THE EFFECTS OF CARBON TRADING ON THE SMALLHOLDER LIVELIHOOD PRODUCTION SYSTEM.
A CASE STUDY IN THE BRAZILIAN AMAZON REGION

By

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To my family that loves me and believes that future is a collective construction

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The human civilization is nearing a global climate disaster, and any proposition to alleviate the crisis is welcome. Reducing carbon emission and increasing terrestrial carbon storage is the priority to avoid an increase in atmospheric carbon, the main atmospheric gas related to climate regulation. Reducing tropical deforestation as appears to be the cheapest and quickest action to reduce carbon emission, nevertheless a wide range of political and technical issues about the mechanism of implementation are still unsolved.

Meanwhile, significant deforestation is expected to take place in the Amazon forest in the next decades. Brazil is the fourth largest carbon emitter in the world, where nearly 40% of historical emissions from deforestation derive from smallholders' activities. At the same time, smallholders could play a fundamental role in forest conservation due to their ability to adopt a highly diverse production system that does not require clearing of forest for production in the same way as agribusiness or cattle ranching. Programs and political commitment to avoid deforestation are in debate and soon will be implemented (such as REDD- Reducing Emissions from Deforestation and

Forest Degradation). Internal and external interventions in smallholders' livelihoods will consist of the adoption of new technologies, policies and institutional arrangements. In this context it is essential to understand the implications of these programs for smallholders' livelihoods and land use patterns.

This study analyzes potential effects of carbon trading policies on smallholders living in two sites in the Brazilian Amazon: the Transamazon highway, in the east, and Chico Mendes Extractive Reserve, in the west. Land use change and cash income variations were estimated through an ethnographic linear programming model over a five-year period encompassing twelve households in both research sites. Carbon balance was estimated based on land use change and using aboveground carbon estimation developed for the Amazon region.

The research findings show that the ethnographic linear programming model is a robust methodology to understand and predict smallholders' livelihood and land use changes. This methodology could be adapted to predict carbon balance at the policy implementation level. Results show that the main constraints on implementing a Reduce Deforestation and Forest Degradation program with smallholders consist of a lack of integration between carbon initiatives and development of alternative production systems and consolidated markets for forest and agroforestry products. Failure to consider these research findings in the design of climate change programs aimed to improve forest conservation could lead to a deterioration of smallholders' livelihoods. Consequently, social inequality in the Amazon may be increased by the exclusion of smallholders from the developmental agenda.

CHAPTER 1
INTRODUCTION

Tropical deforestation avoidance has achieved a high priority status on the climate change agenda for two reasons. First, carbon stored in tropical forests and released to the atmosphere by deforestation reached 20% of annual global greenhouse gas emission. Second, it is the cheapest and fastest strategy for reducing carbon emission (Verchot & Petkova, 2009). The emergence of the climate change agenda as one of the highest global political priorities may potentially change the fate of tropical forests. In this scenario, the huge forested area in the Amazon makes it extremely important for conservation.

Before the 1980s, tropical deforestation was not perceived by society as a great problem. The main Brazilian and international development agencies did not include forest loss reduction as a goal to be reached with development projects. This situation only changed when the negative effects of large-scale development projects, mainly in the Brazilian Amazon, became evident. This negative image associated with deforestation was presented to the world by a coalition of environmentalists from the North with local grass roots movements and indigenous peoples affected directly by these projects. The assassination of Chico Mendes, one of the main rubber tappers' leaders, by cattle ranchers in the area where one large-scale development project had been established prompted the need to change developmental policies in the Amazon. The global dimension of tropical deforestation was exposed to stakeholders from all over the world during the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. The result was the establishment of international agreements to act against the main drivers of deforestation. Inclusion of environmental regulations in international development bank projects, creation of an international fund to protect tropical forests, and creation of a Convention on Biological Diversity and Framework Convention on Climate Change were set as legally binding agreements (UNFCCC- United Nations Framework Convention on Climate Change, 2005).

This first global mobilization against tropical deforestation brought forest dwellers to the forest conservation arena as central actors to implement sustainable uses of forest (Nepstad & Schwartzman, 1992; Schmink & Wood, 1992). Since then multilateral agencies have been promoting and supporting initiatives that link environmental protection with forest livelihood systems development. However, despite the effectiveness of this approach to change environmental policies that have brought some trends in deforestation during the last decade, the reality of tropical forest use has not been transformed on a large scale.

As a consequence of macro policies and market expansion of agricultural commodities, deforestation has increased in the proceeding decades. A lack of political support for compliance with environmental treaties resulted in limited advance of environmental propositions regulating the agricultural sector, commercial trade and research institution agenda. The main international regulation agencies such as the World Trade Organization do not design or apply any environmental regulations (Fergusson, 2007). As a result, the first global action to reduce deforestation and improve local livelihoods based on forest use was not consolidated, despite political advances. A new round of possibilities emerges now within the climate change debate.

Climate change officially became part of the multilateral agenda during the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. This convention defined that countries should establish a climate change treaty to reduce greenhouse gas emissions. Since then new technologies have been developed to measure and model large-scale atmospherics patterns and relate changes in atmospheric composition to human activities. More intense glacier melting, hurricanes, droughts, sea level rise and other atmospheric phenomena have been associated with increased greenhouse gases concentration promoted mainly by fossil fuel use (IPCC- Intergovernmental Panel on Climate Change, 2007b). In this context climate change issues have become a major global environmental concern.

Despite the long process of convincing policy makers regarding the relevance and efficiency of including tropical forests in Kyoto's Protocol, it was only in 2005 that these appeared as important issues to mitigate climate change (Moutinho, Santilli, Schwartzman, & Rodrigues, 2005; Santilli et al., 2005). In Copenhagen in December 2009 during the 15st United Nations Climate Change Conference the importance of including tropical forest in climate change agreements was emphasized, being one of few agreements to emerge from meeting. The term Reduction Emission from Deforestation and Forest Degradation (REDD) was forged to represent all policies linked with introduction of forest in climate change agreements (UNFCCC- United Nations Framework Convention on Climate Change, 2008). A refining of the REDD acronym was adopted to stress the importance of including carbon enhancement (REDD+) and land use change (REDD++). The term REDD is used in this thesis to represent all three concepts.

As mentioned in the first paragraph, avoided deforestation has gained momentum and is considered as a win-win policy among developed countries, which are the largest carbon emitters, and developing countries holding most of the tropical forests. Because buying carbon related to avoided deforestation is cheaper for high carbon emitter countries in comparison to changing their energetic matrix, tropical forest countries have the opportunity to receive large amounts of financial resources as payment for reducing emission from deforestation. For this reason is imminent the establishment of a large tropical forest carbon trade.

In this context environmentalists and forest dwellers that were responsible for introducing forest in the climate change arena see REDD as the most promising opportunity to reduce deforestation and social inequality in tropical forests. However, as REDD implementation advances, there is no consensus on how to balance equity outcomes, cost efficiency and effectiveness of climate change mitigation (Lewis, 2009). Currently environmental groups defending tropical forests' smallholders and indigenous groups are concerned with equity in REDD implementation (Peskett, Huberman, Bowen-Jones, Edwards, & Brown, 2008; UNFCCC- United Nations Framework Convention on Climate Change, 2008). If REDD focuses only on reducing deforestation, carbon market agents will target the main drivers of deforestation such as large soybean producers, loggers and cattle ranchers, setting apart smallholders and indigenous groups, which have a marginal role in the deforestation process. Market trends will direct resource allocation to areas with low transaction costs, such as those controlled by large landowners, an example that happened in the volunteer carbon markets (Hall, 2008). Exclusion of these traditional groups recognized as “forest guardians” could bring negative effects to the long-term transformation of forest conservation, representing a huge social problem to countries with populated tropical forest areas, such as Brazil.

Research Objectives

This thesis aims to understand how effective REDD schemes are to reduce carbon emissions and to improve smallholders’ productive systems in the Brazilian Amazon. This study is especially relevant in light of the need to understand impacts of REDD in smallholders’ livelihood. The main concerns are to: 1) determine the carbon balance in terms of smallholders’ land use change; 2) simulate the effects of REDD policy on smallholders’ productive systems and income generation and 3) determine effectiveness of maintaining reduced carbon emissions through fire and forest management, and combined strategies of agriculture and cattle ranching.

To address these issues I analyzed data from two regions with distinct land use trajectories: Chico Mendes Extractive Reserve, in the state of Acre, and one Transamazon settlement, in the state of Pará. The research objectives were to: 1) understand smallholders’ role on REDD target achievements; 2) test the ethnographic linear programming model as an analytical tool for understanding changes in productive system and land use resulting from REDD implementation; and 3) understand the effect of REDD projects on household cash incomes.

Research Sites

Selection of study sites was based on the following criteria: presence of smallholders with different land use patterns; availability of previous studies; and personal experience about land use history. Studies were carried out in the summer of 2008 in the municipalities of Xapuri, Acre (western Amazon) and Anapú/ Pacajá, Pará (eastern Amazon) where the most successful ProAmbiente Poles were implemented. ProAmbiente is a pilot public policy in Brazil aiming to pay smallholders for environmental services (Bartels, Schmink, Borges, Duarte, & Arcos, 2009).

Methodology

There has been a wide range of methodologies used to understand and model land use evolution based on profit maximization. However, this methodology is not adequate to explain smallholders' behaviors, which include a wide array of family attributes such as labor endowment, subsistence requirements and risk aversion (Caldas et al., 2007). In this research an ethnographic linear program (ELP) was used to simulate land use evolution for different types of smallholders' families. This modeling methodology maximizes a goal based on household's characteristic (Hildebrand, Breuer, Cabrera, & Sullivan, 2003) . The modeling objective was to account for carbon balance and understand cash income variations inside households. For each study site two sources of data were used: 1) datasets provided by ProAmbiente from 2004 (Pará) and 2007 (Pará and Acre) consisting of information on land use, family life history, livelihood activities, and product prices for 307 households in Pará and 258 in Acre; and 2) a survey applied in 12 households selected from the ProAmbiente dataset to represent livelihood systems based on extractive, annual crops, perennial crops and cattle. My previous personal experiences of working in these areas and with the ProAmbiente program were key to facilitate the interaction with households and social movements in both sites.

Organization of the Thesis

This thesis is organized in four chapters. Chapter two gives an overview of smallholder livelihood systems in the Amazon based on previous studies on land use, deforestation, land tenure and conservation strategies. It discusses their potential to reduce deforestation and shift to new land uses. Land users are classified based on land tenure- large farmers, small farmers, extractivists and indigenous populations - and compared in terms of relevant characteristics to REDD implementation. At the end of this chapter the reasons for prioritizing small farmers, indigenous populations and extractivists in the context of REDD implementation are discussed.

Chapter three describes the use of the Ethnographic Linear Programming Model with smallholders in Transamazon and Chico Mendes Extractive Reserve as a method to describe and simulate land use change in smallholders' possessions. The objective is to develop a tool allowing analysis of the effects REDD policies. To test the sensitivity of the model to policies, the method is tested with policies of credit, that already have well-known effects in smallholders' livelihood productive systems. First, sampled households are clustered according to their main income source as Extractivist, Annual crop, Perennial and Livestock. Then, for each type, families are modeled individually to business-as-usual, credit to annuals and livestock, and credit to perennials and extractivism. Results show how family income composition and land use parcels have changed over a five year period after the intervention of a credit policy. Models are validated with smallholders' perceptions and with other cases analyzed in the literature.

