Humaitá settlement. The statistical method used in the correlation analysis is the Spearman's rho index of correlation, which is a non-parametric test. Before, I used Pearson's index to test for correlations between lot area and deforestation, and the outcomes were statistically significant. But after scatter-plotting the data, however, I noticed that no linear relationship between both variables (deforestation and lot area) seemed apparent and that Pearson's index could thus not be used. Spearman's *rho* correlation index, as a non-parametric test, is more appropriate to test for statistical correlation when no linear relationship is present among the variables (Joe and Joe, 1997).

The potential relationship explored into detail by Campari in "Challenging the Turnover Deforestation Hypothesis" (2002), which states that lot turnover followed by out-migration to new frontiers and by lot consolidation into large properties in the older frontier, is a primary mechanism of explaining deforestation in the Amazon, could not be observed from the analysis I conducted on this chapter. My approach to test the Turnover Hypothesis of Deforestation is, however, only capture part of the process since I did not study rates of deforestation promoted by out-migrating Humaitá settlers in neighbor frontier settlements, such as Tocantins. Also, by using proportions of deforested land in the lot as the variable used in the correlation analysis, I might be overlooking part of the lot consolidation effect on the rates of deforestation observed in Humaitá.

Fieldwork experience and results from Chapter 2 show that while land investors buy land to consolidate lots into larger properties, often big cattle-ranches, medium and small farmers also use cattle-ranching or mixed husbandry systems with a strong (and pasture dependent) dairy component, which does also require significant conversion of forest to pastures[74]. Thus, I conclude that while lot turnover and its most frequently associated outcome, which is lot consolidation, have been connected to large-scale forest conversion to pasture in Humaitá, small farmers oriented mainly to cattle-ranching and mixed husbandry have been also clearing substantial forest land to pastures. Moreover, lot turnover rates of 65.1% in Humaitá, as pointed out earlier, and 71.1% of Humaitá's properties being composed by single lots, tells us that substantial rates of lot turnover has been occurring in single lot properties (in opposition to consolidated properties). The lot-turnover effect by itself is probably a factor that might lead to higher conversion of forests to pasture, independently of being connected to lot consolidation or not. This would be the case if we consider, for example, that newcomers are not liable for deforestation events practiced by his/hers antecessors, and could thus obtain licenses to clear extra land in their recently acquired lot, with higher chances of success when compared to farmers who have been living in their lots for longer periods.

Despite failures and problems, land redistribution and regularization is an historical need in Brazil and in the Amazon, and should continue to be a policy priority. There have been enough experiences in the Amazon to inform better governance approaches to promote the development of colonization settlements and rural development. This chapter points to the

[74] Other factor to be considered is that if I had used land concentration (instead of land consolidation) as the variable to be correlated with proportions of deforestation per lot, different results would be probably obtained, since a considerable proportion of lots considered as "one-lot property" at the property level of analysis (under which the correlation analysis was conducted), are in fact part of the wealth of a larger land owner that was not able to concentrate his/her investments on land on buying lots that are contiguous to each other.

importance of considering the role of land market during different stages of settlement formation and infrastructure quality as forces undermining the goals of land reform in the region.

CHAPTER 6 – LAND-USE OPTIONS AND LIVELIHOOD STRATEGIES ALONG SETTLEMENT AGING

The arrival of settlers from several parts of Brazil to the Transamazon colonization scheme in the early 1970s has been marked by rich patterns of social interactions among newcomers and between them and native *caboclo* peoples, a process explored in detail by Moran's 'Developing the Amazon' (1981), and his recent studies as well. As opportunities and challenges of the new agricultural frontier were being vividly experienced in almost every aspect of everyday life, migrant settlers have learned important adaptive strategies from local culture. From fishing and hunting to selection of optimal sites for agriculture; from knowledge of herbal medicine against malaria and other diseases to detailed knowledge about nutrition and processing of native foods and crops; and from the fabrication of tools to architectural technologies adapted to the humid heat incorporation of *caboclo* knowledge might have entailed the difference between survival and death for many colonist families. According to Moran (1981), detailed knowledge on local ecosystem conditions was responsible for more effective economic performance of *caboclo* households, when compared to colonist families, including higher crop yields, better nutrition standards, housing arrangements better adapted to the heat and humidity of the Amazon climate, and less dependence on INCRA personnel. Perhaps more important theoretically, it was observed that families with more flexibility to engage in a diversified set of economic alternatives, were also the families with higher chances of hiring external labor and owning businesses, and more likely to succeed economically in the frontier. Subsistence and specialized farmers, however, were found to be the ones with higher chances of abandoning their lots and moving either to the local urban center (Altamira, in Moran's study), or further into the frontier.

Diversification of land-use activities might be constrained by the environment, as for example the availability of fertile soils, as observed in a more recent study in the same Altamira site (Moran et al, 2002). Also, studies on household and land-use relationships showed that demographic characteristics of households, such as composition and size were important on conditioning the range of land-use options and investments that were feasible at different stages of farm-lot development (McCracken et al, 1998; Brondizio et al, 2002). For instance, larger households with more individuals engaged on production activities allow for a wider scope on potential land-use options to be explored, when compared to smaller households. Household life cycles and land-use combinations have been also studied in other fronts of the Transamazon colonization scheme, such as in the Uruará region, by incorporating market forces and decision-making under risk in the discussion of possible LUCC scenarios (Walker et al, 2002). Yet in an agricultural frontier in the Ecuadorian Amazon, technology adoption determinants, market forces and agricultural background of different households were combined in the study of land-use and land-cover change from which diversification on livelihood options emerged again as an important strategy to cope with the challenges and uncertainties typical of frontier contexts (Pichón et al, 2002). The following question investigates land-use and economic change along with aging of the Humaitá settlement:

Question (5) *What kinds of economic systems (e.g. land-use, fisheries, off-farm employment) do farmers adopt during their life in a settlement? How do these systems change? What patterns emerge? Do different farmers specialize and/or diversify their economic portfolio?*

I describe some of the experiences of Humaitá previous residents (local ex-rubber tappers), colonist farmers and more recent land investors, and how they responded to challenges during their life in the region, such as the lack of access to markets and to basic public services (education and health) and to the harsh environmental conditions of the Amazon. I present short "life-story" narratives for three Humaitá residents/landowners, one for each social group used in this dissertation as well as quantitative analysis using data from the sampled population. The life-stories are focused on the livelihood strategies that take place as the settlement ages, and on the social learning processes that are both a driver and an outcome of such strategies. This discussion is important to understand farmers' land-use options as an experiential process affecting future choices on livelihood strategies, and how these options are related to the structural factors observed at the settlement level in land reform projects.

More specifically, I am looking into the range of land-use activities and livelihood choices that had been evolving since farmers first arrived in the frontier, by testing the following hypothesis:

Hypothesis 5 – *Households present a wider range of income related activities in 2003-04 then when they arrived at the settlement. As households mature in the frontier, they engage in* *increasingly larger number of economic activities, aiming at diversifying income and minimizing risks.*

The survey instrument included questions on land-use strategies, agropastoral production and commercialization, both by the time of arrival at PAD Humaitá and by the time of the interview. It included also questions on other economic strategies for both time periods, including employment, retirement, subsistence strategies (hunting, fishing, gathering) and remittance of money by relatives.

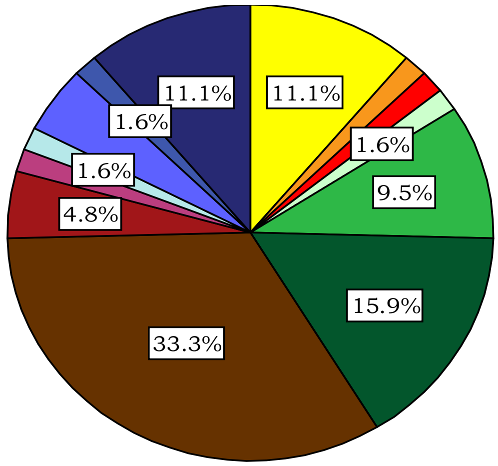
Quantitative analysis focuses on the importance and range of livelihood strategies between the time settlers first arrived in Humaitá and during fieldwork (2003/2004). My discussion focuses on issues relevant to the livelihood strategies in the region such as construction of ponds, rural producers' associations and agricultural credit, and the relationship between environmental legislation, demand for pastures and increase in land prices.

6.1 – Diversification on livelihood options along settlement aging: quantitative analysis

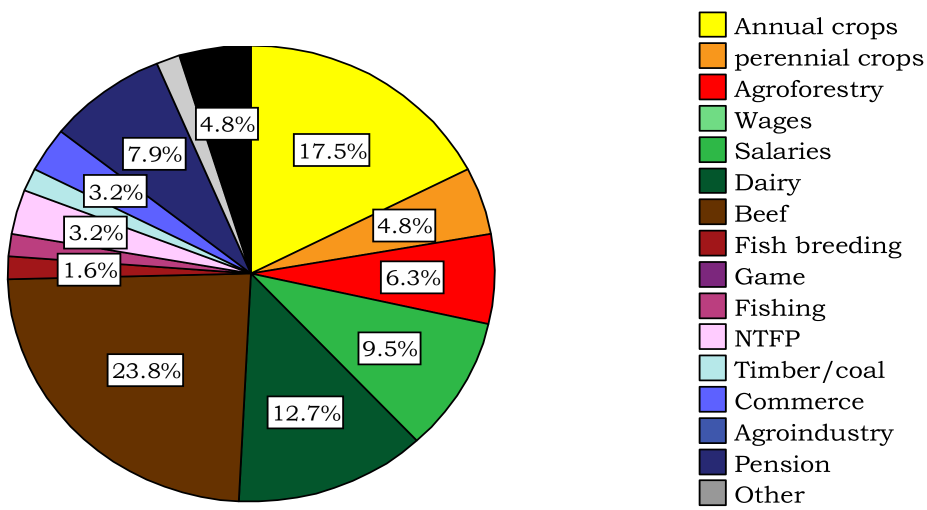
Before presenting richer and more detailed life-stories of local farmers, this section compares the range of livelihood options explored by Humaitá farmers when they first arrived in the settlement with the range of livelihood options explored in 2003/2004. When I conducted the land-use and socio-economic survey, farmers where asked to rank their livelihood options according to its economic importance at each of these two moments. The economic importance of each livelihood option includes both market value and non-market value (as for example options used for household consumption, such as game or fishing). The results are presented on Figures 6.1 - a,b, and c and Figure 6.2 - a,b, and c.

Figure 6.1 a,b, and c – Livelihood options in Humaitá in 2003/04 (% of survey):

a) Most important



b) Second most important



c) Third most important

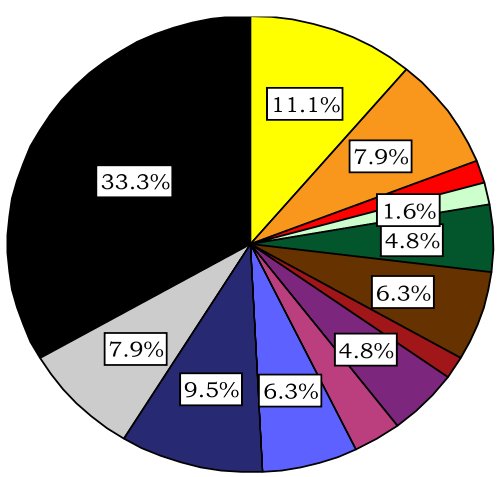
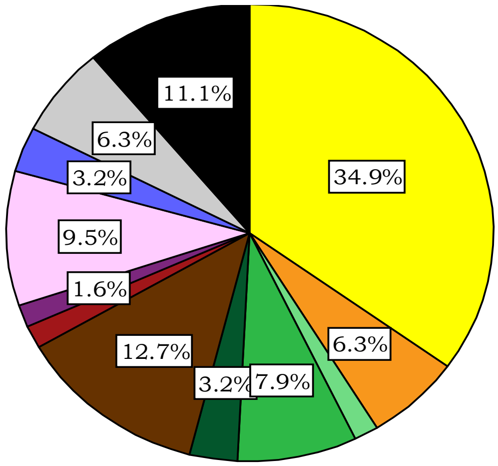
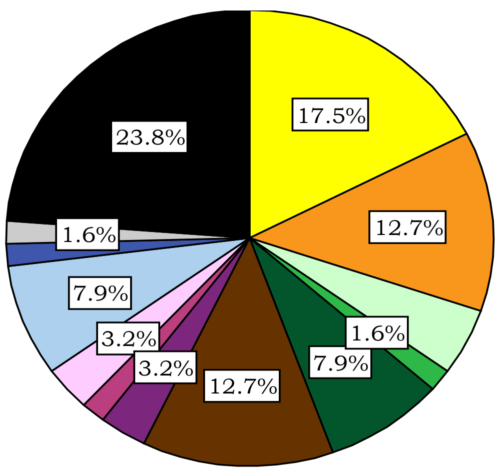


Figure 6.2 a, b and c - Livelihood options in Humaitá when settlers first arrived (% of survey):

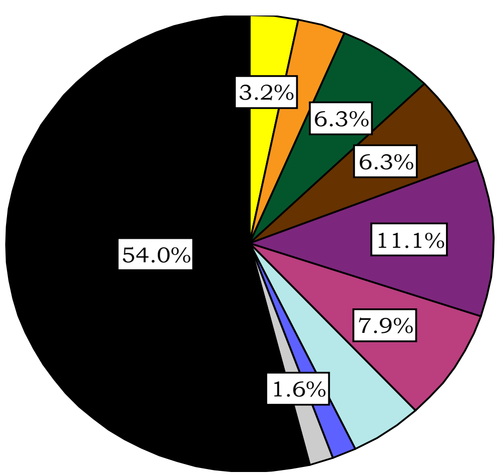
a) Most important:



b) Second most important:



c) Third most important:



Cattle-ranching for beef is the leading economic activity among farmers in 2003/2004, or the one that 33.3% of the interviewed farmers considered the most important as a livelihood option for maintaining their households (Figure 6.1-a). 15.9% of the farmers considered dairy as the most important activity; 11.1% considered annual crops and other 11.1% considered pension as the most important economic source. For the second most important economic option, beef is again the most frequently listed, with 23.8% of the preferences, followed by annual crops and by dairy (Figure 6.1-b). As for the third most important economic option, annual crops come are mentioned first, followed by perennial crops and by beef (Figure 6.1-c). Note, however, that 33.3% of the farmers did not mention a third most important option (referred as missing, which seems to limit their activities to ranching and agriculture).