In chapter four the Ethnographic Linear Programming Model is used to predict carbon balance in smallholders' areas. The model is developed for the cluster of smallholders presenting a more intensive deforestation rate, and within this cluster households with larger forest areas were selected. These households were holding more carbon and, therefore were a more adequate group to model prospective REDD projects. The objective is to develop a particular methodology that is able to capture carbon release and sequestration due to land use change, applying indirect carbon valuations through equations and quantities defined in other studies. The model is used for calculating smallholder's carbon baseline, based on land use evolution previous to project implementations, and carbon balance to scenarios of business-as-usual, project with carbon price of US$5/ ton of CO_2 and project with carbon price of US$10/ ton of CO_2. The chapter concludes discussing the effectiveness of REDD to stimulate changes in smallholders' production in a scenario of no deforestation and no fire use to manage the land.

The last chapter (fifth) summarizes the main findings of the study and discusses the challenges faced by REDD policy implementation to include millions of smallholders in the Amazon. It also discusses the adequacy of using Ethnographic Linear Programming Models to predict land use change and the applicability of this methodology at the project level implementation. Finally, some of the research limitations and potential results that could be taken as insights to develop new research and to adapt this research to other contexts are present. When REDD programs reach the implementation phase, this research shows that smallholders will represent a huge challenge. It also shows, however, that this small, widespread, and deeply-rooted social actor in the Amazon has many potential contributions to share about of how to use carbon credit money in an efficient manner.

CHAPTER 2

ARE FOREST DWELLERS IN THE BRAZILIAN AMAZON A "SOCIAL ISSUE" TO BE ADDRESSED IN CLIMATE CHANGE AGREEMENTS?

Introduction

Today there is a growing consensus among countries that climate change effects will not be stemmed without reducing the current tendency towards tropical deforestation, which releases at least 20% of the total global carbon into the atmosphere. Although the world debates in global meetings about the contribution of anthropogenic carbon emissions to changes in global climate since the industrial revolution, the same world harbors 1 billion people (Chomitz, 2007) living in forests distant from this debate, who are less concerned with global issues. Rather, they worry about how to survive until the next crop season, maintain their lands fertile for crops, and cope if rains do not arrive on time. The emerging question is: how to apply most effectively the financial resources generated by a future carbon market to stop carbon emissions by deforestation? In this context, is it possible to support large producers, smallholders and indigenous people using the same mechanism? Is the inclusion of equity and other social issues in the climate change agenda wanted or will it represent a bias in a mechanism that aims to reduce carbon emission from forest?

This chapter grapples with these questions for the Brazilian Amazon, the largest tropical forest in the world. It begins by highlighting some key factors that drive forest conversion from the point of view of different human agents. Then, it describes the proposals of the main Brazilian players-- the larger farmers, small farmers, traditional populations, and indigenous groups-- to avoid or reduce carbon emissions, and finally argues that including forest dwellers[1] is more just than a social issue, but also a strategic partnership to change short and long term carbon emission in the Amazon.

The Role Played by the Brazilian Amazon Forest in Climate Change

As the primary causes of climate change, the Intergovernmental Panel on Climate Change Panel (UNFCCC- United Nations Framework Convention on Climate Change, 2008) highlights fossil fuel use and land use change plus agriculture, the latter accounting for roughly one third of total anthropogenic greenhouse gas emissions (IPCC- Intergovernmental Panel on Climate Change, 2007b). Forests play a twofold role in climate change by sequestering large quantities of carbon: growing trees absorb carbon dioxide from the air and store carbon by the process of photosynthesis. Forests can also become a major emission source when the stored carbon is released into the atmosphere by means of forest degradation and deforestation.

The Brazilian Amazon covers around 60% of the country (5.217.423 km^2) and it is one of the least populated zones in the world. The Amazon rain forest is the

[1] Forest dwellers in this text have a similar connotation to the term traditional populations adopted by the United Nations, with the addition of living in forested areas, and having part of their production activities linked with the forest. They can be Indigenous, extractivists, or small farmers. For the Brazilian case, the indigenous are not included in this category due to the extreme difference in land rights and land use between these groups. So, forest dwellers is here used to designate the conjunction of colonists, extractivists, and riverines (living on the banks of a river), who are characterized by low family income and a productive system based on family labor.

largest continuous tropical forest and stocks 15% of the carbon in the world (Nepstad et al., 2007; Santilli et al., 2005) . Historical deforestation shown in Figure 2-1 results in reduction of the total forested area by 18 percent by 2008 (INPE-Instituto Nacional de Pesquisas Espaciais, 2009). The governmental strategies of occupation and development of the Amazon in the past few decades transformed Brazil into the fourth largest carbon emitter in the world. The annual emissions caused by deforestation in the Brazilian Amazon are estimated at 200 million tons per year (Houghton, 2005) plus the unintentionally burned area that emits up to 150% more carbon than deforestation alone in el Niño years (Cochrane, 2001; Nepstad et al., 2001). Global models simulating changes in weather conditions in Amazonia predict an increase in drought frequency and intensity (Malhi et al., 2008). A recent study (Phillips et al., 2009) about the effects in the forest of the severe drought of 2005 shows that the Amazon forest, which usually absorbs 2 billion tons of CO_2, emitted about 5 billion tons of CO_2 in that year, more than all the European countries' emissions in the same year. It is unquestionably important to include tropical forests in global warming agreements.

Despite the very recent slowdown in deforestation rates since 2005 (INPE-Instituto Nacional de Pesquisas Espaciais, 2009), is still potential for huge deforestation in Amazonia, as more roads are built and as international demands for tropical timber, soybeans, and beef continue to grow. Figure 2-1 show two recent deforestation peaks in the 90s and 00s related to smallholder credit expansion and agribusiness expansion simultaneously. Existing pressures might be exacerbated by accelerating worldwide demand for biofuels, maybe the next proximate cause for deforestation (Nepstad, Stickler, & Almeida, 2006b). Current development plans and lack of governance could reduce the forest area from 5.2 million Km^2 in 2001 to 3.2 million Km^2 by 2050 (Soares-Filho et al., 2006a). This exceeds the likely threshold for rainfall maintenance and would emit 32±8 billion tons of carbon (Malhi et al., 2008), more than the projected reduction in carbon emission by 2012, the end of the first international commitment to carbon emission regulation.

The Inclusion of Forests in the Carbon Market

The international forum about climate change was organized by the United Nations in the Framework Convention on Climate Change (UNFCC), which was adopted at the Earth Summit in Rio de Janeiro in 1992. The main agreement negotiated as an amendment to the convention was the Kyoto Protocol, under which industrialized countries agreed to reduce their collective emissions of greenhouse gases by 5.2% compared to the year 1990. At this time, credits for forest maintenance were excluded until 2012 (UNFCCC- United Nations Framework Convention on Climate Change, 2005) due to doubts on how to control carbon storage and the negative effects on carbon prices of cheap forest carbon that could create disincentives for other initiatives of fossil fuel emission reduction. Until today the only way to commercialize carbon credits from natural forests is through the volunteer market. But this market represents less than 2% of the regulated market, and the forest participation in this market is less than 1% (Hamilton, Sjardin, Marcelo, & Xu, 2008).

In the regulated market, developing countries are not obligated to reduce emissions until the end of the first climate change commitment in 2012. However, the aggravation of the carbon emission scenario by developing countries, mainly

China due to industrial growth, and forested countries, especially Brazil, Papua New Guinea and Indonesia because of rising deforestation rates, brought these countries to the center of the debate. If these countries continue to cut down their forests, all the carbon emission reduction due to changes in fossil fuel proposed by the Kyoto agreement will be overcome by the carbon release due to deforestation (IPCC- Intergovernmental Panel on Climate Change, 2007b).

The most influential fact leading to inclusion of forests was the support of countries such as Costa Rica, Indonesia, Congo, and a posteriori Brazil, which together hold most of the threatened forests in the world (UNFCCC- United Nations Framework Convention on Climate Change, 2005). Previously opposed, forested countries and environmental movements came to see the problem as a window of opportunity (Karsenty, Pottinguer, Guéneau, Capristano, & Peyron, 2008). Bringing value to the forests as carbon reservoirs, and associating deforestation with the low value of standing forest as well as the lack of resources to protect the forests, are the goals of these countries in getting financial resources to promote forest conservation and recuperation.

In this way, forest, once excluded from Kyoto's protocol, became important in the global arena of climate change, overcoming the initial mistrust caused by the perception that their inclusion would make carbon prices fall, due to the abundance of carbon offered, then making infeasible the technological change needed to reduce industrial carbon emissions. Since the meeting held in Montreal in 2005, forested countries have presented proposals to include standing forests as one alternative for the carbon market in an attempt to include it in trades between annex I and annex II countries (developed and developing nations, respectively).

During the COP 13, the Conference of the Parties from the UNFCCC, held in December of 2007, forests were officially included in annex II countries with the name of REDD, Reduction of Emission from Deforestation and Degradation (UNFCCC- United Nations Framework Convention on Climate Change, 2008).

This scheme will compensate tropical countries for their nationwide reduction in emissions from deforestation and forest degradation in accomplishing the Kyoto's Protocol agreement. Policy makers perceive this new carbon trading mechanism as a great opportunity for short-term carbon reduction, while the fossil fuel energetic matrix changes. An amount of more than 15 billion dollars for REDD payment is expected in the next 5 years (Johns et al., 2008; Moutinho et al., 2005). Brazil, holding the greatest tropical forest in the world, should receive large amounts of carbon credit in this new regime under negotiation.

Who is Driving or Advancing Deforestation in the Brazilian Amazon?

The ways to reduce deforestation have been discussed for more than three decades in the Amazon, and defining the agents and what the motivations are is the first approach to try to initiate it. Geist and Lambin (2002) analyzing 152 cases in tropical areas with high deforestation rates, deduce that the most prominent underlying causes of deforestation and degradation are economic factors, lack of governance, and remote influences that drive proximate causes of agricultural expansion, timber extraction, and infrastructure extension.

Main Deforestation Drivers

Deforestation and degradation in Brazil follow the same global pattern. The Brazilian policy makers perceived the Amazon forest as an empty frontier. The slogan "land without man for man without land" used during the 70s represented the national vision that the Amazon forest must be colonized (Hebette & Marin, 1979; Schmink & Wood, 1992). These policies catalyzed the greatest rural population growth trend ever in the Amazon, which increased from nearly 1 million inhabitants in the 1960s, to about 4 million at the beginning of the twenty-first century (Hall, 2008; IBGE- Instituto Brasileiro de Geografia e Estatística, 2006). Since then, large properties of cattle and soybean, timber extraction, as well as smallholder farmers, have changed the Amazon's socio-economic and environmental profile.