When asked about the first most important economic option when they arrived, 34.9% of the farmers answered that it was annual crops, while other 12.7% responded it was cattle-ranching[75] and 9.5% responded non-timber forest products (NTFP), which includes rubber-tapping and Brazil-nuts[76] (Figure 6.2-a). For the second most important option, annual crops comes again as the most frequently cited (17.5%), followed by perennial crops and pasture in the second place and dairy and timber in the fourth place (Figure 6.2-b). For the third most important option, game is the most important, followed by fishing and by beef and dairy (Figure 6.2-c).

[75] Very few 1st owner farmers (farmers originally settled by INCRA and local farmers) had enough pasture by the time they arrived to consider beef as their first option by that time. Therefore, this figure represents mostly 2nd owner colonist farmers and land investors buying land already formed with pastures.

[76] The 'missing' values in this case (11.1%) represent second generation residents that moved to Humaitá when they were still children

Tables 6.1 and 6.2 show the same information for each social group in Humaitá. Note that while beef is the most frequently cited primary economic option for local farmers and for colonist farmers in 2003/2004, it is not for land investors, for whom the most frequently cited primary economic option is wage salaries (Table 6.1). Yet the most frequently cited secondary economic option for local farmers is annual crops; dairy for colonist farmers and beef for land investors.

In relation to when farmers first arrived in the settlement (1980 for local farmers), the most frequently cited primary livelihood option for local farmers is extraction of rubber, while for colonist farmers it is annual crops and again salaries for land investors (Table 6.2). The most cited secondary source of livelihood option for local farmers is annual crops; perennial crops for colonist farmers and beef for land investors. Some additional important differences between initial and current economy and land-use in the settlement shown by these tables include:

- Annual crops might have lost much of its commercial importance in Humaitá, but continue to be important for household consumption for both local and colonist farmers;
- Retirement pensions seem to be more important than both salaries and hourly wages for both local and colonist farmers;
- Fish breeding does not seem to be ranked among the most important economic options for any of the social groups;
- Steady sources of income including salaries, hourly wages and retirement pensions were not available to local farmers of the sample by 1980, and almost non-available to the colonist farmers of the sample;

- Annual crops were important to all three social groups, even to land investors who used to intercrop them with pasture in the first year of pasture establishment;

Table 6.1 – Livelihood options observed among Humaitá farmers in 2003/2004:

	Local farmers (n = 13)			Colonist farmers (n = 37)			Land investors (n = 13)		
Livelihood options	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Annual crops	7.7	30.8	-	16.2	16.2	10.8	-	7.7	23.1
Perennial crops	-	-	15.4	2.7	8.1	8.1	-	-	-
Agroforestry	-	7.7	-	2.7	8.1	2.7	-	-	-
Wage labor	-	-	7.7	2.7	-	-	-	-	-
Salaries	-	7.7	-	5.4	8.1	-	30.8	15.4	-
Dairy	7.7	15.4	-	21.6	10.6	8.1	7.7	15.4	-
Beef	30.8	15.4	-	37.8	24.3	10.8	23.1	30.8	-
Fish breeding	7.7	-	-	2.7	2.7	-	7.7	-	7.7
Game	-	-	15.4	-	-	2.7	-	-	-
Fishing	7.7	-	-	-		5.4	-	7.7	-
Non-forest timber products (NFTP)	-	15.4	-	-		-	-	-	-
Timber/coal	7.7	-	-	-	2.7	-	-	-	-
Commerce	7.7	-	7.7	-	5.4	8.1	15.4	-	-
Agro-industry	-	-	-	-		-	7.7	-	-
Pension	23.1	7.7	7.7	8.1	10.8	13.5	7.7	-	-
Others	-	-	23.1	-	2.7	2.7	-	-	7.7
Missing or no opinion	-	-	23.1	-		27	-	23.1	61.5
Total	100	100	100	100	100	100	100	100	100

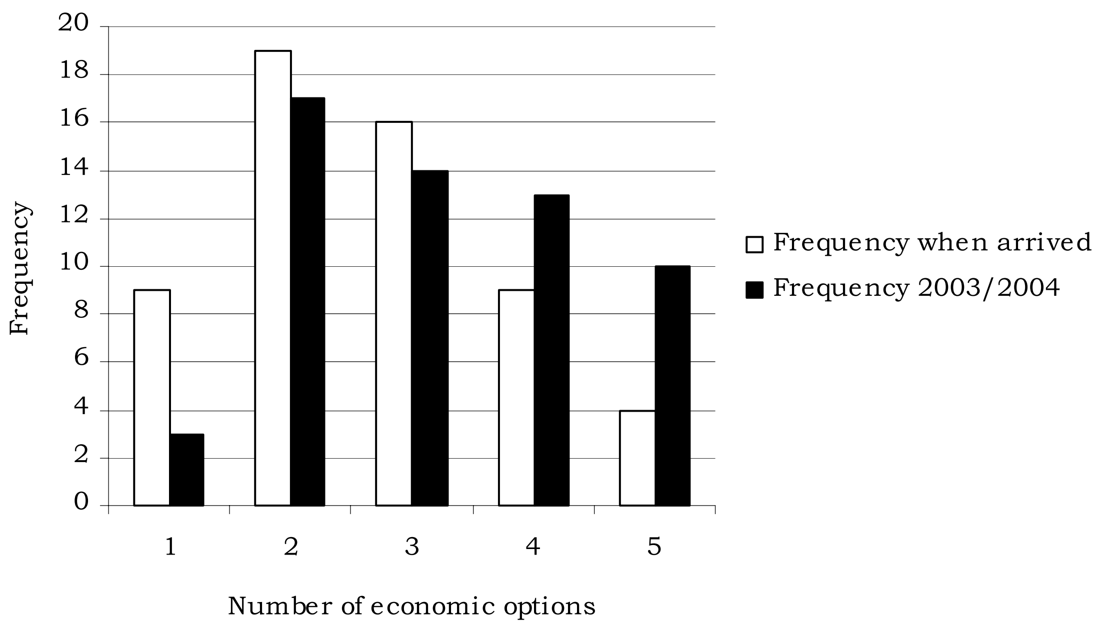
Table 6.2 – Livelihood options observed among Humaitá when farmers arrived[77]:

	Local farmers (n = 13)			Colonist farmers (n = 37)			Land investors (n = 13)		
Livelihood options	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Annual crops	15.4	23.1	7.7	51.4	16.2	2.7	7.7	15.4	-
Perennial crops	-	-	7.7	8.1	21.6	2.7	7.7	-	-
Agroforestry	-	-	-	-	-	-	-	-	-
Wage labor	-	7.7	-	2.7	2.7	-	-	7.7	-
Salaries	-	-	-	5.4	-	-	23.1	7.7	-
Dairy	-	-	-	2.7	10.8	10.8	7.7	7.7	-
Beef	7.7	7.7	-	13.5	10.8	10.8	15.4	23.1	-
Fish breeding	-	-	-	2.7	-	-	-	-	-
Game	-	7.7	15.4	2.7	2.7	13.5	-	-	-
Fishing	-	-	15.4	-	2.7	8.1	-	-	-
Non-forest timber products (NFTP)	46.2	15.4	-	-	-	-	-	-	-
Timber/coal	-	-	7.7	-	13.5	2.7	-	-	7.7
Commerce	-	-	-	-	-	2.7	15.4	-	-
Agro-industry	-	-	-	-	2.7	-	-	-	-
Pension	-	-	-	-	-	-	-	-	-
Others	15.4	7.7	-	2.7	-	-	7.7	-	7.7
Missing or no opinion	15.4	30.8	46.2	8.1	16.2	45.9	15.4	38.5	84.6
Total	100	100	100	100	100	100	100	100	100

Figure 6.3 shows a comparison on the number of economic options explored by farmers when they first arrived in Humaitá and in 2003/2004. The frequency of citations of four economic options[78] by farmers in 2003/2004 is 44% higher than the frequency of citations of four economic options when farmers arrived, and the frequency for 5 economic options is 150% higher than when farmers arrived, which points to clear pattern of diversification in livelihood strategies occurring trough the studied period.

[77] For local farmers, this corresponds to 1981, when INCRA begun settlement implementation.
[78] Includes only the economic options considered important by farmers. Farmers were allowed to include as many economic activities in their ranking as they considered important.

Figure 6.3 – Number of economic options by the time of arrival and in 2003/2004:



6.2 – Livelihood strategies as perceived by colonist farmers, ex-rubber-tapers and land investors

The information is organized in a way to allow the visualization of the socio-economic, cultural and biophysical diversity within the study area and through time. I picked three distinct life-stories from household-heads interviewed during fieldwork, highlighting their adaptation strategies as a function of changing individual preferences as well as environmental, infra-structure and labor/capital constraints as households mature. I selected these life-stories based on the richness of details about factors shaping livelihood choices, and on how they illustrate the opportunities available to farmers along settlement aging. Some of the factors affecting these strategies include the availability of labor and capital, subsistence resources, road conditions and commercialization of agropastoral products, household size and composition, and governmental policies such as agricultural credit, technical assistance and research initiatives.

6.2.1 - *Seu* Claudenor[79]: a local ex-rubber tapper engaged in cooperative networks

> *"Camarada acostumado na floresta sente muito a cidade grande. Seringueiro, quando vira colono, tenta se acostumar com roçado e gado; mas depois vê que o ramo dele é andar mata mesmo..."*
>
> *"The fellow who is used to the forest feels it hard in the city. When a rubber-tapper turns into a settler, he tries to get used to agriculture and cattle; but sees later that his business is in fact/indeed to walk the forest…"*
>
> *'Seu' Claudenor, 6/9/2004*

Seu[80] Claudenor used to be a rub'ber-tapper until 1981, when INCRA arrived and implemented the land reform. He was born in Plácido de Castro, Acre, in 1948, and migrated to *Seringal* Panorama (rubber-farm Panorama) in 1976, to an area that corresponds to the actual *Mutum* road of Humaitá settlement, where he acquired informally a *colocação* (household unit of rubber extraction[81]) with seven *estradas de seringa* (roads of rubber-trees), which was equivalent to approximately six INCRA lots or around 360 hectares. But he soon found out this *colocação* was not as productive as he expected it to be, and exchanged it later for another one located near what is now known as *Ramal Bujari* (Bujari road, not existent though when he arrived), and where he and his family still live today. The main

[79] All names presented are pseudonyms.
[80] 'Seu' is usually a respectful form of addressing someone (men) in Portuguese; ('Dona' is used for women).
[81] He paid 80 cruzeiros for this colocação to the previous *posseiro* (squatter).

reason he chose this *colocação* was that it had plenty of productive rubber-trees, Brazil nuts and game. After INCRA's implementation of the land reform, he was assigned an area of 66 hectares around his house and lost user rights to the rest of his *colocação*. While this gave him secure property rights to this piece of land[82], it represented also a turning point in his life, since he no longer could live from rubber-tapping and had to change instead to agriculture and cattle[83]. The same drastic change on livelihood means occurred for other 265 rubber-tapper families living in Humaitá area starting in 1981 (INCRA, 1994).

Seu Claudenor met his wife *Dona* Doralice in his first *colocação* in *Seringal* Panorama. As they moved to Bujari, her brothers came along and a kin-based cooperative network was soon established. Since commercialization of agricultural produce was almost impossible due to the lack of roads (Bujari road is still one of the most problematic in the settlement), an exchange economy including extractive products from the forest (including game) and annual agriculture was established through the family network. Today, Claudenor and Doralice have 12 sons/daughters, three of them living in the lot, seven in Vila do V (located about nine kilometers from the lot, along Bujari road) and two in the recently established Porto Acre settlement[84]. The three sons and daughters living on the lot are responsible for the agricultural production, which is shared among the whole family. The ones living in Vila do V are either studying or employed; the ones employed and Seu Claudenor, who is also employed as a security guard with the local school, help the ones living in the lot financially. One son is employed in the local sawmill, another as a cowboy,

[82] Many *posseiros* by the time feared loosing their land through disputes with *seringalistas*, who often sold land to cattle-ranchers, who in turn often found themselves in the right to expel rubber-tappers from their *colocações*.
[83] The rubber-tapping activity, as it is normally practiced in Acre, requires at least 300 – 400 hectares of land per household to be economically efficient (Gomes, 2001).
[84] This new settlement carries the same name as the municipality of Porto Acre. It is a small settlement with some 40 lots averaging around 30 hectares. It used to be a private property, which was found abandoned (the owner supposedly left Acre) by local residents, who organized then an invasão (squatting), by establishing small agricultural plots in it. Later, use rights were requested and granted by INCRA.

one daughter as a social assistant and another son as a teacher in the local school. While the three sons/daughters living in the lot did not finish elementary school, three of the other siblings did finish the 8th grade, three finished high-school and the other three are still studying. The family owns a small cottage in Vila do V, where they stay during most of the week. Dona Doralice, who is also employed in the local school as a cook, and Seu Claudenor are constantly moving back and forth Vila do V to their lot, where they supervise agricultural activity. They own a motorcycle and a bicycle, which comprise their means of main transportation. They also use collective cabs (*peruas*) that drive often the Bujari road route up to Dois Irmãos road, in Projeto Porto Acre, during the dry season. Transportation during the rainy season is very problematic, when most Bujari residents have often to walk their way to schools and/or jobs in Vila do V. Some have horses and others have motorcycles, which are more adapted to muddy roads when compared to most four-wheeled vehicles. Only land investors owning ranches in Humaitá can afford four wheel-drive vehicles.

Everybody in Vila do V and in Bujari road knows Seu Claudenor. He is a very kind person with friends everywhere he goes. Talkative, making jokes and ready to help neighbors in need, he has been the president of the local producers' association for the past 8 years. Associação São Bento currently has 69 associates along Bujari road, and is considered one of the few 'successful' producers' associations in Humaitá in the long term, given the rate of approval of agricultural loans, projects, and overall attendance of associates to meetings. Despite commercialization difficulties, Seu Claudenor believes in the potential of agricultural crops to develop the region, and is fighting for the approval of a big loan with BASA. More on this loan is discussed on section 6.4 (rural producer's associations). Seu Claudenor was going to run for the city council of Porto Acre (*vereador*) in the 2004 elections. He assured me he would be willing to continue working with São Bento if he wins.

Seu Claudenor took two agricultural credit loans through FNO from 1998 to 2004, and could be considered a risk-taker for his willingness to invest on agricultural crops (see discussion on the end of Chapter 3). However, he and his family adopt clearly a livelihood strategy which is based on the diversification of income sources and of other subsistence means. For instance, the agricultural credit loans were invested in cattle, infrastructure (fences, corral, pond construction), equipment (a manual weed cutter and a domestic manioc flour mill engine), and in a small coffee plantation. Besides owning 34 cattle heads for both dairy and beef, maintaining a diverse home-garden with several species and working with annual and perennial crops for both domestic use and commercial sale, Claudenor and Doralice's household maintains a diversified set of animal husbandry activities (fowl, pork, horses and fish). Fish production in 2003 was of around 1,000 *curimatãs* (popular specie of Amazonian fish) in two ponds, from which 600 kg were sold, and another substantial quantity was either consumed among household members or given to neighbors. The household maintains some 12 hectares of forest cover in the lot (or 18%), from which *açaí*, Brazil-nut and timber are explored for domestic consumption. Game is no longer available, but was an important source of protein in the past.

The household cooperative system seems to work reasonably well, though I interviewed only Seu Claudenor. I don't know how his sons and daughters feel about it (specifically, I don't know if the ones living in the lot are satisfied with their role and share in the system), or his wife. Although this kind of household cooperation network is not uncommon in Humaitá, and plays a significant role on eliminating risks otherwise significant in non-cooperative livelihood settings (household and kin cooperation networks are probably much more important at the settlement level than the ones observed in producers' associations), I haven't observed this level of specialization (with divisions of activities and sharing of outcomes from agricultural production, wage salaries and social network activities) in any other household in the settlement. Household size plays a key role in this setting, and so does the leadership role of Seu Claudenor on maintaining the system operating.

6.2.2 – *Seu* Sebastião, a colonist farmer specialized on making cheese

> *"No ano em que cheguei no Acre (1976), recebi um convite de um fazendeiro para ir fazer derrubada no Amazonas. Fui com meus cunhados, mas não valeu a pena; terra ruim, madeira dura, cheio de mosquito, malária, nos lascamos...a terra foi abandonada para quem quisesse. Naquele tempo, não tinha Incra, pegava 'o tanto de terra que os olhos dava'..."*
>
> *"When I arrived in Acre (1976), I received an invitation by a cattle-rancher to go to the State of Amazonas to put down trees. I went with my brothers-in-law, but it did not pay off; poor soils, hard timber, lots of mosquitoes, malaria, we went broke…the land was then abandoned to whoever was willing to take it. During that time, there was no Incra, and anyone could 'take' land 'as far as your eyes could see'…"*
>
> *Seu* Sebastião, 5/9/2004

Seu Sebastião was born in the State of Minas Gerais, Southeast region of Brazil, in 1946. He used to work on clearing forests to third parties, and he married Dona Neusa when both were still teenagers. They then migrated together to the State of Mato Grosso (South of the Amazon Basin), and later to Mato Grosso do Sul. Neither Seu Sebastião nor Dona Neusa received much formal education. He attended only to two years of school, while she is illiterate. In 1976, they made their third migration to the municipality of Xapuri, Acre, were Seu Sebastião was hired by a logging company. In Xapuri, they joined the 7th Day Adventist church, and formed a united religious group that moved to nearby Capixaba municipality where they were settled in the agricultural production unit (*Pólo Hortigranjeiro*) of the Alcobrás[85] project area. By that time, Alcobrás was already doomed to failure due to a big corruption scandal from the misuse of public funds. Seu Sebastião and colleagues enlisted as settlement beneficiaries in P.C. Humaitá, where they were granted lots by INCRA in 1982. In 1983 Seu Sebastião, Dona Neusa, their four children and their group of approximately 60 Adventist people moved together to the Concórdia road.

When they arrived, the Concórdia road was still a trail in the forest, and their belongings had to be carried in with several trips 'on their backs'. With their son and three daughters[86], they cleared and cultivated an average of five hectares per year with rice, beans and corn. This area was usually planted with grass in the second year. Pasture establishment has often been problematic due to poor burns of agricultural fallows, and re-planting of grass has been common throughout following years. As fluctuation in annual crop prices and poor road conditions cut down profits of agricultural activity, they gradually begun to replace part

[85] Alcobrás was an ethanol production project established by a private group in the early 1980s with substantial government subsidies. The project was composed by sugar cane plantations, an ethanol production plant and an agriculture production unit, designed to supply the project with food.
[86] A fourth daughter has a disability and has been unable to help in agricultural activities.

of the recently cleared areas with pastures, instead of planting annual crops, up to the point they stopped completely with annual crops, which happened in 1998.

The Concórdia road once had an association of rural producers that included the Adventist families and other residents; this association owned a tractor donated by a populist governor in the past. During that time, according to Seu Sebastião, he had an agricultural 'bonanza' and made some significant profits from commercialization of papaya, manioc and manioc flour. The key factor for the 'bonanza' was that the produce could be transported to Vila do V by the association's tractor. Seu Sebastião and his family had also significant economic outputs from selling chickens, and there was always something to sell during difficult times. The tractor did however not survive much longer, and the association disappeared due to out-migration of residents. From the initial 60 member group, only four families remained in the area in 2003; all others moved either to Rio Branco, to new settlement fronts, or to neighbor villages Vila do V or Vila do Incra. These were replaced by land investors who consolidated lots into larger properties.

Seu Sebastião and Dona Neusa's main land-use option in their 63 hectare lot today is pasture for dairy (1st income source) and beef (2nd income source) production. They don't sell milk because of problematic road access and make cheese instead, which is sold once a week in the Rio Branco's central market for US$ 0.90 a piece of 650 grams. Given that milk production is seasonal, cheese production is of 170 kg/month during the dry season and 80 kg/month during the rainy season, totaling an average of 1,500 kg/year or US$2,150/year. Last year, however, they were forced to sell most of their cattle because a big fire burned most of their pasture, and made some US$ 5,300 which was used to reform their house. Another important source of income is Dona Neusa's retirement pension of one minimum wage salary (about US$ 80/month in 2003), and another equal amount received for the disability of their daughter.

According to Seu Sebastião, the fire that decimated their pasture resulted from a neighbor burning a slashed fallow under inappropriate conditions. It spread throughout 600 hectares of forest, secondary vegetation and pastures affecting around 10 lots. Fortunately, it could not cross the strip of forest that separates Concórdia lots from Bujari lots. According to Seu Sebastião, the frequency of fire incidents like this one has been increasing along with the increase in deforested areas. Other environmental problem affecting most of the lots along Concórdia and Mutum roads is the ‘death of the pastures’ already mentioned on Chapter 2, which affects some 10% of the pasture area along these road. The alternative recommended by Embrapa-Acre and being used in the area has been to replace *Brachiaria brizantha* grass by *B. humidicola*, which is less vulnerable to death of the roots by asphyxiation. This is however an expensive measure and farmers have been experimenting this in small patches only. Seu Sebastião, for instance, has been unable to do anything about this problem by the time I interviewed him, since his focus has been on helping pastures to recover from the fire lost.

Their other three daughters and son have all formed families and are presently living in Rio Branco, with one daughter living in a settlement in the Senador Guiomard municipality. Only one daughter finished elementary school. She works in the commerce in Rio Branco. The oldest son attended only to the second school year and knows how to write, but not much, as with his two other sisters. He used to work in a timber saw mill in Rio Branco but is now unemployed. None of Seu Sebastião and Dona Neusa’s son or daughters has ever helped them financially, after leaving the household.

Seu Sebastião life-story in Humaitá illustrates a pattern of livelihood strategies that is common in areas with poor access to markets and in households that cannot count anymore with the labor force they once had. Seu Sebastião and Dona Neusa once had a more diversified set of economic activities, including commercial agriculture and mixed husbandry. Road conditions have been always poor, but with the association's tractor (which was provided by a local politician) no produce was lost in the field. But as many neighbors started selling their lots to land investors, the association became weak and died. By the same token, after four of their sons and daughters left the lot[87], their range of options on land-use activities became constrained, and Seu Henrique specialized into the cheese business.

6.2.3 – *Seu* Henrique, a land investor with a diversified portfolio

> *"Com a venda do gado, faço mais açudes; o relevo ajuda, e só no lote 31 há 8 vertentes. Minha previsão para 2004 é de 2000 kg de peixe em cada um dos 12 açudes, a R$ 3 mil / tonelada, dá R$ 72 mil..."*
>
> *"By selling the cattle, I make more ponds; the relief helps, and only in lot 31 there are 8 water springs. My forecast for 2004 is of 2000 kg of fish for each of the 12 ponds, at R$ 3,000 (US$ 940) per ton, results in R$ 72,000 (US$ 22,500)"*
>
> *Seu Henrique, 3/16/2004*

[87] Only the disabled daughter remains with them

Seu Henrique was born in Cruzeiro do Sul, State of Acre, in 1961, in a family used to live from agriculture. As a teenager, he migrated to Rio Branco, where he took the military service, went to college, and got later a graduate degree. Actually working as a public agent for the government, he comes every weekend to his farm in Linha 3 road. The first two lots were bought in 1984, from a rubber-tapper and his daughter, who were both willing to move to Rio Branco. According to Seu Henrique, he had to choose, by that time, between buying a new car and buying these two neighboring lots, of 64 hectares each. He does not regret his choice, since as he puts it, land was initially bought with the intention to use it as a hedge against inflation, but he figured out soon that substantial money could be made out of cattle-ranching. Recently, he found out fish breeding is even more lucrative.

Both lots were entirely covered in forest when Seu Henrique bought them in 1984. In 1987, he took a CrN$ 100,000 (in Cruzados Novos, Brazilian currency by the time[88]) loan from a Acre State bank which was used to convert 50 hectares of forest to pasture, and to build a corral and a house in the lot. He was very concerned at the time with escalating interest rates on that loan, especially because of the rising inflation rates. By the end of 1987, however, and according to Seu Henrique, the government announced that due to the inflationary 'rendevouz' in Brazilian currency, all bank debts up to CrN$ 100,000 were cleared, so he did not have to pay anything back to the bank (!).

The formation of these 50 hectares of pasture was very difficult, according to Seu Henrique, because of the poor burns and the high incidence of snakes, and secondary re-growth occurred in part of the area. In 2002, 20 hectares of secondary forest were manually converted to pasture, by contracting daily workers. Today, each lot is 77% formed with pasture, the remaining 23% covered with forest. Each lot has also 6 ponds, which are used

[88] CrN$ 100,000 are equivalent to US$ 2,420 of 1987

both to supply cattle with water and to breed fish. Seu Henrique bought two additional lots in 1999 also connected to each other, but connected only through Linha 3 road to the other two lots that are around 1 kilometer away. The size of the lots acquired in 1999 is of 71 hectares and 69 hectares, both of them about 50% deforested by the time, with other 15% and 20% in secondary succession and the remaining in pasture. Each of these lots is about 85% formed with pasture today, with the remaining 15% still covered with forest. In 2004, the acquisition of a fifth lot of 65 hectares across Linha 3 road was being negotiated.

Connection among lots is an important issue to land investors, as it facilitates cattle and pasture management and reduces transaction costs. The same importance of connectivity among lots has been observed in consolidated soybean plantations in Santarém, (Ludewigs et al, under review-b), which contributes to the increase in land prices observed in the region[89]. Yet in Humaitá, demand for pasture instead of demand for potential soybean fields is what drives land prices up. Indeed, Seu Henrique mentioned land valorization rates of 100% a year along Linha 3 road[90]. Valorization on land prices has been also observed along paved roads or where infra-structure investments, such as ponds, corrals, fences, and electricity have already been high. Linha 3 is not paved, and was considered in very bad shape until 2003, when Seu Henrique asked Acre's government to reform the road. His request was approved and Linha 3 was one of the best unpaved roads of Humaitá in 2004.

Another important factor determining sharp increase in lot prices relates to the recent decrease in rates of approval of clearing licenses emitted by IBAMA in Humaitá and elsewhere in Acre. As cattle herd sizes tend to increase, leading to a corresponding increase

[89] Soybean farmers increase often the amount of money offered to small farmers whose lots are 'in between' potential soybean production areas, when their first bid is not accepted by small farmers.
[90] For example, one neighbor offered R$ 35,000 for one of his lots in 2003 and another one R$ 70,000 in 2004. These prices are consistent with land prices observed in other highly valued areas of Humaitá settlement, such as along paved roads.

in the demand for new pasture areas, prices of lots formed with pasture tend to rise in a higher rate than prices of forested lots, since restrictions to convert forests to pasture are stronger today than ever before in Humaitá. Thus, I observed in 2003/04 that one hectare of land-covered with well-formed pasture costs as much as six to eight hectares of land-covered with mature forest. As a consequence, the temptation to sell land faced by colonist farmers has been reaching a peak. One settler from Minas Gerais sold recently his 70 hectare lot in Humaitá to buy a 250 hectare farm in Sena Madureira for a lower price. Others are buying land in Boca do Acre, State of Amazonas, (and connected through some 150 km of dirt-road BR-317 to Rio Branco), where the local government has been receiving cattle-ranchers 'with open arms', and where enforcement of forest legislation has been ignored.

While many land investors in Humaitá conduct cattle-ranching extensively, meaning that investments on increasing cattle-ranching productivity are kept moderate to low, Seu Henrique has been investing heavily on technology. With technical support from Embrapa-Acre, he has been rotating pastures, using electric fences, providing plenty of mineral salt to cattle, and even experimenting with artificial insemination of cows. Soil fertilization is not necessary since all his lots are located in rich Alfisols. Good harvests of corn have been obtained during the first year of forest conversion to pasture, by intercropping grass in corn rows. Corn production in 2003 was of 5600 kg and was used to feed commercial husbandry (cattle and fish) and animals for local use/consumption (horses, pigs, chickens) of Seu Henrique's family and families of the two cowboys working for him. After feeding 44 cows and 55 oxen with grass and corn, these were sold in 2003 for US$ 19,800. Other 688 cattle heads maintained on his 210 hectares of pasture represent a grazing pressure of 3.27 cattle heads/hectare[91], which is considered very high for both Acre and Brazil standards, and probably the highest rate in Humaitá. As may be noticed from the introductory note about Seu Henrique, he is a strong believer and supporter of fish breeding. In 2003, he sold 5 tons of *curimatã*, *matrinxã* and *piau* species all-together for a total of US$ 4,800, 30% of which considered by him as profit. A larger quantity, however, was stolen by neighbors. According to him, fish stealing is the single most important factor that kept him from investing more resources into fish breeding. Another farmer shared with me his strategy to keep fish robbers/stealers out of his ponds; being also a cattle-rancher and a butler, he disposes cattle carcasses around the ponds, which keeps his several watch-dogs busy in these places and robbers away from it.