Until the 70s, the main deforestation drivers were cattle ranchers, subsidized by the Brazilian Government, and small farmer colonization induced by government policy that brought a huge migratory flux to the heart of the Amazon. On this period, roads crossing a great part of the Amazon were opened (Hebette & Marin, 1979; Schmink & Wood, 1992). During the 80s and the first half of the 90s, Brazil faced an internal debt crisis that shrunk the state capacity to invest. Deforestation during this period was mostly related to illegal activities caused by spontaneous intraregional migratory fluxes of poor farmers from the Northeast region, and the illegal appropriation of large land areas (Costa, 2005). This period was characterized by large-scale credit for the first time to small farmers. Most of this credit was used by these farmers to introduce livestock activities, resulting in a deforestation peak in 1995 (Figure 2-1). After this period, Brazil adopted a neoliberal doctrine focused on opening the international market to producers and increasing exports. Combined with currency devaluation, the export oriented sector became extremely competitive (Laurance, 1999), leading to an agribusiness boom that was directed toward international markets. Moreover, the development of new crop varieties and the increase of international food demand led to agricultural expansion in the Amazon tropical forest. This new phenomenon driving deforestation, described by Nepstad et al. (2006b), emphasizes the influence of global trade on deforestation, a process they called “telecommunication expressions of deforestation” that resulted in another peak of deforestation in 2005 (Figure 2-1).

As a result, the Amazon landscape became a mosaic of land uses that already lost 18% of the original biome. With 78% of all open areas involved in cattle ranching, it is the most widespread activity, growing 77% between 1985 and 2000. Annual crops cover 10% of the deforested area, and the remaining open areas are covered by fallow, degraded areas and perennial crops (Rodrigues, 2004). The forest products, which were traditionally the basis of the Amazon economy, are losing their importance in most of the Amazon, and even timber is not the priority in the new frontier dynamics (Barreto, Pinto, Brito, & Hayashi, 2008).

Linking Deforestation to the Actors through Land Tenure

Developing a deeper understanding of the relationship between Amazonian actors and the region’s development pattern is not easy. One way to make sense of these links is by attributing land rights to the main agents (Barreto et al., 2008; Nepstad et al., 2001). In the Amazon there are four main types of land designation: Conservation Units, Indigenous Reserves, private areas, and public lands without designation (Treccani, 2001). This definition was used to link agents to the land in this chapter, and the results are showed in the Table 2-1.

The clear separation of land among these groups is difficult due to the extent of irregularities associated with land titles. Barreto (2008) found that 92% of all private land in the Amazon had some kind of problem in their legality, mainly in properties larger than 200 ha. Using the limit of area to categorize a division between what can be considered small farms and agribusiness, INCRA (National Institute of Colonization and Agrarian Reform) defines small farms as those with areas up to 200 ha (INCRA- Instituto Nacional de Reforma Agrária, 2002). Using this classification, Barreto (2008) found that 36% of the private land areas and 94% of the number of properties is owned by small farmers. Considering the whole Amazon, small farmers retain 4% and large farmers 12% of the area, the great majority illegally occupied. Deforestation on private properties is allowed by law up to 20% of the total area; however the majority of these properties have already been deforested more than the legal limits (Pacheco, 2003).

The Protected Areas Allowing Human Occupation

Conservation Units and Indigenous Lands, which comprise 10.3% and 23.4% of the total Amazonia area respectively (ISA- Instituto SocioAmbiental, 2008). Conservation units represent 43% of the Amazon area. It was expanded by 28% during the last 5 years (ISA- Instituto SocioAmbiental, 2008). Despite the fact that sustainable use conservation units allow deforestation due to activities previously approved in their management plan, there are constraints regulated by law that make it more difficult to deforest, such as limiting cattle production[2]. The most

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[2] For more details about conservation units in Brazil see SNUC (2000)

important conservation unit category that allows people to live inside is the Extractive Reserve (RESEX), which was designed to align the concept of conservation with development goals, in this case for extractive populations (Cronkleton, Taylor, Barry, Stone-Jovicich, & Schmink, 2008; Schmink & Wood, 1992). Later, the importance of this land tenure for climate change mitigation and adaptation will be discussed.

Indigenous reserve legislation gives to the indigenous groups permanent use rights over their land, but they have no special benefits outside of the reserve, and most of the time they need official permission to sell their products (Capobianco & Verissimo, 2001). Some indigenous lands have been actively protected from outside invasion by their own indigenous groups, which exert efficient control over the border (Capobianco & Verissimo, 2001; Ricketts et al., 2010).

Deforestation and Land Use Strategies among Actors

The land use dynamics are very different among small farmers, extractivists, indigenous, and large farmers, leading to different patterns of deforestation. The extent to which the forest is integrated into the livelihood strategy is one of the most important indicators of the degree to which carbon is emitted from the system. The relation between forest and poverty has been discussed extensively in the literature (Chomitz, 2007; Dasgupta & Maler, 1994; Pagiola, Arcenas, & Platais, 2005). These studies conclude that in general, people who have their economy based on extractive production are poorer than people whose economy is based on annual crops and cattle. Among extractivists, low deforestation patterns are correlated with lack of financial resources, difficulties to access market, or low labor availability. If these constraints are overcome, extractive people may become *small farmers* (Gomes, 2001). Reynal et al (1995) studying small farmers in Marabá, Brazil, found a tendency of specialization in cattle production after 20 years of lot occupation by the family. The forest and extractive production give way to cattle, the more profitable activity in that area. Farmers who are unable to follow this sequence sell their property to small farmers who are cattle specialists.

Extractivist smallholders are different from small farmers because of two main characteristics that make the deforestation patterns different. The first is the intensive use of the forest biodiversity such as rubber, plant oils, game animals, fruits, fishes, and others (Kainer & Duryea, 1992) that make the forest valuable for them. Second, social and cultural values mean that the traditional economic cost benefit analysis is not so meaningful, as is the case for small farmers. Interaction with forest in the same area for generations and contact with indigenous populations make this actor introduce cultural values for forest, which is not perceived in small farmers or large landholders. The combination of this two characteristic makes deforestation be smaller than in small farmers(Gomes, 2001; Schmink & Wood, 1992).

The *large landholders* have a very different pattern of land use decisions. The forest does not interact with the production system. The most intense use of forest is timber exploitation, that later is converted to pasture or mechanized agricultural land. The rate of deforestation is determined by financial resource availability, market demands for commodities, and access to market, mainly defined by the presence and quality of roads (Alencar et al., 2004a; Nepstad, Stickler, Filho, & Merry, 2008; Soares-Filho et al., 2006a).

Each of the above-mentioned actors has different land use strategies that define their deforestation pattern over time, depending on internal and external factors such as currency valorization, commodity prices, subsidies, infrastructure, and others. During the 1980s and 1990s, small landholders and cattle ranchers were the most relevant actors accounting for deforestation (Pasquis, 1999); however since 2000, deforestation within large soybean farms and large cattle ranches has increased dramatically (Nepstad et al., 2006b). Estimating deforestation from small farms is not easy due to difficulties of determining property boundaries by satellite images. Thus, estimates of total deforestation from smallholder land use in the Amazon range widely from 1% (Pacheco, 2003) to 65% (Sawyer, 2001), with a range of intermediate values (Fearnside, 2005; Nepstad et al., 2006b; Nepstad et al., 1999). Brandão and Souza Jr.(2006), overlapping official deforestation data with settlement polygons, found that 15% of the total deforested area was implemented by small farmers.

Deforestation inside extractive reserves and indigenous lands is less intense than outside the reserves. Nepstad and Schwartzman (2006a) found deforestation to be 1.7 times and 8.2 times lower inside than outside extractive and indigenous reserves respectively, showing that people living inside these areas play an active role in developing subsistence strategies that conserve forest better, compared with others actors. In the last twenty years more than two-thirds of all deforestation can be related to increases in livestock by medium and large farmers (Margulis, 2004). These characteristics are compiled in Table 2-2.

The Actors' Readiness to Implement Forest Carbon Deals

This section will present and discuss the processes that have been implemented in the Amazon to change deforestation patterns and carbon emissions by small farmers, extractivists, indigenous people, and large farmers. The results are synthesized in Table 2-3.

The *large farmers*, or agribusiness actors, deforest as a means to increase production in response to market stimuli for more commodities. The optimal solution for the landowner is converting all the available land into crop or pasture. Forest has no value, and its maintenance depends on the opportunity cost of the land (Lemos & Roberts, 2008). Although they have no intention to include forest in their production system, they can take advantage of the carbon market by greening their farms through increasing riparian forests or implementing specific best management practices such as contours and zero-fire pasture management. This environmental compliance could represent a market advantage compared with non-compliance farms, and tied to a process where farms are registered in a geo-referenced database with activities audited to monitor implementation of environmental compliance. Large producers could then sell the carbon from deforestation avoidance as an incentive for this land use change (Nepstad 2008).

The great uncertainty is if carbon value of REDD payments will compensate the costs associated with implementing environmentally friendly activities within a scenario of increasing demand for food and biofuels (Johns et al., 2008). However, it is unlikely that the carbon market will successfully induce voluntary large-scale carbon emission mitigation because the opportunity cost to produce agricultural commodities is so high. The more likely scenario to mitigate carbon emission is environmental law enforcement by the government, which will make it more expensive to grow soybeans and pasture in forested areas. However, without social pressure, the government has no interest to reduce private profit from gross domestic production. Directed campaigns, such as the one coordinated by Greenpeace, links consumption of McDonald's' Burgers in Europe to deforestation caused by cattle ranching in the Amazon. The subsequent threat of reduced market demand could effectively reduce deforestation (Greenpeace, 2008). The approach forces landowners to internalize the negative externality costs to the environment, that today are paid by the global society, into their production costs.

Deforestation *by indigenous populations* is minimal compared to the other actors (Soares-Filho et al., 2008). Some indigenous groups have been intensifying cattle and annual crops inside their reserves, but it is not the most common practice (Carvalho, 2000). The greatest threat to their forests comes from outsiders entering in the reserve to practice illegal timber extraction and, in some cases, burning and deforesting and thus grabbing the land illegally (Elasquez, Villas Boas, & Schwartzman, 2006). Because indigenous reserves provide efficient barriers to deforestation (Nepstad et al 2006) they could be interpreted within a REDD framework as candidates for receiving massive financial resources. On the other hand, however, REDD schemes need to prove additionality in deforestation (the difference in deforestation with and without REDD project), and this additionality might be considered small with indigenous lands because by law, they cannot be integrated to the commodity market. The proposal, very strong at this moment (WSF 2009), is that indigenous groups have been historically acting as forest guardians, and REDD is the opportunity to reinforce this role for 23% of the Brazilian Amazon land, at low cost among all the other areas (Nepstad 2008).

The *extractive populations* have low deforestation rates too, mainly associated with the most intense use of forest and low demographic density when compared to small farmers in colonization areas. Extractive populations have three main constraints to maintaining their areas forested: The devaluation of the main extractive products, lack of viable production alternatives that conserve forest, and the presence of external pressures leading to illegal deforestation, such as timber extraction and cattle ranching (Salisbury & Schmink, 2007). Like indigenous reserves, extractive reserves have proven effective in slowing deforestation when compared to land outside of the reserve border (Nepstad et al., 2006a). This fact, associated with the history of extractive populations in the Amazon as forest guardians, enables the National Rubber Tapper Council, a social movement representative of the extractivists, to have the same argument as the indigenous movement. The Forest Alliance is an organization established in the 80s that unites non-indigenous and indigenous peoples in a common pro- environment agenda. With the support of national and internationals NGOs, they are present at the majority of international forums that discus REDD, requiring the inclusion of social issues in the debate and to guarantee the rights of traditional populations in the carbon market (Aliança dos Povos da Floresta, 2008; UNEP- United Nations Environment Programme, 2008).