Most land investors and cattle-ranchers in Humaitá have not been investing as much resources as Seu Henrique into productive activities, or into techniques to increase agropastoral productivity. From an economic perspective, many farmers might argue that buying more land is good enough of a strategy to attend demands from increasing cattle herds. With increasing land prices and with promising technologies offered by Embrapa (Valentim, 2006), however, investments on pasture productivity have been calling the attention of a larger number of cattle-ranchers in Humaitá and Acre. As increases in pasture productivity are matched by increases in agropastoral profits, the big question is whether improving technology is helping forest conservation in Acre (Vosti, 2001). Even with stricter enforcement of forest legislation accomplished in recent years, the lack of regulatory policies (such as taxes and incentives to less destructive land-use alternatives) on the expansion of

[91] 298 oxen (1 ox = 1 cattle head), 320 cows (1 cow = 0.75 cattle heads), and 300 calves (1 calf = 0.5 cattle head)

agro-pastoral activities into forested areas might undermine efforts on controlling deforestation rates.

Seu Henrique's entrepreneurship on the adoption of new technologies is matched by his strategy on diversifying his income portfolio. As a well paid public agent with a secure flow of income, he may afford experimenting alternative land-use options such as fish breeding. As a well-educated professional of the financial sector, however, he is also very well informed about profit possibilities of several of these options and would not invest in fish breeding without previous supporting information and experience. Other land investors interviewed in Humaitá are also well employed and could therefore afford to invest more in technology adoption or in diversification of land-use activities. Many of them, in the other hand, own lots in less accessible roads, and others just don't have time or will to do it, and prefer to adopt the 'risk-averse' strategy of focusing on extensive systems alone. This 'risk-averse' gradient might be though relative to the temporal context; what is considered risk-averse at the short term might be considered risk-taker in the long term: a cattle-rancher that does not invest in new technologies today might be facing problems of lack of pastures for growing cattle herds in the future. Moreover, Seu Henrique's case and Seu Claudenor's as well show that while diversification of land-use and livelihood options might be regarded as effective strategies to spread risks of financial failure, by 'not keeping all eggs in a unique bag', this does not turn them into risk-averse farmers. By the contrary, both like to experiment new alternatives and pursue new economic opportunities, which implies taking risks. Diversification of land-use options, in Humaitá, might thus be seen not only as a risk minimizing strategy, but also as a more efficient way of resource use and of taking advantage of a wider range of economic opportunities. And opportunities are, as pointed by Frederick J.

Turner 100 years ago, the main engine leading migrants to frontiers and shaping their economic decisions.

6.3 - Hypothesis 5: Are farmers diversifying their economic portfolio?

Both quantitative data analysis and descriptive analysis show Humaitá households investing in a more diversified portfolio of economic options today than when farmers first arrived in the settlement. **Hypothesis 5:** "*Households present a wider range of income related activities in 2003-04 then when they arrived at the settlement. As households mature in the frontier, they engage in increasingly larger number of economic activities, aiming at diversifying income and minimizing risks"* is, therefore, **accepted**. Indeed, there are some additional considerations about restrictions on the range of economic options available to farmers when they first arrived in the settlement that help to support the acceptance of Hypothesis 5:

a) When 1st lot owners were settled by INCRA between 1981 and 1986, they had to start agro-pastoral investment in lots when most lots were still completely covered with forest. Given that most families faced substantial restrictions on labor force during that time, that forest clearing requires considerable inputs of labor, and that cattle-ranching requires larger areas of land to be cleared (per financial unit of output) when compared to annual and perennial crops, very few farmers were able and/or willing to invest resources in pasture formation from their very start in Humaitá. Another reason not to proceed so is that most small farmers in the frontier context operate with high discount rates (Schneider, 1995), which leads them to prefer land-use options that are capable of offering financial return in the short term. Farmers arriving at later periods in the settlement (2^{nd} and n^{th} lot owners), however, were eventually able to buy land already partially cleared and with pastures, which allowed them to include cattle-ranching in their livelihood portfolio in Humaitá from the beginning.

b) Labor markets are rarely available at early stages of frontier development (Sawyer, 1984). Wage labor opportunities in Humaitá's early stages were indeed limited, as shown in Figure 6.2. Also, many rubber-tappers and/or eventually colonist farmers receiving retirement pensions by 1981 would be unlikely to be included in my sample, since chances of they being deceased by 2003/2004 would be high.

c) Given that practically all ponds in Humaitá were built after INCRA started settlement implementation, fish breeding and other forms of animal husbandry dependent on water were harder to be conducted by 1981-1986 (see discussion on Figure 6.3 below).

d) Most households arriving in the region were formed by young couples. Given the household size and composition relationship with land-use diversification, it is more likely for young couples to manage more targeted land-use portfolios when compared to "matured" households.

On the other hand, there were some economic options during initial stages of settlement, such as rubber-tapping, Brazil-nut collection, high valued timber exploration, game and other forest extractive economic options that were un-available or less available to most farmers in 2003/2004.

6.4 – Processes and policies influencing the range of livelihood options

This section discusses some processes and policies that became salient during fieldwork and data analysis, and have been influencing the range are believed to influence the range of livelihood opportunities during the life of this settlement.

6.4.1 - Construction of ponds

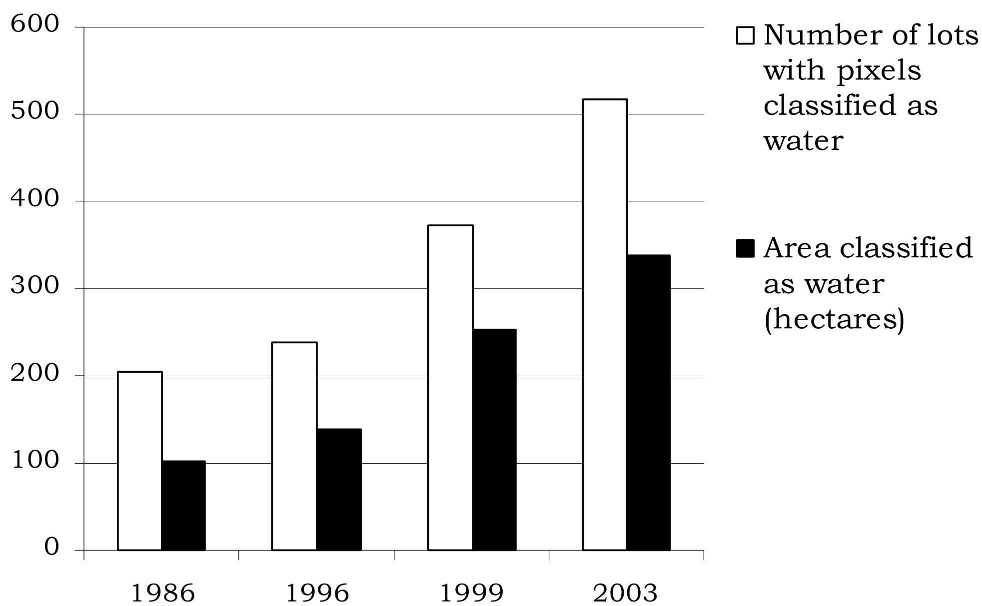
Ponds have multiple uses in Humaitá, and their number across the settlement have been increasing considerably in recent years. Figure 6.4 shows the evolution in the number of lots with pixels classified as water and in the total area classified as water across the temporal frame of the remotely sensed imagery dataset[92]. It shows that the number of lots with ponds has been increasing faster than the total area of ponds. Field observations confirm the importance that farmers attribute to ponds: ponds represent a cheap alternative to supply cattle with water, remain full-charge (of water) along the dry season, and, most importantly, allow for the diversification in land-use and economic options, since it serves for a diverse set of husbandry projects, especially fish breeding.

Interviews with farmers revealed that by the second half of the 1990s, facilities to finance the construction of ponds were provided by local governments (including INCRA, Porto Acre municipality and the State of Acre government). The main mechanism of pond financing is connected to road repair and maintenance operations, and works in the following way: farmers organize and demand collectively for better road quality from local governments; depending on the agreements done with these governments (farmers sharing

[92] The years 1975 and 1992 were excluded from this analysis (evolution in the number of ponds) because of separability problems between water and shadow classes.

part of the costs or not), and on the political agenda of governors (investments on roads are substantially higher in electoral years), heavy machinery is sent out for road repairs and ends up being used for a second objective which is the construction of ponds. One particular Acre State governor was often mentioned to me by farmers as being "sensitive to farmers' problems", by allowing heavy machinery originally budgeted for road repairs to be used for pond construction, as long as farmers helped co-financing part of the costs (diesel and wages of machine operators).

Figure 6.4 - Evolution in the construction of ponds along settlement aging:



Two other common ways of financing ponds include deals with the timber sector (*madeireiros*) and loans from agricultural credit programs. Log prices paid by *madeireiros* to farmers used to vary between R$ 40 and R$ 60 (around US$ 16 and US$ 24 for late 1990s currency rates), which is substantially below the market price for good quality hardwoods (including *cedro*, *cerejeira* (or *cumaru-de-cheiro*) and *cumaru-ferro*). As a compensation, *madeireiros* build and fix roads, and construct small ponds for farmers as well. Another important mechanism of financing of ponds is agricultural credit from FNO for pond construction, as seen in Chapter 3 and in Mr Claudomiro's story in this chapter. Application for agricultural credit is conditioned to affiliation to rural producers' associations.

The sharp increase in the number of ponds observed in P.C. Humaitá illustrates the importance given by farmers to diversify their livelihood portfolio, since most ponds allow fish breeding which provides an important source of protein to the household, and produces often surplus which might be commercialized. A well-established market for fish in Rio Branco helps to maintain fish prices relatively stable. The high increase in the number of ponds illustrates also how farmers make use of opportunities provided by local governments, credit programs and loggers to invest in their lots. Pond construction is expensive and most settlers would not be able to/willing to pay this price, if it were not for the multiple opportunities of pond financing that have been created by them (by their negotiation power). Negotiation of ponds itself does not depend as much on collective action as the process of learning the strategies necessary for success.

Farmers in settlement projects and elsewhere are always observing and learning from their neighbors experiences, and use also details from shared experiences (e.g. negotiation stories are openly shared among farmers through social interactions taking place during festivities, religious celebrations, or in markets, associations, etc…) to increase their chances of getting a good deal. For instance, if a logger contacts a farmer and tells him that for an x amount of logs we would be willing to pay the farmer by constructing a pond of size y, farmers may use information gained from social networks to argue: “I need a pond of size 2y, and I know you can do it since this was the deal you have been offering people around here”. This type of negotiating power gained from sharing experiences applies also when farmers deal pond projects with local politicians and bank representatives, and illustrates the social learning process that develops in farming communities as farmers try to maximize the use of opportunities available in settlement projects.

6.4.2 - Rural producer’s associations

As mentioned in Seu Claudenor life-story, Associação São Bento is locally considered a ‘successful’ association. For instance, the financing of a completely subsidized manioc flour mill project has been approved, recently after Seu Claudenor and colleagues from the association’s directory were able to prove to the Agricultural Production sector of Acre’s government that there were sufficient agriculture oriented farmers associated with São Bento to supply the mill with raw material (manioc). In 2003, São Bento was negotiating the approval of a US$ 156,000 loan with BASA, to finance the purchase of two tractors (one regular, one crawler), a plow, a planting machine and a harvest machine, for planting corn, manioc, rice and beans, and for the construction of ponds. If granted approval, each of São Bento’s 69 associates will be liable to cover part of the loan, with additional collateral as the value of the association (US$15,600). Interest rates will be of 4% a year under FNO – Pronaf financing system, with 4 years of grace period and other 8 years for repayment.

According to Seu Claudenor, if granted approval, individual members of the association will be responsible for operating the machinery and to manage its’ agenda. Associates will pay only diesel and operators’ wages, non-associates will pay more. Some residents of Bujari road doubt, that, this project will produce positive outcomes. They argue that poor road conditions won't allow for commercialization of harvests, that associates don't have enough experience managing common property (agricultural machinery), and that the loan cannot be repaid by association members, who might be forced to sell their lots to pay the bank. Another issue is the ecological impact of heavy machinery on soils. Soil compaction might increase erosion problems, especially on Plynthic Ultisols (*tabatinga*), present in moderate proportions along Bujari, which should not be plowed at all. According to Seu Claudenor, however, most soils are good for mechanization, as proved already by some successful experiences of settlers renting heavy machinery and planting larger areas of land with annual crops, and *tabatinga* soils would not be used for agricultural crops. In relation to the roads, Seu Claudenor points out that he and other associates will press the government for better road maintenance, since "where there's agricultural production, there should be good roads".

Seu Claudenor believes also the 'organization' of the São Bento association is already sufficiently strong to allow for successful management of the loans and equipment use (meaning social capital within the association is already strong). The apparent 'success' of the São Bento association on approving and preparing projects, and getting associates to attend meetings would be more difficult if it were not for the outstanding dedication of Seu Claudenor and his leadership skills. According to him, several farmer producers' associations ceased to exist because when presidents and members of the directory have to work hard on their own lots to make a living, they can't dedicate enough time to the associations, which end up 'dying'. In Seu Claudenor's case, according to him, he is fortunate to have a job and a family organization which allows him to dedicate considerable part of his time to the association. Otherwise, it could have already 'died' as well, which indicates that most responsibilities on the maintenance of São Bento's activities are centered on himself. Thus, it seemed to me that if we consider democratic values as being important, among other things, to build strong institutions (Ostrom, 1990), and that democratic values consist on sharing rights and responsibilities with equity, Associação São Bento might still have some considerable work ahead to be able to craft strong institutions and to become effectively a strong producers' association.