The *small farmers* differ from indigenous and extractivists in that their land use leads to more intense deforestation and results in a more heterogeneous production system that produces forest loss (Perz, 2001a; Schmink & Wood, 1992; Walker, Moran, & Anselin, 2000). Despite this general tendency, there is a consensus among scientists and producers that this production system does not promote long term sustainability for the families (Tura & Costa, 2000). This evidence led the rural workers movement to start an ambitious movement to change this reality. The proposition was to help producers switch from the traditional slash and burn agricultural practices to more diversified and sustainable agricultural and extractive practices, thus slowing down forest conversion and carbon emissions (Bartels et al., 2009; Hall, 2008; Wunder, Borner, Tito, & Pereira, 2008).

Unlike existing agricultural credit programs, ProAmbiente, a Brazilian initiative of payment for environmental services would create an incentive for more sustainable economic activities by compensating, directly or indirectly, family-based producers for good agricultural practices and associated environmental services. This program had massive support of small farmers, and engaged more than 4000 small properties in the Amazon. However, despite its success among the small farmers, the program has failed to attract the political power and investments needed to implement the production changes (Hall, 2008) as a consequence of the lack of governmental support to this initiative (Bartels et al., 2009). In the REDD debate, small farmers and extractivists claim that the Brazilian government should support them through resources from the Amazon Fund, recently created to receive donations supporting Brazilian initiatives of carbon emission reduction (Paulo Moutinho, personal communications). Preliminary studies found the potential of carbon emission reductions from ProAmbiente to be more than 430,000 ton of CO_2, that could result in more than US$ 1200/year/family (Carvalho, Moutinho, Nepstad, Mattos, & Santilli, 2004).

Four Reasons to Include Extractivists, Small Farmers, and Indigenous Groups

The REDD carbon offset scheme will not resolve all the environmental and economic concerns in the Amazon, and the best choice to apply REDD money should be where it presents the best opportunity cost to reduce deforestation, not only during the duration of the project, but promoting durable land use change. Using the criterion of permanence, which actor group should be the focus of a REDD program in the Amazon? The question is not easy to answer, and actually any answer could be contested. This section offers an overview of the issues that make the Brazilian Amazon forest interesting within the climate change agenda, and presents evidence that reduced carbon emissions from avoided deforestation can only be achieved if the interests of local actors are considered in the next climate change commitment in 2012 was presented (UNFCCC, 2008).

The previous sections in this chapter present evidence that the main deforesters changed in the last two decades from large cattle ranchers to small farmers in the 90s to large soybean producers in the last decade (Morton et al., 2006). At least 70% of all deforested area becomes pasture (Nepstad et al., 2008). However, little evidence suggests that strategies to avoid deforestation could pay the opportunity cost necessary to avoid the expansion of soybean and beef into forested areas, due to the high profitability of these products (Wunder et al., 2008). Another impediment is an important legal aspect associated with this issue. The majority of large landowners have no legal property rights, which could represent a barrier to develop long-term carbon projects (Amacher, Koskela, & Ollikainen, 2009). If owners cannot be paid enough money to cover their opportunity costs and the costs to increase carbon socks in the short term, other market mechanisms, such as certification could be more effective. Over the last decades, a series of new market interventions have been implemented, such as certification of products, for which consumers would pay a bonus. However, these initiatives have been failing in two main points: the market does not demand high scale certified products, and the bonus paid for certified product does not compensate increases in production costs (Taylor, 2005). Perhaps with climate change concerns growing within consumers, the pressure over government to change the world trade of commodities could be the best alternative to reduce deforestation over large owners of forest areas, inducing permanent changes in production system (Greenpeace, 2008).

The other group of actors, the indigenous, extractivists, and small farmers, control almost forty percent of the Amazon area, a rate still increasing with the creation of new legalized lands (Barreto, 2008). They have deforested less than large-farmers, despite having lived in the Amazon much longer and having produced the majority of food consumed in the Amazon region (Costa, 2005). If deforestation is greater in large landholdings, what can justify discussing REDD to benefit small landholders? In the next paragraphs I present some reasons why investing REDD money to change permanently the productive systems of indigenous, extractivists and small farmers into low emission systems is a promising field.

The first argument relates to the issue of social justice. These peoples comprise more than two million individuals who live from the mouth of the Amazon River to its headwaters. From highly threatened ecosystems to pristine forest areas, there are Amazonians managing the forest. They produce about 93% of the cassava flour, 95% of the rice, 100% of the beans, and 58% of the cattle in the Amazon (Costa, 2000). On the other hand, most of the smallholders in the Amazon live on less than two dollars per day, the poverty line established by the Word Bank. This poverty is the result of low product prices associated with deficient market opportunities as well as inadequate roads and rural technical assistance (Börner, Mendoza, & Vosti, 2007) . REDD schemes could represent an opportunity to open markets to forest products and associate carbon monitoring with production monitoring, allowing an increase in the price for some low carbon products and reducing the transactional costs of the certification process for both carbon and products (Wunder, 2008). In the Amazon the main possibilities tested to reduce deforestation are to include perennial crops, pasture management, silvopastoral systems, forest management, and fire management and control (Perz, 2001a). All are related to lessening the pressure on forest conversion and at the same time increasing family income. These initiatives have being spread all over the Amazon with promising results to increase family income (Almeida, Sabogal, & Brienza, 2006)

The second argument in favor of these actors is land tenure, one of the main REDD problems to include traditional populations in many parts of the world. In Brazil small farmers, extractivists and indigenous have land rights assured by law, despite implementation problems in land title policies (Barreto et al., 2008). Even the doubt about the rights of indigenous groups to receive credits for their forest due to the special regime of land tenure was proved not to be a legal impediment (The Katoomba Group, 2008).

A third and compelling argument to include these groups relates to the capacity for their livelihood systems to change to low deforestation systems. An effective way of reducing deforestation rates on small farms is to make *agriculture more productive and sustainable* and make the *forest more valuable*. Agriculture will continue to be an important activity for large numbers of people in tropical regions. An increase in productivity through intensification, for example, can lessen the pressure on the agricultural frontier and reduce deforestation. Von Ambserg (1988) argues that agricultural improvements will only have positive effects on deforestation if they do not increase the profitability of agricultural activities in newly cleared areas. It has been argued that technologies that promote the intensification of agriculture could lead to a decrease in deforestation rates; however, the link between technology and a decrease in deforestation rates is ambiguous (Angelsen & Kaimowitz, 2001b). Another possibility is to make the forest become economically attractive to local populations. Timber management practices (FAO- Food and Agricultural Organization of the United Nations, 2005) and non-timber forest products (Nepstad & Schwartzman, 1992) were considered some of the best ways to raise forest-based incomes for local people (Perez & Byron, 1999). The REDD mechanism can support both 1) an increase in the value of the forest through the payment for biomass carbon, and 2) a change from the slash and burn crop system to lower carbon emission crops such as agroforestry systems and rotational crop systems.

The fourth reason to consider small farmers, extractivists, and indigenous groups relates to the opportunity cost of implementing REDD schemes. Studies from Instituto de Pesquisa Ambiental da Amazônia- IPAM (Mattos & Nepstad, 2002; Mello, 2008; Stella, Pinto, Rettmann, Mello, & Castro, 2009) show the mitigation cost for small farmers in the Transamazon ProAmbiente pole is about US$6 ton of CO_{2eg}, or US$22 per ton of Carbon. This value is the amount needed to compensate small farmers to maintain family income during the project implementation phase. Comparing with IPCC findings (IPCC- Intergovernmental Panel on Climate Change, 2007a) that only 25% of the carbon emitted by agricultural activities could be mitigated at carbon values less than US$60 per ton of carbon, the opportunity cost to invest in smallholders is highly competitive.

Conclusions

During recent years human beings have been challenged to reverse the pattern of carbon emission to the atmosphere, a global threat as never seen before. The United Nations coordinates the main policy forum where international agreements have been discussed since 1997. However, only in 2005 was the Kyoto protocol ratified, becoming a legally adopted international regulation about climate change. Since then little progress occurred in the implementation; the world not only missed the goal to reduce global greenhouse gas emission by 5.2% compared to the year 1990, but also, global emission increased by 38% (UNFCCC- United Nations Framework Convention on Climate Change, 2008).

In this scenario, forests become a major issue due to their twofold effect on the carbon balance. Deforestation in tropical areas is responsible for one quarter of the global emissions. Since 2005 during the COP 12, tropical forest stands have become an issue to be addressed in the next climate change protocol that will replace Kyoto Protocol in 2012.

Meanwhile polemic issues must be addressed in any future tropical forest agreement. The most important issues are how to keep track of forest carbon stocks changes as well as the socio economic effects brought about through reduced deforestation. The first issue has been addressed by an improvement in the technology associated with remote sensing technics (Angelsen, 2008). The Brazilian system, for instance, makes it possible to monitor deforestation at municipality level (INPE- Instituto Nacional de Pesquisas Espaciais, 2008). The second issue is more complex and involves a rearrangement of the socio economy in forested areas to make a living without relying on deforestation.

In this chapter, the case of the Amazon tropical forest in Brazil was analyzed in the context of its possible interactions with the main climate change issues, such as how to reduce deforestation without increasing poverty. The analyses focused on identifying the main drivers and actors converting forests, and discussing the interactions between them and climate change forest policy.

Small farmers, extractivists, and indigenous group characteristics enable these groups to request significative attention in REDD discussions. Diversified and labor-intensive production systems and control over large forest areas, even if individual possessions areas are small, makes them able to reduce deforestation based on a livelihood system adaptable to the introduction of low emission carbon systems, which are important for the success of any carbon efficient project that aims to change the human carbon footprint. For this reason, transition to a new Amazon economy, which uses intensive forest biodiversity, fits better in these groups than in the agribusiness model, that has no economic use for forest resources, and payments to avoid deforestation are not likely to fit the opportunity cost to avoid expansion of soybean, cattle, or other monoculture and at same time induce a permanent change in these production system. Other options, such as direct market forces driven by well-informed consumers that require the certification of best management practices among large soy and beef producers are likely to have a much more positive impact on conservation of forests in this sector

In the third chapter, the smallholder production system will be analyzed using two case studies: first the Transamazon Highway, one of the oldest smallholder colonization areas in the Amazon; second the Chico Mendes Extractive Reserve, one of the most representative examples of extractive populations that had their land rights recognized in the 90s.

Table 2-1. Proportion of the Brazilian Amazon biome allocated for each land destination class.

Land allocation category		No.	Area (Km²)	Proportion of the biome (%)
Military area		6	26,235	0.6
Indigenous land		281	987,219	23.4
Strict protection	State	44	137,385	3.3
	Federal	37	231,072	5.5
Sustainable use	State	72	201,918	4.8
	Federal	80	233,523	5.5
Total protected		520	1,817,355	43.0
Small farmer			918,225	4.0
Large farmer			524,700	12.0
Undesignated land			1,792,725	41.0

Source: Adapted from (Barreto et al., 2008; Soares-Filho et al., 2008)

Table 2-2. Deforestation patterns related to each one of the rural actors in the Brazilian Amazon. Source: Chapter compilation.

Actors	Land tenure	Deforestation drivers	Contribution to deforestation[a]
Small farmers	< 200 ha	Credit, market, infrastructure	15%- 40%
Extractivists	Extractive reserves	Extractive products market	< 0.4%
Indigenous	Indigenous land	Illegal extraction, mining	< 0.5%
Large farmers	>200 ha	Market, roads, credit, currency valuation	30%- 60%
Logging, roads, mining, dams, urbanization			< 5%

a- Compilation of values present by authors cited in the text. The percentage is the total amount of deforestation.

Table 2-3. Comparison of propositions for carbon mitigation and adaptation. Source: Chapter compilation.

Actors	Advantages	Disadvantages	Propositions
Large farmers	Large deforesters Large areas	-High cost to avoid deforestation -High possibility of leakage -Land tenure	- Receive the equivalent of their loss to stop producing - Certification to environmental compliance
Indigenous groups	Land tenure Large areas Livelihood system	-Verify project additionality	- REDD to increase land borders security - Money to guarantee culture values
Extractivists	Land tenure Large areas Livelihood system	-Lack of governmental support to implement the reserve management plan	- REDD as source of financing forest management
Small farmers	Land tenure High deforestation pressure	-Small areas -Fragmented forest	- REDD resources to ProAmbiente program of payment for environmental services

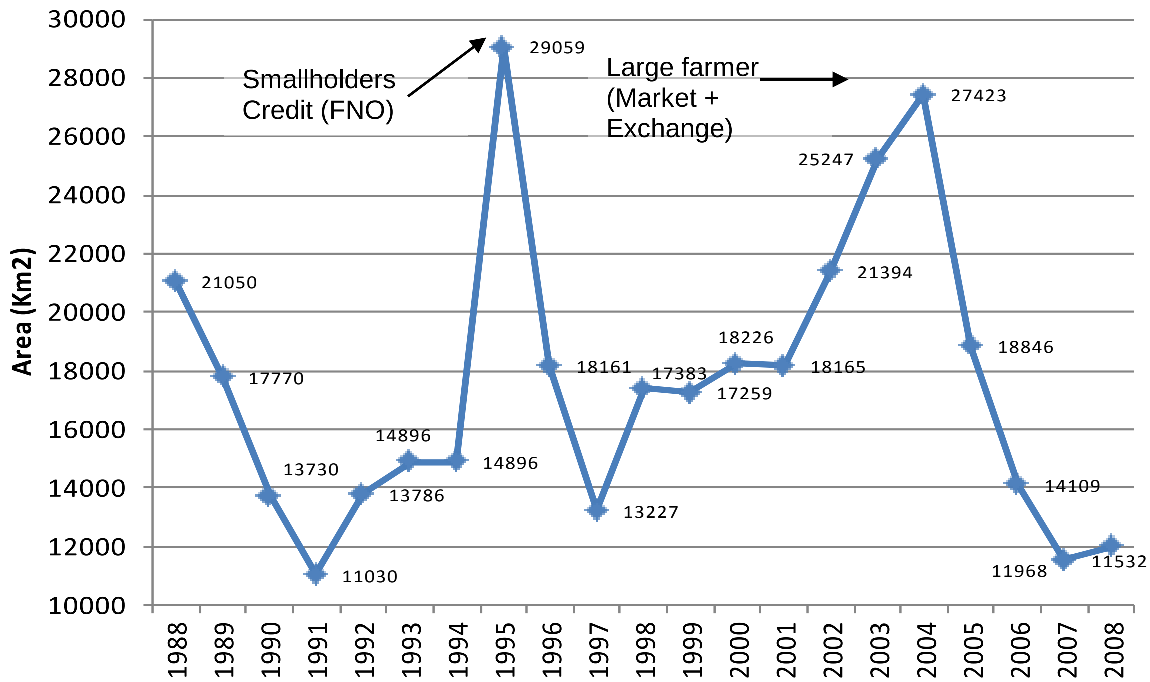

Figure 2-1. Historical deforestation pattern in the Brazilian Amazon and the relation to actors. [Adapted from INPE. http://www.obt.inpe.br/deter/]

CHAPTER 3
A TOOL TO ENGAGE THE AMAZONIAN SMALLHOLDER PRODUCTION SYSTEM WITH THE POST 2012 CLIMATE CHANGE COMMITMENT

Introduction

Annual land-use decisions of smallholder farmers, estimated to approach a million in the Amazon, have significant impacts on the future of the largest rain forest. Given the biodiversity and climate change consequences to humanity of the disappearance of this forest as well as in the livelihoods of marginalized and poor smallholders, it is essential to understand these farmers' reactions to combinations of technologies, policies, and institutional arrangements and to predict their land use implications and reactions to internal and external factors.

This chapter aims to find whether different smallholder characteristics in the Brazilian Amazon contribute to land use change, and if they do, what is the impact of this land use evolution on deforestation and family incomes. Potential adoption of two market strategies and their economic and environmental impacts were predicted using a farm level ethnographic linear programming model. The four production systems were centered on extractive products, centered on annual crops, centered on perennials, and centered on livestock. The chapter begins by presenting Amazonian smallholder characteristics that link their livelihoods to climate change issues. Then it describes field data for the Transamazon and Chico Mendes extractive reserve sites. This includes the family livelihood production systems, identifying sources of income, impact on forests of the production systems, as well as the main land use strategies. Then an ethnographic linear programming model is applied to understand smallholders' land use decision making. The potential of this tool to planning household level intervention projects aiming to change production systems is then discussed.

Smallholder Occupation in the Brazilian Amazon

During the last century, almost all tropical rain forests have suffered some human intervention that drives forest cover losses. At the same time, the population that depends on forest stands has doubled to approximately 800 million (Scherr, White, & Kaimowitz, 2004). From 1990 to 1997, 5.8 ± 1.4 million ha of humid tropical forests were razed each year, and another 2.3 ± 0.7 million ha of forests were degraded (Achard et al., 2002). The actors and factors behind this phenomenon are diverse and range from local dynamics to global market teleconnections (Geist & Lambin, 2002; Kaimowitz, Mertens, Wunder, & Pacheco, 2004).

Brazil has a similar development pattern. The Brazilian policy makers perceived the Amazon forest as an empty frontier. The slogan "land without man for man without land" used during the 1970s represented the national vision that the Amazon forest must be colonized (Hebette & Marin, 1979). Since then large properties of cattle and soybean, timber extraction, and smallholder farmers have changed the Amazon's socio-economic and environmental profile, resulting in 20% forest cover reduction, and the prediction that by 2050 current trends will eliminate a total of 40% of the Amazon forests and degrade another 40% (Nepstad et al., 2008; Soares-Filho et al., 2006a). The demographic trend in the rural population, from nearby 1 million in the 1950s, mostly indigenous and extractive populations, to about 6 million at the beginning of the twenty-first century, suggests the need to implement Amazon forest conservation actions that have a strong link with the improvement of human welfare (Hall, 2008; IBGE- Instituto Brasileiro de Geografia e Estatística, 2006).

The occupation of the Brazilian Amazon by smallholders comprises a wide range of different types of socio-economic arrangements that have specific imprints on forest use and deforestation. The most widespread smallholder occupation was linked with forest extraction of rubber latex, which brought to the Amazon hundreds of thousands of immigrants from other Brazilian regions, mainly the northeast region. The migration occurred in two waves when the external demand for rubber grew: the first due to expansion of manufacturing of bicycle and automobile tires at the end of nineteenth century, and the second came with the Second World War as a consequence of the interruption in rubber supply from Asia (Barham & Coomes, 1994; Salisbury & Schmink, 2007). After 1945, when the war effort was abandoned rubber production struggled. In addition to the traditional rubber system, rubber tappers become diversified producers, commercializing annual crop production, other extractive products, such as Brazil nut and other seeds, and, recently, raising cattle (Gomes, 2001; Salisbury & Schmink, 2007). These new forms of extractivism, called neo-extractivism or agro-extractivism, reflect changes in traditional extractivist systems, incorporating a wider variety of activities, including timber, diverse non-timber forest products, agriculture and cattle production (Rêgo, 1999; Ricketts et al., 2010; Scherr et al., 2004; Schmink & Wood, 1992) The smallholders that encompass these characteristics are called “extractivists” (Schmink & Wood, 1992) for the purpose of this study.

Despite these changes in the livelihood system with the increase in livestock and annual crop production, extractivists still have low deforestation rates (Salisbury & Schmink, 2007). Nepstad (2006a) found that inside extractive reserves, a most important category of protected area designed to support extractivists' livelihoods, deforestation was 1.7 times higher along the outside of the reserve perimeters versus the inside, with only about 3% of the reserve area deforested in 2007 (Soares-Filho et al., 2008). By 2008, 43 RESEX (Extractive Reserves) had been created in the Amazon with a total area of 118,204 km^2, representing 2.6% of the Amazon forest biome (ISA- Instituto SocioAmbiental, 2008), encompassing more than 123,000 families (CNS- Conselho Nacional dos Seringueiros, 2006).

The following sequence of smallholder migrations to the Amazon biome happened after the 1960s with governmental promotion of in-migration from overpopulated regions of Brazil, mainly from the impoverished northeast and from southern farmers who, with the advance of the Green Revolution, were forced off their lands. To accommodate these new migrants and expand the occupation of the Amazon, the government implemented the most ambitious plan, transforming the Amazon landscape forever: 1) roads were opened in thousands of kilometers of forest to interconnect the region; 2) mining and dam projects attracted large contingents of poor northeast migrants (Becker, 1991); and 3) large and ambitious smallholder colonization projects (Schmink & Wood, 1992) were developed along the roads. As a result between a half million (IBGE, 2006) and two million (CONTAG- Confederação Nacional dos Trabalhadores na Agricultura, 2004) small farm families now controlling 4% of the biome (Figure 3-1), generating 71% of the total rural production value, and growing 89% of the daily food (IBGE- Instituto

Brasileiro de Geografia e Estatística, 2006). The increase in production was accompanied with deforestation. A study by Pacheco (2004), compiling data from the National Aerospatiale Institute (INPE) and National Institute for Agrarian Reform (INCRA), associated 35% of the deforestation accounted for by 2003 in the Amazon biome to small farmers, defined by the authors as farmers possessing less than 100 ha.

Land Use Strategies of Amazonian Smallholders

Understanding land use inside smallholder areas in the Amazon requires a deep look inside the property. The Amazonian "smallholder" or colonist could be interpreted as the Russian economist Chayanov described the farms in Russia after the revolution of 1917, in that smallholder decisions could be explained by family subsistence requirements and labor availability in situations where land was abundant and labor limited (Reynal et al., 1995). In this situation, family consumption and production had a strong relation. This situation characterizes the early Amazonian frontier, the situation where the Chayanovian model could be applied. However the existence of market conditions, even in early colonization areas, that absorbed production and labor surplus, indicated that pure "peasant" theory was not sufficient to explain family decisions (Walker, Perz, Caldas, & Silva, 2002).

A "Chayanovian" adapted evolutionary sequence of the small farming systems in the Amazon has been described by Reynal et al. (1995) as a sequence of three phases: installation, diversification and specialization. The first characterizes the moment when a farmer enters a property fully covered by forest; the household depends on forest products to survive. Small forest openings to grow annual crops are the main labor investment. During the second phase, families start to have surplus annual crop production, which is mostly invested in cattle production. In the third phase, pasture becomes the dominant landscape that now has better infrastructural conditions, mainly roads, providing better access to market, which expands the possibilities of production.