6.4.3 - The *Reserva Legal* in Humaitá

The Forest Code of 1965 instituted several norms for protection of forested areas on private and public lands, located in rural and urban areas of Brazil (Brasil, 2001a). Among these norms, the Forest Code included the implementation of the *Reserva Legal* (Legal Reserve), which states that a minimum percentage of land in rural properties above a minimum size shall be maintained with native vegetation. For the Amazon region, this minimum percentage of *Reserva Legal* was established at 50%. Enforcement of the *Reserva Legal* in Humaitá, as stated in the Forest Code legislation of 1965, was weak up to the late 1990s, when state agencies increased monitoring and control of irregular forest clearing. This increased control was reinforced by the *Medida Provisória* N.º 2166/67 (Brasil, 2001b), issued by the federal government in August 2001, that changed the 50% rule to an 80% rule. The election of president Luiz Inácio Lula da Silva in 2002 is also believed to play a role on increasing control over deforestation in the State of Acre[93]. There is a strong political reason for that. Since Acre has been administered by the Workers' Party (PT) since 1999, the same

[93] This does not imply that the federal or the state government were effective on curbing down deforestation rates by that time in the Amazon and in Acre, respectively. By the contrary, Figure 2.1 shows increasing rates of deforestation until the 2003-2004 measurement, after which rates begun to drop again.

party of president Lula, and since it is also the home state of Lula's Minister of the Environment Marina Silva, it has been set as the state where the implementation of the idea of sustainable development should serve as an example to other states in the Amazon and to the country as a whole. To be consistent with deforestation rate reduction goals expressed in the *Amazônia Sustentável* program (MMA, 2003), both environmental agencies operating in Acre -IBAMA and SECTMA (State Secretary of the Environment), would have to increase control over deforestation, which has been pursued through stricter monitoring and enforcement of fines, and through restricting the number of deforestation licenses granted[94]. Most Humaitá residents have been expressing dissatisfaction to what they consider an unfair change in the rules of the game, because: a) by the time settlement opportunity was offered to them, and up to the late 1990's, the 50% rule of the Forest Code of 1965 was never really enforced; suddenly, in 2001, it is not only enforced but changed to an 80% rule, without any consultation with representatives of the farmers; b) according to Humaitá farmers, several large forest clearings (over 100 hectares) were allowed between 2001 and 2004 in cattle-ranches surrounding Humaitá settlement which passed unnoticed by the environmental agencies monitoring the region they add: "If large farmers can deforest large areas, how come we small farmers cannot clear smaller areas ?" c) Many farmers that had followed the *Reserva Legal* rules have been recently denied license for clearing extra land; many of these farmers regret not having cleared the whole lot before, when Forest Code legislation was not being enforced, since their neighbors with lots more than 50% deforested are considered better off financially and are not facing any penalty for not following the rule; d) Some

[94] It has been argued, however, that political influence played by corporate ranchers might have allowed them to escape fines in several instances.

Humaitá residents have been buying land in the Tocantins settlement project[95], where most 60 hectare lots are still under 20% deforested, and where the new 80% rule is also being enforced; they argue that it is not economically feasible to carry out agro-pastoral activities with only 12 hectares of land available, and defend the idea that the government should create protected areas for each settlement project, and allow settlers to undertake agricultural activities in the whole lot (instead of promoting settlement of families and later keeping these families from making economic use of their lots).

6.4.4 – Cattle ranching as a preferred economy but not a 'cure all' strategy

As mentioned elsewhere in this dissertation, cattle-ranching is the preferred land-use option in Humaitá, for several reasons: less dependence on good quality roads, on electricity, or on qualified labor; it may work as a retirement fund or as an insurance policy, since cattle herd size keeps growing and can be promptly sold whenever money is needed. Beef prices are more stable than many other products; cattle-ranching is also relatively easy and cheap to manage. Thus, it is no surprise that cattle is part of the livelihood strategy portfolio of 95% of Humaitá households in my sample, and the most important in 65% of the cases. However, it cannot be implied from this that cattle is an effective strategy for all types of farmers to improve their economic condition in the long term, since most small farmers cannot afford the amount of land which is required to yield consistently larger income from cattle-ranching alone. This is probably why mixed husbandry and diversification on land-use and livelihood options have been found to be so important in Humaitá. There is also indication that livelihood options based on more intensive land-use systems (higher inputs/area of land) such

[95] Tocantins was established in 1996 neighboring the northern border of Humaitá. Many second generation residents of Humaitá were either direct beneficiaries in Tocantins (originally settled by Incra), have been buying land there, or have been working on selective timber exploration in Tocantins.

as agroforestry, annual and perennial crops and fish breeding, provide more consistent opportunities for improvement of economic situation in the long term that does cattle alone. This is especially true if some kind of extra value can be aggregated to products, such as by processing fruits into dried bananas and pineapples (as in the fruit drier processing plant owned by the Group of Ecological Farmers of Humaitá), processing milk into cheese or production of manioc flour or powder (*goma para tapioca*). Other important strategy to increase household earnings is to take opportunity of marketing agricultural produce directly to consumers in the farmers' market in Rio Branco, as it has been practiced by farmers oriented toward organic agriculture. By offering differentiated products (organic products[96]), this group of Humaitá farmers was able to guarantee a stand (physical place in the market) and a stake (share of consumers preferences) in Rio Branco's market.

While production from annual and perennial crops might be able to improve farmers' livelihoods and income, this is true only for families that can rely on good roads to get to markets. Risks of loosing harvests due to lack of rain, infestations and diseases are also high, and so are risks of poor payoffs due to low crop prices (e.g. many coffee-growers went broke in the early 2000s due to low prices). Again, these circumstances provide background explanation for the diversification of land-use and livelihood options observed in many areas.

Steady sources of income (such as monthly salaries or other guaranteed income flows) have been found to be very important for maintaining Humaitá's lower income families, such as the ones living off subsistence agriculture and extractivism, when they run low on their budgets. As seen in Chapter 3, income from non-agricultural sources composed mainly by retirement pensions responds for 58% of local ex-rubber tappers' total annual income. Jobs available locally in ranches, timber companies and Vila do V and Vila do Incra

[96] Certification of their "*Produto Orgânico do Acre*" ("Organic product of Acre") stamp is underway

villages (such as in local schools, health centers, furniture factories and commerce) are also important on providing secure sources of income to several households in Humaitá; Not that there are plenty of jobs available. To the contrary, unemployment levels were believed to be very high in both villages at the time fieldwork was conducted there, as population in both villages have been steadily increasing, as discussed in Chapter 5. Timber companies take advantage of this situation and continue to buy high quality timber at prices significantly below market prices in Rio Branco or prices of pre-processed timber elsewhere. Since there is practically no more timber in Humaitá, selective timber exploration is done mostly in Tocantins settlement and neighboring farms. Humaitá residents are either contracted by service (*empreitada*) to realize forest clearings (*derrubadas*) or work as autonomous selective tree loggers, when they own an electric saw, which allows for higher payoffs; in this case, they purchase trees directly from Tocantins' settlers, cut them down, process them into boards which are then sold to furniture factories or construction firms.

The life-stories presented in this chapter point to diversification of livelihood options as a dominant strategy of adaptation to the dynamic conditions of settlement areas. Diversification of land-use activities requires inputs of labor, which might be less available to small households or farmers with restricted budgets. Social interactions with neighbors and social learning processes play an important role on increasing farmers' chances of making productive use of the changing opportunities available in colonization areas. And, from a perspective based on Turner's thesis on frontier expansion (1920), 'it's all about opportunities'.

CHAPTER 7 – CONCLUSIONS

The overall objective of this dissertation, as stated in the introductory chapter, was to examine relationships between land-use decision-making at the level of farm-lots, and settlement-level conditions (e.g. infra-structure), policies and processes. Specifically, the idea was to focus on how farmers respond to limited access to the information and infrastructure and to opportunities that are typical of a settlement project undergoing different phases of frontier development. In this process, I analyzed interactions among variables affecting families, communities and the agrarian structure of the settlement, and the land-use and land-cover outcomes (LUCC) resulting from these interactions. The analytical strategy used to approach these relationships was based on the discussion of five (5) research questions and seven (7) hypotheses[97]. The guiding principle to select these questions, among others, was their relevance to the problem of lot turnover, deforestation, and to the success of land reform programs in Amazônia and in Brazil.

This chapter concludes this dissertation discussing the outcomes of hypothesis testing and highlighting particular theoretical contributions offered by the study case presented here: -the importance of social learning in settlement projects, -factors affecting the von Thünen's model of land allocation and rent, and -the utility of Household Lifecycle Theory on explaining land-use diversification in the study area. Last, I discuss the implications of these findings to land reform programs in Amazônia and in Brazil.

[97] Research questions 1,3, and 5 were approached by testing one (1) hypothesis for each question, and research questions 2 and 4 were approached by testing 2 (two) hypotheses for each question.

7.1 – Hypotheses testing: the meaning of outcomes

Hypothesis 1 (H1) was oriented towards exploring differences in land-use and land-cover change among the three social groups of farmers included in this study: local ex-rubber tappers, colonist farmers and land investors.

Hypothesis 1 (H1) - *Variation on rates of land-cover change between farmers belonging to different groups is larger than the same variations observed among farmers belonging to the same group, during the 1975 – 2003 period of analysis.*

A Kruskal-Wallis non-parametrical test of k independent samples was used to test for H1. If I were to base my conclusion only on this statistical test, I would simply reject H1, since no statistical difference was found among land-cover change proportions observed between social groups of farmers. This would mean that despite differences on cultural background, on occupational history, on social position, and on structural conditions affecting land-use options, and based on a sample size of 63 interviews, social groups respond in a similar way to market forces on their land-use options.

However, the p-values obtained for comparisons across social groups were found close of being statistically significant in two cases: a) forest cover in 2003 and b) forest cover since 1975 ($p<0.001 = 0.068$ and $= 0.072$, respectively). These "almost significant differences" are explained by tabulated data on land-cover ($n = 63$) showing proportions on forested land in 2003 about 14% higher in lots belonging to ex-rubber tappers when compared to colonist farmers, and 9.5% when compared to land investors. Later in Chapter 5 it was found that proportions of deforested land in 1975 at the farm-lot level were positively correlated ($p<0.001$, **n=739,** which includes all social groups) to proportions of forested land in 2003. Since deforestation rates prior to 1975 took place almost exclusively in rubber-tappers' lots (colonist farmers and land investors were not settled in Humaitá by the time, and land devoted to their future occupation showed virtually no clearings in 1975), these results may be interpreted as higher proportions of forest in 2003 in lots belonging to ex-rubber tappers. These results are consistent with my field observations, which point to ex-rubber tappers still maintaining strong consumptive ties to forests, even though rubber-tapping is not economically viable anymore. Forests have a higher cultural value to ex-rubber tappers, who collect a wide variety of fruits and other non-timber forest products more often than individuals belonging to other social groups. This helps to explain the outcomes of both survey data and satellite data, that proportions of forested land in lots belonging to ex-rubber tappers are apparently higher than in lots belonging to colonist farmers and land investors. Thus, I do not entirely reject H1, since the factors listed above point to rates of deforestation in lots belonging to ex-rubber tappers as being lower to the ones shown in the other two groups. Protected areas and extractive reserves have been receiving considerable attention in the Amazon, and have been increasing in number and area as well. A better understanding of the land-use and land-cover change differences across social groups of farmers/rubber-tappers might be important on guiding future development programs on which conservation of forest cover plays an important role.

Despite increases in deforestation rates observed at the State and regional levels from 2000-2003, when compared to previous periods, deforestation rates observed in P.C. Humaitá decreased during this same period. One possible explanation is the apparent reduced number of deforestation licenses issued by the environmental protection agencies IBAMA and SECTMA after 1999. Another complementary explanation is that most forest cover in Humaitá settlement was already cleared by 2000. Lower proportions of forested land tend to result in lower deforestation rates, independently of deforestation control policies. The latter helps also to explain the apparently lower proportions of recently disturbed forest in lots belonging to colonist farmers.

While almost all ex-rubber tappers of my sample were already living in Humaitá by 1975, some 55% of colonist farmers and practically all land investors arrived only after 1986. This presents a potential limitation to the analysis of land-cover change, particularly when comparing social groups on earlier stages of colonization, for which no information on previous occupants is available. Some distinctions between colonist farmers and land investors may, however, trace back to earlier stages of colonization, and allow for comparisons across social groups after 1986. Such distinctions include: a) lot turnover proportions of 68% on lots belonging to colonist farmers (32 % being original settlers) compared to 92% of turnover proportions on lots belonging to land investors; b) while 40.5% of colonist farmers are oriented toward land-use strategies that require good access to urban markets (agriculture and mixed husbandry), only 15.4% of land investors fall within these categories. In fact, most land purchases by investors done along the late 1980s and early 1990s[98] were in remote areas with poor connection to markets, and where proportions of forested land are higher than in more accessible areas, while colonist farmers purchased land with better connections to markets.

High deforestation rates observed during the 1993 to 1996 period at the settlement level, associated with lower proportions of secondary re-growth in 1996 might point to

[98] Land investors bought land mainly for cattle ranching purposes or as a shelter against inflation, which do not require good access to markets and can thus be purchased at lower prices, when compared to land better served by roads.

overall better economic conditions following *Plano Real* (in 1994) which resulted in effective control of inflation at the national level.

Hypothesis 2A (H2A) and 2B (H2B) were proposed to test farmers' responses to uncertain conditions of access to urban markets and of access to agricultural credit:

Hypothesis 2A (H2A) – *Time-distances from farm lots to local urban centers are significant for explaining variation in land-use strategies adopted by farmers.*

Hypothesis 2B (H2B) – *Enrollment in agricultural credit programs is not significant for explaining variation in land-use strategies adopted by farmers*.

A Multinomial Logistic Regression (MLR) model was used to test for both hypotheses, and resulted in the acceptance of H2A: time-distances from farm lots to urban centers have a significant effect on explaining comparative differences on land-use strategies adopted by farmers; this represents the confirmation of the importance of the von Thünen's model to explain variability on allocation of agricultural land in the study area (the meaning of this outcome is explained in section 7.2.2). The MRL model resulted also in the rejection of H2B: while some comparisons on the effect of credit adoption over land-use strategies did not result significant, other comparisons did.

The higher the number of agricultural credit loans a farmer enrolls, the higher the probability of this farmer being "agriculture" oriented when compared to "subsistence/ extractivism" or "mixed husbandry". Also, when comparing "agriculture" and "cattle-ranching", *p* values come substantially close to 0.05, meaning the level of significance had been almost reached. Thus, H2B is rejected because use of agricultural credit has been shown to be associated with "agriculture" as a land-use strategy. Credit lines for annual crops entail less bureaucracy (promptly available cash, less administrative hassles) and more flexibility (farmers are allowed more flexibility on the use of loans) than credit lines for cattle-ranching, dairy production or infra-structure, and are thus more attractive to farmers.

Another interpretation is that agriculture-oriented farmers in Humaitá are more prone to take risks and maximize income, and could be called risk-indifferent, according to Ortiz (1967) terminology. Therefore, they would be less concerned about risks and uncertainties[99] of not being able to repay credit loans, when compared to farmers oriented towards other land-use strategies, and engage thus more often in agricultural credit programs. This rationale is consistent with riskier/more uncertain returns to investments associated with agricultural crops, given that constraints on transportation networks, and fluctuation in both market prices and environmental factors affect agricultural crops more often than cattle-ranching, as discussed in the introductory chapter and pointed out by the literature in land-use in Amazônia. Probably both interpretations (better credit lines for agriculture and risk-indifference) are valid and complement each other on explaining credit adoption rates.

The objective of Null Hypothesis 3 (H3) was to test if some specific attributes of farmers are important for approval of credit loans for agriculture:

[99] As discussed in Chapter 1, decisions under risk/uncertainty refers to decisions falling within the risk/uncertainty *continuum*.

Null Hypothesis 3 (H3) – *Neither household income, level of education, possession of titles to land, nor credit history are significant in explaining credit enrollment variation across farm lots from 1998 to 2004.*

The use of a Binary Logistic Regression model resulted in the acceptance of H3: none of the explanatory variables included in the model show significant effect on explaining variation on adoption of agricultural credit during the period analyzed. credit history, however, could not be included in the model because it was considered a sensitive issue and data quality might have been compromised.

Even with no significant effect of any of the variables included in the model, credit-users showed income levels 37% lower than non-credit users. This shows that agricultural credit programs are (possibly) being effective on addressing the needs of the lower income portion of Humaitá residents. An indirect (or "triangular") relationship might help to explain this outcome: 1) FNO resources are preferentially allocated for loans focusing on annual and perennial crop projects; → 2) agriculture as a land-use strategy is associated with lower income farmers; → 3) lower income farmers focusing on annual and perennial crops would have higher chances of having their applications for agricultural credit approved. This indirect relationship is probably helpful on explaining the association between low income levels and credit adoption rates (I am assuming here that, based on my interviews with extension agents, low income has not been used as a condition favoring approval of credit loans).

Eighty percent of credit-users have been found to be affiliated to rural producers associations (RPAs), while sixty percent of non-credit users are not. This outcome was expected since banks established the rule that credit loans approval were conditioned to affiliation to RPAs. It suggests that if it were not for purposes of enrollment in credit programs, most Humaitá residents would not be affiliated to RPAs, and that many RPAs are short-living precisely because they were created mainly (or exclusively) for credit enrollment purposes.

Possession of titles to land and level of education are also unrelated to credit use in Humaitá, indicating that approval of agricultural credit loans are not conditional to land titles being offered as collateral, neither to the level of education of Humaitá farmers.

The local-level analysis of the impact of agricultural credit on land-use and its regional contextualization allowed highlighting important issues associated with the impact of credit policies on equitable and sustainable development. Regional data confirmed the existence, at an aggregated level, of a positive correlation between credit acquisition and an increase in deforestation. The historical overview presented revealed how this correlation can be the product of the control of particular stakeholders over credit policies (e.g. support for large cattle-ranching operations), especially during the 1970s and 1980s, and of the stage of settlement (i.e. newer frontier versus older frontier). However, the local-level analysis only partially supports these considerations. In fact, there is no significant difference in the proportions of forested land in lots of credit-users and non-credit-users[100] in P.C Humaitá. Cattle-ranching in the Amazon is mostly a self-financed activity that seldom depends on government subsidies or credit programs anymore (Faminow, 1998). This is supported by results from Chapter 3 showing that most credit-users in Humaitá are agriculture-oriented farmers, and confirms earlier findings that factors affecting land-cover changes in the Amazon vary in explanatory power across levels (intra- and inter-regionally), and cannot be

[100] As a caution note, the analysis in use of credit extends only through the five years preceding fieldwork.

fully understood based on regional-level analysis alone (Brondízio, 2005, 2006; Brondízio *et al.*, 1994).

The trends observed in the use of agricultural credit in Humaitá are indicative of the importance of empowering the broadest range of social actors in the definition of economic and development policies. This had occurred, for example, with the implementation of *FNO Especial*, and is now occurring with the implementation of *Proambiente*. These represent important steps towards improving the distribution of agricultural credit resources, in relation to the credit policies of the 1970s' and 1980s', but there is still a lot of work that remains to be done. Particularly, agricultural credit loans should be less bureaucratic (allowing promptly disbursement of funds to farmers), and more flexible in the use of resources. Some credit lines such as *PRONAF* (National Program for Family Agriculture) micro-credit loans for annual crops are already effective on considering these issues and should be used as an example to other credit lines. Participation by all social actors involved in agricultural policies in the Amazon is critical for achieving governance outcomes that effectively balance the requirements of social equity, regional integration and development, and sustainable land-use and use of forest resources.

Hypothesis 4A (H4A) and 4B (H4B) were proposed with the objective of understanding better the context and land-cover associations of lot consolidation within P.C. Humaitá's agrarian structure:

Hypothesis 4A (H4A) - *Lot consolidation is higher where time-distance to local urban centers is higher.*

Hypothesis 4B (H4B) – *Deforestation rates are higher where lots are consolidated into larger properties.*

The Spearman's rho test for non-parametric correlation based on all properties in P.C. Humaitá (n = 739) was used to test these hypotheses. H4A was accepted: lot consolidation showed a highly significant positive correlation with time-distances of lots to urban centers, and H4B was rejected: proportions of deforestation at the farm-lot level are not correlated with lot consolidation. While survey data (n = 63) showed rates of lot turnover of 65.1%, data from the entire settlement (n = 739) showed lot consolidation happening in 28.9% of P.C. Humaitá's lots. This indicates that a significant proportion of lot turnover is not associated to lot consolidation.

The positive correlation found between lot consolidation and time-distance is interpreted as follows. Along the settlement's lifetime, difficult access to urban centers in remote areas of Humaitá contributed to increase the number of farmers willing to sell their lots at lower prices when compared to more accessible areas. Returns to investments in land purchases in these areas have been favorable to land investors interested on either cattle-ranching or land speculation (purchase of land as a shelter against inflation). Land investors took advantage of opportunities to purchase contiguous lots, since management of cattle herds is favored by consolidating lots into larger properties. On the other hand, lots located in areas served by better quality roads and closer to urban centers have greater rent values and present higher demand. This demand is composed not only by land investors but by colonist farmers willing to move to Humaitá (and live there) as well. Lots being put for sale in these areas might be used for a more diverse set of economic alternatives, including the ones with higher returns to area of land. Higher competitiveness for lots associated with lower time-distances to urban centers contributes to lower proportions of lot consolidation in these areas.

The potential relationship explored in detail by Campari in “Challenging the Turnover Deforestation Hypothesis” (2002), could not be observed in the study area (rejection of H4B). My approach to test the Turnover Hypothesis captures, however, only part of the process since I did not study rates of deforestation promoted by out-migrating Humaitá settlers in neighbor frontier settlements, such as P.A. Tocantins. Also, by using proportions of deforested land (relative deforestation) at the farm-lot level in the correlation analysis, I might have overlooked part of the lot consolidation effect on the rates of deforestation (absolute area in hectares) observed at the settlement level.

The lot turnover effect by itself is probably a factor that might lead to higher conversion of forests to pasture (when compared to lots that have not been sold), independently of being connected to lot consolidation or not[101]. This is especially valid if buyers are not considered liable for forest clearings by previous owners whenever applying for licenses to clear extra forested land. While land investors buy land to consolidate lots into larger properties, mostly cattle-ranches, newcomer colonist farmers also use cattle-ranching or mixed husbandry systems with a strong (and pasture dependent) dairy component, which also requires significant conversion of forest to pastures.

A comparison of land concentration (area of land by owner) in the study area in 1997 (Cavalcante, 1998) with land concentration in 2004 showed that the area of land under single-lot owners dropped from some 70% in 1997 to less than 50% in 2004, while the area

[101] The type of lot turnover that does not result in lot consolidation is not considered in the Turnover Hypothesis of Deforestation as framed by Campari (2002)

of land under five-lot owners more than doubled in size. Gini indices in land distribution estimated in 0.12 in 1981 increased to 0.39 in 2004. These results point to active land markets in the study area leading to an increasingly biased land distribution, and undermining the goals of re-distributive land reform. This dissertation points to the importance of considering the role of land markets during different stages of settlement formation and infrastructure quality as forces undermining the goals of land reform in the region. In relation to land markets, there are two points to be considered: 1) control over transference of untitled land in land reform areas is clearly not working under current INCRA policies and the overall institutional environment operating in Amazônia. For effective restriction on commercialization of untitled land, better conditions are needed for farmers to remain in their lots; 2) The achievement of these conditions might be too expensive under the current institutional setting; land reform could work better under a system more open to participation of a diverse set of actors, such as the beneficiaries themselves and a varied set of service providers from the private sector (see more ideas on section 7.3). Such measures could speed up land titling in land reform areas, allowing land markets to develop without the distortions created by current restrictions (see Deininger 1999 for a more elaborate discussion on land markets in land reform areas). Settlers would in this case receive better offers for their lots, allowing them to expand the range of economic alternatives that usually follow offers by buyers, including selling only part of the lot and not the whole lot. Land commercialization taxes need, however, to be implemented, preferentially within a system that balances taxes according to the size of land purchases and the financial capacity of taxpayers. Revenues from land taxes could then be used to finance future land reform projects.

We have known for a long time that reliable all-weather roads are needed for successful settlement projects in the Amazon (Nelson, 1973). Greater participation of both public and private stakeholders in land reform programs may also help to provide better services on road construction and maintenance. Recently, some promising examples of public-private partnerships in road operations have been reported for the Santarém region (Nepstad et al, 2004). These partnerships are more effective on attending farmers' demands for better road infra-structure and titling of land, and helped also to increase legal commercialization of timber. Such examples show perspectives of more efficient use of resources, and a mechanism to enhance chances of settlers to remain in their lots.

The objective of Hypothesis 5 (H5) was to test if diversification of economic activities has been an important risk minimization strategy in P.C. Humaitá.

Hypothesis 5 (H5) – *Households present a wider range of income related activities in 2003-04 than when they arrived at the settlement. As households mature in the frontier, they engage in an increasingly larger number of economic activities, aiming at diversifying income and minimizing risks.*

Hypothesis testing was conducted through quantitative analysis on economic choices according to its relative importance to households and was complemented by descriptive analysis (life-stories) on the livelihood strategies adopted by farmers along settlement aging. H5 was accepted: households engage in an increasingly wider portfolio of livelihood options (which include both market and non-market economic options) as the availability of economic opportunities increase with settlement aging, aiming to diversify income and minimize risks.

Quantitative data highlighted some points including:

- A noticeable pattern of diversification in livelihood strategies occurred during the study period [within the sample of farm-lots studied here (n=63)].
- Cattle-ranching is the preferred land-use option in Humaitá, and part of the economic portfolio of 95% my sample. It is also the most important land-use strategy in 49% of the cases. However, cattle-ranching is not a 'cure-all' remedy, given land limitations of most agricultural family enterprises. In Humaitá, this gap is filled by mixed husbandry and diversification of land-use and other economic options. Fieldwork showed that agroforestry and fish breeding, for instance, provide more consistent opportunities for improving the economic situation in the long term that does cattle alone.
- Annual crops were an important economic alternative for all three social groups when they first arrived in the settlement (or by 1981, in the case of local farmers), but lost much of its commercial importance by 2004. However, annual and perennial agriculture continue to be important for household consumption for both local and colonist farmers; annual crops are important to some land investors as well, who intercrop corn with grasses in the first year of pasture establishment.
- Retirement pensions seem to be more important than both salaries and hourly wages for both local and colonist farmers. Pensions are more important for local farmers, as this group has a higher elderly population proportion than the other social groups. Also, most local farmers have been granted *soldado-da-borracha* (rubber soldier)

pensions, which are equivalent to approximately two minimum wages. Most colonist farmers, however, receive pensions approximately equivalent to one minimum wage.

- Steady sources of income including salaries, hourly wages and retirement pensions were not available to local farmers in the study sample (by 1981), and nearly unavailable to the colonist farmers of the sample as well.

The life histories of different farmers indicated that diversification of livelihood strategies occurs as an adaptation to the uncertain and dynamic conditions of settlement areas. Farmers diversify their economic base to take advantage of the widening range of economic opportunities that are common in developing frontiers. They do so by exploring a range of natural resources available at the farm-lot level, including plants and game from the forest, fish from rivers and raised in ponds, and a wide range of crops and animal husbandry that are used both for household consumption and commercialization. Farmers also are engaged in wage labor and a range of urban and rural commercial activities. Additionally, surpluses are frequently exchanged among households, supporting a parallel economy based on reciprocity and strengthening of social networks and cooperation.

However, diversification of land-use activities requires inputs of labor, which might be less available to smaller households or farmers with restricted capital. In some cases, households with a diversified set of economic options contradict the diversification trend and reduce their range of exploration of livelihood options, occurring for instance in cases where part of the household labor force, typically second generation members (e.g., sons, daughters, and in-laws), out-migrates to urban centers or other fronts. This situation requires the first generation settlers (e.g., their parents) to re-adapt to new conditions, especially when capital availability is restricted, and limits hiring of wage labor. A reduced labor force results normally in a narrower range of economic options to be potentially explored, compromising the risk minimization benefits from economic diversification. Hence, most elderly settlers in this situation choose to focus on cattle-ranching to secure their source of income. For elderly Humaitá residents, retirement pensions often play a key role in providing the basic source of income that sustains their living situation. Remittance money from sons, daughters and in-laws also plays an important role in sustaining elderly settlers.

Life-stories suggest that local ex-rubber tappers have built stronger ties to land and to community life in Humaitá when compared to colonist farmers (most land investors live in Rio Branco and experience limited community life in Humaitá). Rural producers' associations formed by ex-rubber tappers, or by a considerable proportion of individuals belonging to this social group, seem to be focused on multiple projects and 'survive' for longer periods than ones formed mainly by colonist farmers (who are often focused on bank requirements for credit acquisition). Stronger ties to community life result normally from shared kinship and from shared experiences that have evolved since the time before agricultural settlement (including the period equivalent to the 'rubber-tapping frontier'). This social environment and the build up of trust among the oldest Humaitá residents provide the building blocks of social capital among the ex-rubber tapper community.