The land use evolution for extractivists follows a different logic than for small farmers despite carrying similar cultural values and migrating from the same region, the northeast in the great majority. One of the explanations is that extractivists (rubber tappers) migrated to the Amazon region as employees of rubber concessionaires to extract latex, and were not allowed to develop any other agricultural activity (Almeida, 2006). Another possible reason is the contact with indigenous groups who taught them how use forest resources in multiple ways. Finally the constraint imposed by the rubber production system in the early stages of family occupation and the market for rubber made it possible for rubber tappers to learn how to use the forest resources instead of reproducing a traditional production system from the region of migration. This is one of the reasons why small farmer families usually start land use with slash and burn for annual crops before starting to diversify (Walker, Homma, & Scatena, 1998).

Despite the difference in land use among extractivists and small farmers, in the last decades the tendency to increase cattle production has grown among extractivists. This change is due to the end of subsidies for rubber and the reduction of the market price for rubber and other extractive products, such as Brazil nut. At the same time a credit line to finance cattle production was created (Schmink & Wood, 1992). In this context annual crops (rice, maize, and cassava flour) became the main cash crops, and cattle the savings, a strategy similar to that developed by small farmers (Muchagata & Brown, 2003; Schmink & Wood, 1992). A good example of the extent of cattle ranching is a study by Salisbury & Schmink (2007) in which the percentage of families raising cattle grew from 4% in 1994 to 90% in 2004 in the Chico Mendes Extractive Reserve, Acre, and there is no evidence that the Amazon cattle ranching expansion has reached a limit (Kaimowitz et al., 2004). Understanding how cattle ranching became a success with smallholders who do not have knowledge of cattle breeding, nor the resources needed to start the activity, could be important to understanding the mechanisms to implement changes in the current production model driven by cattle ranching.

Factors Affecting Traditional Land Use Strategy

Despite the fact that Amazonian smallholders follow the land use patterns described above, there are also many cases where farmers opt for different production systems. Over the last 20 years smallholder organizations have created alliances to develop production alternatives that reconcile livelihood improvements with standing forest (Almeida, 2006; Costa, Hurtinenne, & Kahwage, 2006; Mello, Souza, Carvalho, Assunção, & Pereira, 2006). The post-UNCED - United Nations Conference on Environment and Development (Rio 92) environmental approach brought substantial support for Amazon social organizations introducing the idea of co-management, or appropriate sharing of responsibility between states, NGOs and local communities. As a result, the Amazon region experienced a boom of community-based natural resource management initiatives (Zhouri, 2006).

Currently, the main initiatives for diversification of production systems of Amazon smallholders are perennial crops, improved cattle ranching practices, and forestry. Perennial crops are based on the experience developed in Central America by CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) and called agroforestry system, in which multiple forest species are cropped in the same area, reproducing the secondary forest growth system (Araujo, 1997). The constraints are the requirement of good infrastructure, such as roads and electricity, and the necessary allocation of considerable labor and capital investments. The advantage is the diversification and intensification of production, producing more per hectare. The second diversification system is an improved cattle ranching system. The traditional system is changed to increase the production per area and have perennial crop production associated, mainly timber species. The main constraint of this system is the requirement of financial investment to introduce the improvements, most of the time not competitive with the opportunity cost of the land (Walker et al., 2000). The third system is forestry, which involves management of timber and non-timber forest resources. The idea behind these initiatives is to develop new procedures to increase production of forest products and not degrade the resource. The main constraints are lack of knowledge, and the limited market for managed products (Zarin, 2004).

The support for sustainable initiatives has been growing during the last two decades as a new market conservation tool, through direct payments for environmental services (PES) (Hall, 2008; Lemos & Roberts, 2008; Mayrand & Paquin, 2004; Wunder, 2007). The basic principle behind PES is that resource users and communities that are in the position to provide environmental services, such as water, forest, and soil conservation, should be compensated for the costs of their provision. In addition, those who benefit from these services should pay for them, thereby internalizing these benefits (Mayrand & Paquin, 2004).

The most ambitious PES schema designed in the Amazon was ProAmbiente. Unlike existing agricultural credit programs, ProAmbiente, a Brazilian initiative of payment for environmental services, aims to create an incentive for more sustainable economic activities by compensating, directly or indirectly, small farmers for good agricultural practices and associated environmental services. This program had massive support of small farmers, and engaged more than 2500 small properties in 12 poles across the Amazon. Families enrolled in the program received technical assistance to design a plan to change the production system to reduce forest burning, water contamination, soil erosion, and initiate sustainable forest usage. Households received support to access credit and an additional $50 per month as a direct payment for the environmental services rendered. The payment was discontinued due a lack of funds but the program still exists in six poles. Acre and Transamazon poles are getting support from the state government and NGOs to continue the rural extension and payment for PES. Once a ProAmbiente program is implemented, the potential to reduce carbon emission for participant families is about 430,000 Tons of CO_2 in 15 years, which could result in more than US$1200 per year per family (Carvalho et al., 2004).

Although PES is still incipient, it represents the best option to provide the resources needed to implement diversified production systems. Wunder (2007) cites some reasons why PES was not able to promote large scale results to conservation and remained at a pilot scale: failure to attract buyers, to have measurable impacts, and to be easy for the local population to understand and implement. ProAmbiente failed to attract buyers.

However, a new factor that recently has been introduced in the debate about development in tropical forest areas is the significant impact of greenhouse gases (GHGs) accumulation in the atmosphere because of deforestation. Combining forest degradation caused by high impact logging, smallholder shifting cultivation, accidental wildfires, and forest fragmentation, the annual emissions from land use change during the 1990s produced about 20- 25% of the total anthropogenic emissions of GHGs (Houghton, 2005).

Because of emerging knowledge about climate change and the urgency felt by governments to respond, the role of tropical forests to avoid global warming is getting closer to serving as a basis for international financial flows to conservation than are other PES such as biodiversity maintenance, water management, or non-use values. During the 13th Conference of Parties that occurred in Bali in 2007, the “Road Map” to the next commitment period after 2012 was established. This schema will compensate tropical countries for their nationwide reduction in emissions from deforestation and forest degradation (REDD). Climate change decision makers perceive this new carbon market as the best opportunity for short-term carbon emission reduction, while the fossil fuel energetic matrix changes. If the lower REDD green gas emission reduction costs are confirmed, the commercialization of more than 15 billion dollars in the next 5 years is expected, much more than all the others PES jointly (Johns et al., 2008; Moutinho et al., 2005).

Many studies consider the REDD mechanism to be the most important tool to change tropical forest use through the valorization of the forest by the non-consumption market (Hall, 2008; Karsenty et al., 2008). Moreover, this mechanism should catalyze sustainable forest use by rural communities, that now own or control approximately 25% of the world's forests, and their share of the total is likely to double again in the next 15 years (Scherr et al., 2004).

The question that remains unanswered is, what real contribution a future post Kyoto agreement including REDD mechanisms will make to change poverty, and to include indigenous populations and marginalized smallholding forest dwellers. The concern was manifested by the organizations of the Indigenous Peoples and Traditional Communities of Latin America, and the Democratic Republic of the Congo and Indonesia, which met in the city of Manaus, Brazil, in April 2008 "*What is the impact of REDD on the traditional peoples and indigenous populations? May it represent the privatization of our forests?*"(Aliança dos Povos da Floresta, 2008) and restated in Bonn, Germany, during the CDB/COP 9 as " *traditional knowledge is key to respond to new times, and we* (the traditional and indigenous populations) *demand to participate in the REDD debate as prominent contributors*"(UNEP-United Nations Environment Programme, 2008).

This demand refers to two main concerns that are related to the thesis objectives. First, carbon accountability needs to incorporate the heterogeneity of production and reproduction livelihood strategies, allowing REDD to be more than "REDD protects the forest against use". Second, tools must be developed to facilitate capacity building inside smallholders groups to deal with carbon issues, such as linking land use to carbon balance.

This chapter pursues part of the answer to these two questions using an Ethnographic Linear Programming (ELP) model (Hildebrand et al., 2003) to develop a tool which makes it possible for small landholders to define for themselves how land use will change inside their production system due to some carbon-related intervention. In addition, this model, with small modifications, can be accessible to any extensionist to read and interpret the outputs, needing only a computer with Microsoft Excel®.

To test accuracy and sensitivity of the ELP in capturing real family livelihood strategies, the study was carried out together with producers who have been working in ProAmbiente. They also have an innovative system of planning land use that fits with the ELP matrix. The heterogeneity of land use types is captured based on the annual family consumption and cash income requirements of extractivists, and is also cattle, annual crop, and perennial crop centered. The research was conducted in the Transamazon and Acre Poles using ProAmbiente databases and field interviews.

Methodology and the Study Sites

There has been a wide range of methodologies used to understand and model land use evolution, mainly using the assumption of maximization of profit. However, this has not been adequate to explain smallholders' behaviors that include a wide array of family attributes including labor endowment, subsistence requirements, and risk aversion (Caldas et al., 2007). In this study an ethnographic linear program (ELP) was used to simulate land use evolution of different types of smallholder families.

To capture the heterogeneity of land use associated with small farmers in the Amazon this study was carried out in the summer of 2008 in the municipalities of Xapuri, Acre (western Amazon) and Anapú/Pacaja, Pará (eastern Amazon) (Figure 3-2). The sites were defined based on the availability of previous studies about land use history, encompassing the entire range of land use trajectories, from extractivism to cattle ranching, and two of the most successfully implemented ProAmbiente Poles. This range will facilitate the future use of the methodological tool to simulate land use changes.

For each Pole I had access to questionnaires and databases generated by the Brazilian Ministry of Environment and FVPP[3] in the Pará site, and PESACRE[4] in the Acre site. Both have partnerships with IPAM[5], an NGO with large involvement in climate change policies. This dataset contained information for 307 households collected in 2004 and 2007 for Pará, and for 258 households in 2007 in

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[3] FVPP- Fundação Viver Produzir e Preservar- Organization that congregates small farm producers in the Transamazon region with the objective of supporting intervention in public policies, providing technical assistance, and formal education. They are the main supporter of ProAmbiente since 2000.

[4] PESACRE- Agroforestry Research and Extension Group in Acre- Organization with sound experience in developing research and extension activities for small farmers, rubber tappers, and indigenous groups in Acre, and is the local ProAmbiente coordinator.

[5] IPAM- Environmental Research Institute for the Amazon- has been working in this area since 1999 providing support to ProAmbiente implementation. IPAM also has participated in all the COPs since 2003 and is a member of the ProAmbiente National Council.

Acre. The data were collected in a one-day period for each household. The procedures for data collection included structured interviews, vegetation sampling along transects to survey the main land uses, and handwritten diagrams to collect information about production strategies and plans for the future (APPENDIX A). The data included information on land use, family life history, livelihood activities, and prices. There were also 12 interviews applied to selected households, with the objective of actualizing and checking information collected by the organizations in the process cited above. This section starts by describing current land use in the study sites in Acre and Pará for each one of the types of household, then introduces the model variables, constraints, and mathematical statements and finishes with model results for each type in situations of high and low marketable prices.

Current Land Use in Acre and Pará

General characterization of the study sites: This section presents the general characteristic of the two study sites to contextualize the study sample with a broad view of processes, institutional arrangements and other aspects that help in understanding household land use decisions.