A similar process is also developing among colonist farmers, who are currently struggling with challenges that are typical of an earlier stage of settlement. Again, lot turnover seems to play a key role in the development of the agrarian structure of Humaitá, in this case acting as a barrier that limits the unfolding of community life and the development of the social structure. With the out-migration of settlement members from Humaitá and their replacement by incoming families, trust relationships are seriously affected, often disappearing with each out-migration and having to be slowly re-built, thereby affecting the development of social capital and of all entrepreneurial activity that depends on it, such as community development projects and infrastructure maintenance, agricultural product processing plants and transformation industries, and other agricultural projects proposed by rural producers' associations (RPAs). Other factors affecting the build up of trust within RPAs include the conflict between individual and common interests of members of RPAs. For instance, many cases of members using the RPA arena for personal political interests were reported to me during fieldwork. Other problems include 'free riding' where members are willing to use RPA resources without giving anything in return to the association.

7.2 –Some theoretical remarks: households, social learning, and land-use allocation

This dissertation aimed to link land-use decision-making processes identified through household-level analysis with the agrarian structure of a settlement project in the Brazilian Amazon. The colonist footprint[102] and the changes observed in settlement structure were studied in P.C. Humaitá, in the state of Acre, based on several household and land-use theories: land-use decision-making, the von Thünen model of land-use allocation, and household lifecycle theory. I used integrative methods that combined social sciences tools and remote-sensing and GIS techniques. The aim was to identify common and specific trends in land-use and economic options of three social groups (and the relationships with the agrarian settlement structure and land-cover change. The sub-sections below discuss some of the theoretical highlights of this dissertation.

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[102] The colonist footprint can be characterized by the process of occupation, consolidation, and progressive expansion of productive activities at farm-lots opened through settlement programs (Brondízio *et al.*, 2002).

7.2.1 – Social learning and land-use decisions in the context of settlement projects

It was said in Chapter 1 that social learning processes play a key role in enhancing adaptive strategies used by farmers in frontier areas, where access to information related to land-use decisions might be very limited more than in non-frontier areas. By interacting with neighbors and observing their behavior and the outcomes of their behavior, farmers complement and reconsider the knowledge obtained from their own experiences in important ways. Here, I want to briefly discuss the meaning of 'social learning' used in this dissertation within a wider theoretical perspective, since the literature offers different interpretations of this. Also, I will discuss some situations where social learning takes place, and why these are important for increasing the welfare of households and communities.

A broad definition of the role of social learning on the composition of human behavior and knowledge is:

> *Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them what to do. Fortunately, most human behavior is learned observationally through modeling: from observing others one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action."* (Bandura, 1971: p.22).

With such a broad definition[103], the 'social learning' concept has been used in many disciplines for a wide range of applications. For instance, it has been used to address problems in formal and informal education systems (Foley, 1999), as a psychotherapeutic

[103] This author is frequently cited in the social learning literature for his theoretical contributions to the theme.

approach to family intervention and to the study of deviant behavior (Patterson and Reid, 1975; Alkers et al., 1979), and to the study of sex differences in behavior (Mischel, 1966). It also has been used in medical studies looking at variables affecting health (Rosenstock et al., 1988), in demographic research on models of fertility (Montgomery and Casterline, 1996) and in biological studies of animal behavior (Nagell et al., 1993).

Within social and political science disciplines, there is a wide range of applications involving the concept of social learning. For instance, 'herd behavior' models were used to study situations where individuals would fail, according to Neo-classic economic assumptions, to act as rational agents; however, under broader assumptions of bounded rationality, 'herd behavior' has been shown to be more efficient in achieving productivity goals than individualistic decision-making processes in several contexts (Chamley, 2003). This is the case with the adoption of new technologies by farmers, as uncertainty about possible outcomes often frequently plays an important role in explaining the spatial and temporal patterns observed in rural areas. By observing outcomes of adoption of new technology by neighbors, farmers make better informed decisions on whether to adopt a new technology. Social learning processes based on rules of thumb that favor adoption of more popular agricultural technologies tend to lead to fairly efficient decisions (effective incorporation of technologies into the production system in the long run), but adjustment can be slow when new technologies are first introduced (Ellison and Fudenberg, 1993).

The variation on rates of adoption of agricultural credit observed among Humaitá farmers in Acre is an example of the previously discussed issues. Farmers observe their neighbors' behavior toward new credit lines offered by agricultural development programs. They organize meetings within rural producers' associations (RPAs) or informally discuss contract rules (e.g., interest rates, repayment period, collaterals, flexibility on resource use) and outcomes of engaging in different lines of agricultural credit. In doing so, they substantially improve their level of information about the payoff structure of different credit lines, which allows them also to negotiate better credit loan deals with financial agencies, especially if the community is 'sufficiently' organized.

A different situation was observed in farmers' reaction to the 'death of pastures' problem that affects up to 40% of farmers' pasture area in some parts of Humaitá. The local branch of EMBRAPA (Brazilian Agro-Pastoral Research Agency) recommends the substitution of affected *Brachiaria brizantha* grass with other species of the genus *Brachiaria* (e.g., *B. humidicola)* or grass varieties that are less susceptible to water-clogging that is often connected to Plynthic Ultisols areas. This represents, however, a considerable investment for most farmers[104], who experiment with several types of palliative measures to keep this problem under control (such as reducing grazing pressure, use of fire and even tilling the top-soil layer), but with very limited success, from what I was able to observe. Other farmers have been following EMBRAPA's recommendations, with better results, but the pace of adoption of this pasture management technique was slow by the time fieldwork was conducted. My interpretation is that most farmers are still looking for less expensive alternatives to deal with this problem, experimenting with alternative practices/palliatives, and keep 'not only one eye but two eyes' on the outcomes of their neighbors' experiments.

In recently established colonization projects in the Amazon, social learning might be more important for making well informed land-use decisions when compared to non-frontier rural areas. This is because factors such as harsh environmental conditions (e.g., excessive

[104] It is expensive not only because of the financial expenditures of replacement operations, but also because *B. brizantha* productivity is normally much higher than the productivity of *B. humidicola* or most other grass varieties.

rains, poor soil fertility), lack of infrastructure and markets for agricultural products, and overall absence of formal institutions contribute to uncertainty in the payoff structure of investments in agriculture. Humaitá farmers have been using social learning processes to better adjust to these conditions and to compensate for the deficiency in access to information. For example, I observed that local economies based on exchange of agricultural/forest goods and reciprocity tend to be stronger in parts of the Humaitá settlement that are poorly connected by roads to urban centers, when compared to more accessible areas. Also, farmers build networks of communication and use them later to get information about eventual government investments in the region. Several Humaitá residents are hired by public agencies to work on local schools, health centers and in the local offices of INCRA and EMATER that exist within the settlement area. Frequently, these workers know ahead of time about government action plans in the settlement, such as road maintenance operations, and inform their friends and relatives about this plans. Before decisions on resource allocation are made by government officials, farmers organize and demand open discussions with settlement residents to be conducted, increasing the chances of having the road that serve their lots to be included in road maintenance program.

In Chapter 6, it was suggested that social interactions with neighbors and social learning processes play an important role on increasing farmers' chances of making productive use of the changing opportunities that are available in colonization areas. This is valid for several stages of the lifetime of Humaitá settlement. For instance, during earlier phases of settlement, settlers learn from locals and from more experienced residents about the ecological attributes of Amazonian forests, soils, and climate. Such knowledge allows them to benefit from game and other extractive resources of the forest, to adopt agricultural practices better suited to local ecosystems (e.g., such as the adoption of swidden agriculture, or incorporating local criteria of agricultural site selection, such as the presence or absence of particular plant species) and to minimize risks and uncertainties related to rainfall distribution (e.g., by following agriculture calendars used by locals and by using popular/ecological indicators of weather variation such as behavior of animals). As the settlement ages, social learning helps farmers to maximize the use of opportunities related to public services[105] such as health services, public transportation, education, identification of better lines of agricultural credit and organizing for the maintenance of better road conditions. Social learning is also critical on enhancing farmers` capabilities to negotiate better commercial deals when selling their agricultural produce, bargaining discounts in agricultural retail stores, or dealing with loggers and politicians on pond construction projects (as discussed on Chapter 6). Thus, social learning might be seen as a product of intercommunications and sharing of experiences within a forming community. It allows farmers to make more effective use of information, and guides farmers in taking advantage of their neighbors' experiences, reducing uncertainties that limit farmers' use of economic opportunities in frontier settings. Moreover, it helps farmers' on acquiring the knowledge that is necessary to diversify their economic portfolio. As mentioned above and elsewhere in this dissertation, diversification of livelihood strategies enhances farmers' chances of success and use of rapidly changing opportunities in settlement projects. Based on Turner's perspective (1920), opportunities comprise the essence of frontier expansion and development.

[105] Including job offers that are put available by public agencies.

7.2.2 – The von Thünen model in Humaitá

The von Thünen's model of spatial distribution of agricultural land states that the rent values for land are directly related to agricultural net income per area, and to proximity to urban centers or transportation costs (Dunn, 1970). Empirical evidence supporting von Thünen's model has been found in Humaitá, Acre, confirming that it is relevant on helping to explain differences on land-use strategies adopted by settlement's farmers. Some land-use strategies such as agriculture and dairy production entail high risks of financial loss, because they depend on road quality conditions that are extremely variable throughout the year. This factor is translated into higher transportation costs, when compared to alternative land-use strategies such as cattle-ranching and extractivism. Thus, transportation costs were found to be highly significant in explaining variation of land-use options by farmers in Humaitá settlement: while subsistence/ extractivism and cattle-ranching are associated with greater time-distances, agriculture and mixed husbandry are associated with smaller time-distances.

As discussed in Chapter 3, however, empirical confirmation of von Thünen's model has already been shown in several studies worldwide (O'Kelly and Bryan, 1996; Chomitz and Gray, 1996; Nelson, 2002). Given its simple structure, flexibility, adjustment to different applications and usefulness, the von Thünen's model is a landmark probably as important to economic geography as the economic principles established by Adam Smith are important to classic economics (Nelson, 2002). So, what's new about the application of von Thünen's theory to the conditions operating in P.C. Humaitá ? Or, in other words, what features linked to transportation costs and net income/area in this settlement project contribute to strengthen or to weaken the von Thünen's relationships, or add new components to it?

First, let us consider the socio-economic and environmental conditions that reinforce the importance of road quality in settlement areas in the Amazon. The agricultural calendar in this part of Amazônia, which is based on rainfall distribution throughout the year, is determined in such a way that the harvest time of most agricultural crops falls during the rainy season. This is also the time of the year when road quality is worst, given the negative impact of rainfall on the maintenance of road conditions. Thus, the harvest season, which corresponds to the time of the year when farmers are most in need of good quality roads to be able to commercialize their crops, is when commercialization is harder due to poor road conditions. Thus, farmers located along bad quality roads can not afford to adopt commercialization of agricultural crops as a significant economic strategy, given the risks of loosing their harvest due to impassable roads. If, however, investments on road maintenance (including gravelling dirt roads) are made during the dry season, most roads remain passable and under good conditions throughout most of the rainy season that follows, but road maintenance operations are temporary and do not last for more than one rainy season. Hence, there is a need to conduct annual road maintenance operations, or pave dirt roads definitively with asphalt, if agricultural development and its effects on promoting regional integration are considered a priority for local governments. This factor reinforces the importance of transportation costs on explaining variation in land-use choices in the study area, which adds an important component to von Thünen’s proposed relationships.

One aspect of this study that complicates the use of von Thünen’s model is the fact that some parts of the study area remain virtually non-accessible by motor vehicles during most of the rainy season. The calculation of transportation costs might be considered, under these conditions and based on the network analysis method of time-distances, excessively subjective or even arbitrary. Given that the time-distance method is based on establishing an average speed value for each road segment of the network, what is the value to be used for road segments that are temporarily non-passable during the rainy season[106]? The alternative I used was to enter extremely low speed values for such road segments, based on an estimated number of days that passage through these segments remains blocked during consecutive rainy days, according to farmer information. Lack of accessibility to urban centers during the rainy season limit commercial land-use options in these areas almost exclusively to extensive cattle-ranching, given that cattle can walk itself to markets, has no storage problems, and does not depend on good road conditions.

A last comment on the adequacy of von Thünen's model on explaining land-use variability in the study area concerns investments on infra-structure development in settlement areas. Land-use changes in frontier areas in the Amazon occur faster than in non-frontier areas, since transportation costs fluctuate according to investments in road maintenance and paving. Frequency of traffic of heavy load trucks and biophysical factors such as soil type, relief, and the geography of the drainage system were all found to influence road conditions in the study area. The allocation of road maintenance operations is however linked not only by the actual condition of roads, but (and most importantly) to the political influence of different farmers and rural producers' associations (RPAs). Land investors with important connections within the government have been shown to have a significant influence on attracting maintenance investments to the roads serving their own properties. On the other hand, well-organized RPAs also have strong political voice, and are constantly pressing local government agencies for more effective operations on road maintenance. Their

[106] Chapter 3 provides details on the calculation of time-distances from all lots of the settlement (n = 739) to three local urban centers, for both dry and rainy seasons.

power on requesting these kinds of investments is higher when a positive benefit/cost ratio can be shown, due to a potential increase in local agro-pastoral output.

7.2.3 – Household life cycles or farm-lot cycles of land-use?

As discussed in Chapter 1, Household Lifecycle Theory (HLT) is based on the household-farm economy approach developed by Chayanov ([1925] 1966) for Russian peasants. Later, the American anthropologist Goody (1958) introduced the study of household stages to complement Chayanov's insights (VanWey et al., 2005). HLT establishes relationships between the extent and pace of agricultural cultivation with cycles of household expansion, aging and dispersion, and has been recently used to address land-use change at the farm-household level in the Amazon (Walker and Homma, 1996; McCracken et al. 1999).

Chapter 6 of this dissertation analyzed the economic strategies adopted by households as they mature in the frontier. It was found that most households tend to diversify their economic portfolio as a strategy to minimize risks and to take advantage of the changing economic opportunities that are available along settlement aging. Diversification of land-use choices and other economic activities requires, however, availability of labor within the household or financial resources to pay for hired labor. While large households show a clear trend to diversify their livelihood alternatives portfolio, small households with lower income tend to focus on a limited set of alternatives, normally cattle-ranching and/or other type of animal husbandry, which might be complemented by retirement pensions. In this sense, HLT seems important to explain variations in the range of land-use strategies, since increase in labor availability with the aging of households is a key factor allowing for diversification of land-use strategies. However, other factors discussed in Chapter 6 (such as the limited set of possibilities of diversification of economic activities during early stages of settlement), and in Chapter 5 (the effect of lot turnover and land markets on land-use and land-cover change) are also important to this discussion, in the sense that they might undermine the explanatory power of HLT in establishing relationships between the range of economic activities observed at the farm-lot level and households expansion, aging and dispersion cycles.