Acre: The Acre study site was located in the Chico Mendes Extractive Reserve (CMER), working with families that are part of the ProAmbiente program (Figure 3-2). The field interviews were conducted in rubber tapper estates (seringal) Nazaré and Floresta. CMER is one of the first conservation units within this category, an innovative land allocation that congregates forest conservation with land use. The extractive reserve model was created as an answer to Acre rubber tappers and environmental group supporters that complained about the increased threat to their forest and, as a consequence, against the rubber-tapper livelihood strategy (Salisbury & Schmink, 2007). The creation of RESEX was well received by the government that needed to contain growing deforestation rates and solve land tenure problems of extractive populations, disseminated to the media by Chico Mendes and the National Rubber Tappers Council (Gomes, 2001; Nepstad & Schwartzman, 1992; Schmink & Wood, 1992). Each traditional resident receives a land use concession corresponding to the area of rubber trees exploited by the family, to be used mainly for extractive production. Up to 10% deforestation of the area to implement other land uses is allowed. All land use is previously defined in a Reserve Management Plan defined in a common consensus between the IBAMA/ICMBIO, a Governmental institution responsible for conservation unities, and residents (IBAMA- Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis, 2006).

The Chico Mendes Extractive Reserve was created in 1990 with a total area of 970,570 ha in six municipalities of Acre. It included 44 % of the 7,000 residents living in Xapuri County at the time, who lived from extractive production of rubber and Brazil nuts, among others, and subsistence annual cropping. However a recent trend from forest extraction to more intensive cattle ranching is occurring as result of the decline in the price of rubber latex and the end of subsidies(Gomes, 2001; Salisbury & Schmink, 2007)

The results of land use strategy changes are reflected in deforestation inside the reserve polygon (Figure 3-3). During the last 8 years the amount of standing forest decreased from 97% to 93%, a loss of 38,800 ha in this period. Considering the 1,878 families inside the reserve, the average deforestation for each family was

20 ha, or 2.5 ha each year. The intensification of forest slash and burn associated with the very

dry year of 2005 originated the worst fire event in recent history of the reserve, burning 80,000 hectares of forest (Brown et al., 2006). The two *seringais* sampled had some special characteristics. First, they have one road crossing the area that reduces the time from Xapuri to less than one hour; second, they have Brazil nut, a valuable natural resource; third, rubber exploitation started again in 2008 in response to demand for natural latex from a new enterprise founded in Xapuri to produce condoms.

Pará: Contrary to the Acre site that has a history of forest use, the second site was colonized to support agricultural production. The Pará study site was located in Anapú and Pacajá Counties, State of Pará, in a settlement area located in the eastern part of the Brazilian Amazon, 600 km or 12 hours by car from Belém, the state capital, and near the Xingu River (Figure 3-2). The area receives annual precipitation exceeding 1,700 mm with five dry months per year with less than 50 mm precipitation (ANA- Agencia Nacional de Águas, 2006). This seasonal rain pattern defines the agricultural cycles and the high inflammability index of the forest in the dry season (Nepstad et al., 2004). This area was colonized in 1972, when the Transamazon highway was opened in the heart of the Amazon tropical rain forest. The settlement was designed as a “fish-bone” with secondary roads (*travessão*), each 5 km long and running perpendicular to the highway (Rocha, 2003). The total population of Anapú and Pacajá is 56,152 with a demographic density less than 2.55 inhabitants/km^2 living in a situation of low GINI index (0.40) revealing the lack of access to medical, educational, and infrastructural services.

Most of the population located in this rural area (75%) is living on small farms. According to the IBGE (2006) census, 68% of the population more than 10 years old is involved in some kind of agriculture, animal husbandry, forestry, and fishing activities. The small farmers interviewed up to 10 km from the Transamazon highway had been settled by the government 20 years ago, while migrants farther from the highway moved in without official permits. The former received subsidies and technical assistance to grow cacao and develop pasture, and deforested more area than the latter (Rocha, 2003). Another notable characteristic is the increase in land conflicts between landless families, the timber industry and large landholders that culminated with the assassination of Sister Dorothy Stang in 2005. After this tragic, but common event in Amazon frontiers, the Brazilian government started to regularize land outside of the original settlement, and now land titling is happening in the region (Schwartzman, Alencar, Zarin, & Santos Souza, 2010).

Currently, the land is mainly used for cattle ranching and subsistence agriculture. Seventy- four percent of the deforested land is classified as cultivated grazing; 29% of it is in different degradation stages. This production of perennial and annual crops, mainly cacao/banana (25%) and manioc flour/corn (32%) is one of the largest in Pará. Extractivism is restricted to timber extraction, mainly illegally, that accounts for the majority of employment in the cities; however it generates only 8% of the rural income (IBGE- Instituto Brasileiro de Geografia e Estatística, 2006). Yet this region has suffered the loss of 17% of the standing forest over the last 7 years, and now only 64% of the forest cover remains (Figure 3-3), the greater part degraded by high impact logging and fire.

Fires have a strong positive correlation with land use in the Amazon. A study by Alencar (2004b) showed that fires in dry years could spread over closed canopy forest, degrading intact forests. Fire occurrence in the last seven years in the region clearly shows the intensity of land use change (Figure 3-3). The tendency of reduction in fire occurrence after 2004 is an interesting situation that proved the efficiency of command and control instruments to reduce environmental degradation. When the Federal Government started land regularization and enforcing environmental laws as a consequence of Sister Dorothy's murder, fire declined. However fire occurrence is still high. Between 1986 and 2004, about 5,743,858 tons of carbon per year were emitted from deforestation in 240,000 ha of forests alone (Mello, 2008).

Understanding Family Land Use Decisions: Typology Based on Source of Income

To ascertain the land use patterns and ultimately the long-term processes of landscape change among the smallholders of Acre and Pará sites, the farm sample was grouped by similarities. The typology adopted for this work follows the division proposed by Pinchón (1997)for smallholders in the Ecuadorian Amazon region. The study used a combination of neo-classical economic principles, where farmers manage the landscape as they would any other useful resource to maximize utility constrained by exogenous (market and environmental) and endogenous (household labor) characteristics (Browder, Pedlowski, & Summers, 2004), with a demographic Chayanovian framework that emphasizes the role of family dynamics in farming (Perz, 2003). Pinchón (1997) estimated the number of farms sharing common land use characteristics based on a statistical cluster algorithm. The resulting typology consisted of four discrete classes of farms: Forest centered; diversified; pasture centered; and perennial centered farms. Browder *et al.* (2004) comparing other study results suggest that diverse factors have influenced land use and forest conversion decisions. The variables that appear as the most important correlating with different farming systems are soil fertility, available adult farm labor, age of farm, off-farm income, land tenure security, and farm distance to market (Browder et al., 2004). A similar typology was applied in this study, using as the dependent variable householder income composition instead of area in a specific land use. The concept is that income expresses land use strategy more than land use area. Each smallholder was clustered based on its income in:

- Cluster 1: Extractivists- if more than 50% of the income comes from timber or non-timber extractive activities;
- Cluster 2: Annual crop- if more than 50% of the income comes from annual crop activities, such as rice, maize, cassava flour, and beans;
- Cluster 3: Perennials- if more than 50% of the income comes from perennial crops, including any production originated from a crop with more than a one-year cycle and;
- Cluster 4: Livestock- if more than 50% comes from livestock (cattle/diary/chicken/hogs).

Four land use clusters emerged from the combined survey data: Cluster 1, “EXTRACTIVIST” in which 93% of the land was still in forest and 74% of income from extractive products; characterizing 23% of the households surveyed; Cluster

2, “ANNUAL CROPPERS” with 13% of the householders that have 71% of the income from rice, maize, and cassava flour; Cluster 3, “PERENNIAL CROPPERS” includes 16% of the overall sample; and Cluster 4, “LIVESTOCK PRODUCERS” households represents the majority of the sample, with 48% of the cases.

The descriptive statistics for each cluster and one-way ANOVA and Tukey’s tests show that the clusters do differ significantly in the mean source of household income from extractive, annual crops, perennial, and livestock. The Acre sample did not have households defined as type 3-Perennial. Cluster Livestock in Pará had the greatest concentration of income (91.2%), and livestock in Acre had the lowest income concentration of any one activity (51.7%) (Table 3-1). The annual crop clusters have no significant difference; all other types differed between sites. In absolute values the total income was not significantly different among extractivists, perennials and livestock, but did differ from the annual crop cluster (Table 3-1). The perennial cluster had the highest income ($ 3,882) and the lowest income occurred in the annual crops centered in Pará ($1,113). Income in Acre was always greater than in Pará. For rural producers, household income results from land use decisions. Each cluster has a footprint in the landscape that is associated with land use. The most important characteristic for land in the Amazon is the effect on forest stands.

Annual crops, livestock and perennial clusters do not differ in terms of percentage of forest remaining. The extractivist cluster does differ from the others. There is also a significant difference between Acre and Pará sites, where Acre had forest stands greater than Pará within the cluster. Extractive types had the greater forest stand (91%) and perennials the least (60%) (Figure 3-4). In absolute values the forest area in Acre is six times greater than in Pará, on average. The smallholder size in Acre is 386 ha while in Pará the average is 90 ha. Larger pastures occur in the livestock cluster in Pará (32.5 ha) and the smallest pastures are among extractivists in Acre (3.8 ha). Land allocated to annual crops had a significant difference between perennial and the other clusters. The perennial cluster showed a significant difference from other clusters in terms of area growing perennials. The largest area is on cluster 3- perennials (4.8 ha) and the smallest area of perennials occurs in cluster 1- extractivism (0.4 ha).

Two demographic characteristics, family size and years in the area, and one spatial characteristic, distance from market, were included in the comparison (Table 3-1). The Acre site differed from Pará in both demographic characteristics. Acre has larger families (average of 4.8 persons) and a longer time of residence (average of 15.7 years) than Pará (2.1 persons and 8.3 years of residency). Livestock in Pará had the longest residency time among other clusters in Pará. Distance to the market was measured using hours from the household to the next city. The results showed that perennial producers were located nearer the market than other clusters. In Para, extractivists are located farther from the market (3.9hr) and perennials nearer (1.8 hr).

Simulating Land Use Decisions in the Acre and Pará Sites Using Ethnographic Linear Programming

The previous section shows that smallholder livelihood systems are a composite of diversified production systems, varying from household to household in a complex interaction among internal and external factors linked to family demography, biophysical conditions, and location, among other factors. The explanation of land use decisions needs to account for this complexity (Walker et al., 2002).

To understand the reality, and how factors are interacting in a multi-complex system, is not an easy task. The use of models helps to understand how one or more variables can be predicted from the set of explanatory variables. Models in social science and elsewhere can be regarded as fulfilling two roles: explanation and prediction. The explanatory role allows relationships in the data to be understood more fully; the predictive role allows the results to be generalized to other datasets. The existence of a linear relationship between the x and y variables is often assumed (Austin et al., 1998). The objective of this chapter is to, based on field data, develop a model that explains the reality observed in the previous section, and be able to predict land use changes.

The conceptual framework of modeling smallholders: The conceptual framework to study small landholders places a family at the center of decision making in resource allocation and consumption (Hildebrand et al., 2003). All fluxes of inputs and outputs associated with production converge at and diverge from the family. The use of Ethnographic Linear Programming developed by Peter Hildebrand and colleagues at the University of Florida, was chosen due to three main advantages: first it was designed to work in dynamic and complex multi-year situations; second it diverged from traditional linear programming-- this method incorporates socio-cultural parameters, changing nutritional requirements, evolving household composition, and other factors to enhance the dynamism, representing a real-world livelihood system (Hildebrand et al., 2003); third the model is developed in any ordinary computer with Microsoft Excel© that facilitates *a posteriori* use by farming system extension agents in the Amazon.