During initial stages of settlement, the range of economic alternatives available to households is, as expected, limited, independently of the stage, size or composition of the household. This happens because many land-use options require some time in the lot to be implemented (Brookfield and Stocking, 1999). For example, cattle-ranching is not an economic option for original settlers[107] when they first arrive in the settlement, since it requires a minimum period of time for clearing forests and formation of pastures in proportions compatible to areas required for cattle-ranching. Moreover, smallholders in settlement projects work normally with high discount rates, meaning that land-use options with short term returns, such as annual agriculture, are normally preferable to the ones with long term returns (e.g., cattle-ranching and perennial crops), especially during the establishment phase. Other factor reducing the range of economic options in the early stages of settlement is the practical absence of job markets. In this sense, households diversify their economic portfolio not only because of the increase on labor availability (which is explained by HLT), but also because of temporal factors related to the formation of the lot and settlement aging.

[107] Original settlers correspond to the first families settled by INCRA in P.C. Humaitá, which happened in the 1981 – 1986 period.

Lot turnover, on the other hand, allows newcomer families to begin their economic life in the settlement with an already diversified economic portfolio, depending on investments already present on the lot by the time they buy it. Again, this is independent of the stage of the household. For example, a young and recently married couple of settlers might buy a lot where a diversified set of land-use investments, such as annual and perennial crops, pastures and ponds for fisheries has already been made by the previous owners, allowing them to start their household lifecycle with an already diversified set of economic activities. Therefore, cycles of land-use within farm-lots and farm-lot history itself (independently of the household history) does also play an important role on the range of economic activities that are carried out within a lot. Lot turnover and the land market may interrupt the relationship between household cycles and farm-lot cycles, but not necessarily the farm-lot cycle itself, which shows us that HLT might not be applicable under these circumstances.

This means also that the range of economic possibilities that are available to families might be explained by their initial economic condition; the wealthier the incoming families, the greater the probability of buying lots with diversified sets of land-use investments already present, or of buying a larger number of lots. The conclusion is that HLT is important in explaining the range of land-use and other economic activities adopted by households in an aging frontier, but factors related to the cycle of the farm-lot itself might be as important or more than HLT in explaining diversification or specialization trends. Again, lot turnover appears to be a key factor driving economic trends and structural changes as settlements age.

7.3 – Implications to land reform programs in Amazônia and in Brazil

The Humaitá case and others discussed here (e.g., chapter 5 comparison with settlements in Altamira and Santarém in the State of Pará) suggest that demographic fluxes associated with land ownership structure in colonization areas are more complex than initially thought and reported elsewhere in literature. A significant proportion of original settlers remain in the settlement and develop local urban "seed" sprawls (or villages), after selling their lots or parts of their lots initially received from INCRA. This finding contrasts and complements earlier ones, where initial settlers who sold their lots were reported to migrate to either: (1) newer agricultural frontiers (Ozório de Almeida and Campari, 1995; Alston *et al.*, 1999); (2) local urban centers (Browder and Godfrey, 1997); or (3) return to their regions of origin (Moran, 1981). Several kinds of occupational changes occurred for these groups of settlers in their transition to local village residents. Many changed from agropastoral activities to local business owners and employees, public services employees, and hourly wage workers in the local ranching and timber sectors. Others manage to maintain their lots, or parts of them, and continue cash cropping and pastoral activities as their main or complementary source of income.

Despite official restrictions to commercialization of lots in settlement projects, informal land markets have been developing intensively in Humaitá, as well as along the Trans-Amazon (e.g., Altamira region) and BR-163 (e.g., Santarém region). Lot turnover follows not only investments in infrastructure (e.g., road paving increases land prices and the incentives of capitalization to moving-out farmers), but occurs also where access to urban centers is problematic. In these problematic areas it is frequently associated with lot consolidation, and other results in larger areas of forest converted to pasture. The lack of infrastructure and governmental support creates an incentive for farmers to shift from annual and perennial agricultural to cattle ranching, thus compromising in some instances initial goals of turning settlement projects into suppliers of a wide range of food products to local urban centers.

The Brazilian Land Reform Program has been an important driver of Amazon colonization and of agricultural expansion in the last three and a half decades. Given that this process is heavily charged with historical inequalities in access to land and political disputes among interest groups, the national government has been pressed for positive indicators of land reform actions. This leads to a primary demand on showing quantitative results: from 1995 to 2001, more than 580,000 families were settled in an area of over 18.7 million ha, corresponding to some 4,000 settlement projects (INCRA, 2002). This is by far the most aggressive land reform agenda ever put in practice in Brazil and among the most ambitious in the world (Sparovek, 2003). According to Teofilo and Garcia (2003), the average price paid by the government per hectare decreased from R$382 to R$264 during the same period. However, these authors point out that "this price is not as low as one might expect" (p. 23), since only 21.1% of this land had been previously in use, and that the average agricultural quality of land distributed was classified under "lands with complex conservation problems and unsuitable for intensive use, but still adaptable to pastures and/or reforestation and/or wildlife" (p. 22). Hence, other indicators and qualitative evaluation, such as the *number of settled families who ultimately stay on the lots*, and are economically successful, should be more fully considered.

The high lot turnover rates and increasing in *Gini* indexes observed in Humaitá (225%), Santarém (49%), and Altamira (270%) result from an inappropriate model of land reform, incapable of providing minimum conditions to incoming settler families to remain on their lots. In this sense, one might ask whether lot turnover and land concentration indicate a vicious cycle of uneven land distribution in Brazil? To what extent does history repeat itself? The answer to the latter question is that it does to some extent, because of the skewed level of support received by settled farmers and the re-concentration trends mentioned above. However, the dynamic of demographic land distribution is complex, and includes, among others, continuous arrival and departure of settlers, intergenerational changes, fragmentation and a move from larger to smaller lots and to local villages, occupational change from producer to off-farm labor, and connectivity between urban and rural families.

If considering the question “What is the fate of public land in Amazônia?” it is known from census data that the percentage of public land in the region decreased from 30% in 1970 to 7% in 1996, showing a substantial contrast when compared to the decrease of 7% to 3% in Brazil as a whole (Gasques *et al.*, 2001, using IBGE data from 1970, 1980, and 1995–1996 censuses). The environmental costs are substantial: forest conversion of some 63.8 million ha to agropastoral use (Pacheco, 2006), and depletion of biodiversity, nutrients, and hydrological resources.

Thus, the implications of these findings to our evaluation of land reform models in the region depend on what we consider as the main objective of the Land Reform Program in Amazônia and throughout Brazil. Is it to reduce the inequality gap in access to land, providing opportunities for landless families to engage in agricultural production and increase agricultural output? If yes, than it can be concluded that the actual land reform model fails to produce the expected results, given the trends in lot turnover and land re-concentration observed in this study. If, however, the main objective of land reform in the

Amazon is to promote urbanization in rural areas, using rural families' labor force as a triggering mechanism for agropastoral expansion, and compensate settlers with opportunities of capitalization from selling their lots, then it can be said that the objectives of land reform in the Amazon are being met.

The question comes down, again, to the debate on the model of land reform and regional development we are looking for. Are we concerned about providing a temporal relief to the landless farmer problem and appeasing MST (Landless Rural Workers' Movement), while making sure public lands are privatized and converted slowly into large grain farms and cattle ranches? Or, are we instead looking for a deeper change in the Brazilian agrarian structure, with effective incorporation of landless farmers into the agricultural production sector? In this case, the actual land reform model is clearly inadequate. According to Abramovay (1996), land reform would be more socially effective in Brazil if it had occurred before the urbanization boom of the 1960s and 1970s (which it could have helped to smooth out). Nevertheless, it still has a potential to reduce rural poverty, if more consistent regional planning and infrastructural provisioning is implemented. An alternative mechanism of financing and executing land reform programs is also needed, including: (1) selection of areas designated for land reform based on criteria of environmental and economic sustainability of future settlements, in which focus is placed on areas served by all-weather roads and close to markets (Moran, 1990), and on achieving consistency between environmental legislation by the Environmental Protection Agency of Brazil (IBAMA) and INCRA, thus avoiding the regularization of settlements on irregularly occupied forested areas; (2) public-private partnerships with more accurate studies on the capability to provide infrastructure investments and delivery of public services (see Nepstad *et al.*, 2004, for some examples); (3) incorporation of representatives of the civic society around community-based programs in all phases of implementation; for example, use of a polycentric governance model based on multiple centers of decision making, formally independent of each other but under a structure of ordered relationships and rules, and with consumers as co-producers of public services (V. Ostrom, 1999); (4) diversified provision of technical assistance and agricultural credit support (also from the private sector) oriented toward the engagement of beneficiaries in agricultural markets (Deininger, 1999); (5) fiscal incentives to cooperatives to establish processing plants and transformation industries of agricultural products; and (6) implementation of a land tax system based in social and environmental indicators, creating incentives for landowners to engage in sustainable projects (Moran, 1990). Further research on the outcomes of recent experiences in land reform, including multi-agency networks, negotiated land reform programs, and community-based approaches are needed.

A challenge of conservation in the Amazon is to maintain forest cover outside parks. The challenge of land reform is to promote land redistribution that is compatible with economic sustainability, market integration, and long-term conservation of natural resources. There have been enough experiences in the Amazon to inform innovative governance approaches and promotion of rural development. Despite disagreements and problems, land redistribution and regularization is an historical need in Brazil and in the Amazon, and should continue to receive attention as a policy priority for the region.

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Appendix 1 – Contingency table for accuracy assessment of Landsat TM 2003 classification:

	Forest	Secondary Succession	Water	Cleared	Total	Comission Error
Forest	324	45	0	2	371	0.1267
Secondary Succession	0	91	0	60	151	0.3974
Water	1	1	90	1	93	0.0323
Cleared	0	38	0	270	308	0.1234
Total	325	175	90	333	**923**	
Omission Error	0.0031	0.48	0	0.1892		**0.1603**

OR 84.7% accuracy

90% Confidence Interval = +/- 0.0199 (0.1405 - 0.1802)
95% Confidence Interval = +/- 0.0237 (0.1367 - 0.1840)
99% Confidence Interval = +/- 0.0312 (0.1292 - 0.1915)

KAPPA INDEX OF AGREEMENT (KIA)

Using NEWCAP_TS_RB03_4CLASSES as the reference image ...

Category	KIA
1	0.8045
2	0.5097
3	0.9643
4	0.8070

NEWCAP_TS_RB03

Category	KIA
1	0.9949
2	0.4261
3	1.0000
4	0.7161

Overall Kappa = 0.7700

Curriculum Vitae - Thomas Ludewigs

Education	**Period**
• *PhD in Environmental Science* School of Public and Environmental Affairs, Indiana University.	*2000 - 2006*
• *MSc in Natural Resource Management — Emphasis in Agroforestry* Centro Agronómico Tropical de Investigación y Enzenanza (CATIE), Costa Rica.	*1996 - 1997*
• *B.S. in Agronomy* Escola Sup. de Agricultura "Luiz de Queiróz", Universidade de São Paulo, Brazil.	*1986 – 1991*

Professional Experience	**Period**
• *Assistant Instructor at SPEA, Indiana University* – Ministration of the course "E419/E519 – Remote Sensing & the Environment".	*Jan 2006 – May 2006*
• *Adjunct Instructor at SPEA, Indiana University* – Ministration of the course "E400-Seeking Sustainability: Use and Conservation of Tropical Forests".	*Aug 2005 – Dec 2005*
• *Research Assistant at SPEA GIS Lab, Indiana University* – Carbon Cycle on Deciduous Forests, Remote sensing, Land use and Land Cover Change, GIS.	*May 2005 – Dec 2005*
• *Research Assistant at ACT* – Anthropological Center for Training and Research on Global Environmental Change – Anthropology Department, Indiana University: GIS, data and database management, fieldwork interviews in the Amazon.	*Aug 2000 – Aug 2001*
• *Research Coordinator* and *General Coordinator* of Project "Arboreto: Agroforestry Research and Education in Acre – Amazônia", at the *Federal University of Acre.*	*Jan 1998 – Jul 2000*
• *Research Assistant with the Agroforestry Department* at CATIE– Costa Rica	*1996 – 1997*
• *Research Assistant with EMBRAPA* (Brazilian Agro-pastoral Research Agency) */ NCSU* (North Carolina State University): *"Alternatives to Slash and Burn Agriculture in the Amazon",* AM, Brazil.	*Jul 1993 – Nov 1995*
• *Research Assistant with INPA* (National Research Institute of Amazônia): *"The Extractivism on Eastern Amazônia: Ecological and Socio-economic Aspects".*	*Jan – Jul 1993*
• *Farm Manager at Agropecuária Fazenda São Bento*, located in Dourado, São Paulo, Brazil. Crew supervisor in the production of dairy, beef, corn and rice.	*Jan – Dec 1992*

Scholarships / funding	**Period**
• PhD funding: CNPq (Brazilian Agency for Scientific and Technological Development); WWF (World Wildlife Fund) Prince Bernhardt Scholarship; Tinker (CLACS/IU) and CIPEC/IU funding for exploratory fieldwork for PhD research.	*Aug 2001 – Jul 2004*
• While with UFAC: DCR (Regional Scientific Development)/CNPq scholarship.	*Mar 98 – Jul 00*
• MSc funding: SUNY (State University of New York)/USAID scholarship	*1996 - 1997*

Professional skills

Computer skills: Wide experience with text editors, spreadsheets (MS Excel), Imaging/Geographic Information systems (ERDAS Imagine, ESRI Arc GIS, Idrisi), statistics software (Statistical Analysis System (SAS), SPSS, Minitab) Database Management Systems (MS Access, some SQL-Oracle).

Fieldwork experience: Large experience on developing and applying a variety of land use and socio-economic surveys with rural communities in Amazonia, as well as protocols for participatory research; familiarity with the use of GPS, collection of training samples for image classification, forest inventories, and collection of soil and plant samples.

Teaching experience: Wide experience on training students, farmers and extension agents and on conducing seminars on agroforestry research, practices and techniques in Amazonia.

Languages: Fluent on speaking and writing Portuguese, English, Spanish and some German.

Selected Publications

Ludewigs, T., Dantona, A., Brondizio, E.S., Hetrick, S., submitted (to World Development). Agrarian Structure and Land Use: Land-Cover Change along the Lifespan of Three Colonization Areas in the Brazilian Amazon.

Ludewigs, T., Fiorini, S. and Brondizio, E.S., submitted (to Human Ecology). Crediting deforestation: agricultural credit, farmers, and factors affecting land use change in the Amazon.

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