Our model was created in Microsoft Excel© with the standard Frontline System Solver© add-in, which maximizes the sum of the gross margins for all activities included in the model, following the objective function $Z = \sum_j c_j X_j$; where X_j are the production or other activities in a small farm; c_j the forecast gross margin of each X. Each activity is subjected to constraints R_i: the use of the resource *i* needed to operate an activity j cannot exceed the available amount of the resource held by the household (Lewis, 2009). The equation form of constraints in the model is $\sum_j a_{ij} X_j \leq b_i$; where b_i is the amount of resource *i* available.

The objective of this model is to maximize the sum of annual cash available for discretionary spending over five years after meeting subsistence needs of the household. Each year is divided into two semesters to account for seasonal household activities. The cash flow is defined by the mix of products sold in the market, non- farming activities, such as social security benefits and temporary work, and consumption requirements, such as purchase of food, clothes, and spending on leisure. The ELP model keeps track of how many hectares of forest and other land uses are contained in any year and the length of time of the different land-uses, allocating household income each year to consumption and on-farm investments. The ELP model is calibrated to a set of initial conditions that define the model's starting point in terms of the resources available (land, labor and cash), the existing land uses and the prevailing technology and prices for each one of the four householder clusters that aggregate the main variability among land uses in the regions: 1- extractive; 2- annual croppers; 3- livestock producers (cattle and small animals); and 4- perennial producers.

The model imposes three constraints on household decisions: 1) farm size: the area used for all farm activities cannot exceed the farm size; 2) labor: households use primarily family labor, but could hire people if cash is available or work for others to earn cash; and 3) household consumption requirements. The labor needed for activities varies between semesters and gender, and family composition evolution was calculated based on incremental yearly age and randomly generated probability of marriage and death, both based on municipal census data. A household must have money for farming and for the necessary household expenditures each year. For this model gender disaggregation for cash income was not introduced due to the limitation of information in the data collection methodology, despite the importance of this kind of analysis in the model. The surplus generated in any semester is transferred to the next semester as beginning cash. Some staple crops are grown primarily for household consumption and require a minimum level of production to meet family needs.

Model sensitivity to explain changes in landowners' decisions in the allocation of land, capital and labor based on external market values is a current important issue related to change in land use in the Amazon (Amacher et al., 2009; Boserup, 1973, c1965; Costa, 2005; Geist & Lambin, 2002; Nepstad et al., 2006b; VanWey, D'Antona, Brondízio, & Morán, 2004). Does an economic incentive such as the Acre government subsidies to rubber have positive effects on slowing deforestation? Does an increase in beef price have a positive correlation with deforestation? These are questions always mentioned; however, they are difficult to answer. An ELP model can help to understand and predict effects of interventions in small landholdings, a very current question when climate change issues are putting the focus on the Amazon to answer the question: how to slow deforestation without increasing the poverty of small landholders in the Amazon?

The model was calibrated with information from four families, one from each cluster, whose livelihoods where explored in depth to feed the model variables. The model used the value of products found in the field data. This model was called Business-as-Usual because it explains the situation as it is. It tested the influence of market price changes on land use and deforestation for increased prices for extractive and perennial products and for annual crops and cattle.

The models were first run for a 5year period to create a business-as-usual scenario against which results of product price oscillations could be compared. The baseline scenario incorporates prices running at the time of field research, for any property products, and collected in the place where the specific product was commercialized. Place of commercialization has a strong influence on prices for producers. In general, prices closer to the final consumer are higher. However rural producers generally do not have access to retail markets but rather sell to a middleman, often receiving unfair prices (Molnar et al., 2008), reducing producer capacity to increase production by intensification of labor and capital or increasing area, where available (Reynal et al., 1995; Walker et al., 1998).

As previously discussed, most options to slow deforestation and reduce poverty of rural small landholders are the Amazon is based on intensification of the production system, applying more labor and capital. The result is increased income per hectare of land. The effect of market price increases on household land use, without introducing any new technological improvement, was tested using the business-as-usual ELP model. The first scenario labeled "increased prices for extractive and perennial products" simulates a successful strategy of paying fair prices for extractive products and perennial crops, as a strategy to value standing forest and stimulate producers to introduce perennial crops in substitution of annual crops and cattle raising. The second scenario, "increased price for annual crops and livestock", is a simulation of householder reaction to commodity price increases, as an answer to global food supply shortages by increasing demand, or decreasing production due to climate change effects. The results for both scenarios are presented in the following section.

Validating the Model: The Business-as-Usual Scenario

Extractivist Production

Households depending on extractivism represent 23% of the total sample of this study. Most of these households are located in the Acre study site. Extractivist families in Acre and Transamazon sites differ in their land use strategies. Extractivists in Acre use the forest as an important part of their livelihood strategy, while extractivists in Transamazon use forest resources usually during their first years in the land to capitalize for future investment in cattle production. Extractivists in Acre have an average of 16 years of permanence in the same area; while extractivists on the Transamazon usually stayed in the same area for only 2 years, the shortest period of stay.

The household studied is located in the Chico Mendes Extractive Reserve, in Acre. This site is the best place to develop extractivist activities among the two study sites. The household is located in the "*Seringal*" Floresta, one hour by car from Xapuri city. Access to the area is facilitated by good road conditions during the entire year. The family of five has lived in the same "c*olocação*" for 29 years. The land encompasses 450 ha, of which 439.5 ha are covered by forests. The remaining 10.5 ha include 4 ha of secondary forests, 1.5 ha of annual crops, 1 ha of home garden, and 4 ha of pasture. The household is composed of three male adults, two female adults, and three children.

In terms of income, the main production systems are rubber and Brazil nut extraction. These production systems generate about 800 kg of latex and 6400 kg of nuts, producing 75% of the family's annual cash income. Annual crop production of manioc and maize (15%) and cattle ranching (10%) make up the remaining 25% of the annual family cash income. A family member employed as a health agent provides an additional 26% to the total cash income.

Business-as-usual model for extractivists: The model was used first to project land use change tendencies. The five-year smallholder production model shows a tendency to maintain the same rate of 0.6% forest loss per year, about 13 ha in the next five years. The forest area cleared is used to grow annual crops (93%), and a small portion is used for pasture. After the annual crop harvest, the area is abandoned and turns into fallow (62%) or is converted into pasture (38%). As result, the pasture area will double to 8 ha (1.8% land size) and the fallow area will triple during same period (Table 3-3).

Second, the model explored changes in household income sources. Table 3-4 shows that family cash income increased from US$ 4,100 to US$ 4,481 as a result of increases in manioc and cattle production. Revenue from extractivist production decreased by 2%; however, proportional to the total family cash income, the reduction was 11%. Revenues from annual crops and livestock increased, respectively, by 19% and 17%.

Annual Crop Production

Households primarily engaged in annual crop production represent 13% of the sample, and are concentrated in the study site in Pará. The production system is based on slash and burn agriculture. This practice is the least costly and most efficient way for smallholders to produce annual crops, since the vegetation burned releases nutrients to the soil and reduces pests and diseases.

Annual cropping is considered as transitional production because smallholders usually need to change from annual crops to cattle or to perennial crop production, or they need to migrate to another forest area before their current working area is completely exploited. Most producers primarily engaged in annual cropping are located in Pará site, two and half hours by bus from Anapú city. Access to the area during the rainy season is difficult due to bad road conditions.

The family has 85 ha of land; sixty percent of the area is covered by forests impoverished by frequent burns and by timber exploitation. The family is composed of five adults (two males and three females) and one child. They moved onto the land seven years ago. At that time, the area was fully covered by forest. The 34 ha of area opened is used for pasture (14%), annual crops (6%), fallow (18%), and perennial crops (2%).

At the time of the interview (baseline), annual family cash income came from on-farm activities and off-farm activities. The on- farm cash income is composed of 61% from annual crops (55% from manioc flour alone). The second main source of cash income was livestock, mainly cattle (20%) and chickens (4%). Households also had a small production of banana and cacao that represented 15% of the family cash income. Forest extractivism was practiced only for subsistence, and not so frequently. Off-farm activities complemented their annual income by an additional 14%.

Business-as-usual model for annual croppers: The five-year annual cropper smallholder model shows a tendency to maintain the same rate of 2.6% forest loss per year, the highest rate among the types of households studied. According to the model, forest cover will be reduced by about 60% to 52%, a loss of 7 ha of forest. The forest area cleared is used for annual crop production. The pasture area increased by 53%, from 14 ha to 26 ha; while the fallow area decreased by 24%. This indicates that the household production started to change from agriculture to cattle ranching.

The total family cash income of annual crop producers increased from US$ 4,516 to US$5,568, 14% more than the income come from extractivist activities (table 3-4). Family production continued to rely on annual crops, but it began to make a transition to cattle ranching. This change was expected to occur sometime during the family life cycle (Perz, 2001b). The relative contribution of annual crop revenue to the family income decreased from 60% to 53%, while the income from livestock production increased from 24% to 38%. Surprisingly, the relative contribution of perennial crop revenue to the family income decreased from 15% to 8%, with no area increment during the five-year period.

Livestock Production

During the last decades, cattle ranching grew among smallholder producers. Producers primarily engaged in livestock activities represent 48% of the study sample, 68% of the sample of the Pará study site and 12% of the sample of the Acre study site. The household studied for this model is located in the District of Anapú, about two hours by bus from the city of Belém. Access to the area is difficult during the rainy season due to bad road conditions.

The family, composed of four adults and two children, has lived in the area for sixteen years. They are originally from Maranhão state and had no previous experience with cattle ranching. The total land area is 110 ha, 68% of the area covered by degraded forest. The area of 32 ha of forest that has been cleared is used for pasture (93%). The remaining area is used for annual and perennial crops, and fallow. There is a clear preference for cattle ranching over other activities.

Cattle ranching accounts for 71% of the household income, mainly through the commercialization of dairy products and calves (table 3-4. Year 1). Perennial crops (cacao and coffee) contribute 20% of the total family income; while annual crops contribute 9% of the income, the lowest value for annual crops among the households studied. This family has no off-farm income.

Business-as-usual model for livestock producers: The five-year smallholder livestock production model shows a tendency to reduce deforestation rates. Over 12 years since the family came to the land, forest stands decreased at an annual rate of 2.6%. The area of forest stands decreased from 110 ha to 75 ha. The model predicted a reduction in the deforestation rate of 3.3% to 1.9% per year. This reduction of deforestation was also predicted by the household, who thought they would not be able to extend pasture area due to lack of labor. The pasture area increased by 9% in five years, covering 38% of the total land. Perennial and annual crops occupied 2.2 ha of the area, and the fallow area occupied less than 3.1 ha (Table 3-3).

Table 3-4 shows model results for family income. Income increased 16% in five years, reaching US$ 5,960. The income is still based on livestock (cattle) only, and it increased from 71% to 77%. The relative contribution of perennial crops to family income increased by 17%, while the contribution of perennial and annual crops decreased by 3%.

Perennial Crop Production

To stop deforestation in the Amazon, the government and often organizations indicate that perennial crops are the best solutions for smallholders. Despite some economic and environmental success, not many families have perennial crops as their main production system because of market limitations and technical issues. According to the study sample, 16% of households fell in this category. This number is higher than the number expected for the entire Amazon, but households in Acre were not included in this category. The household studied moved from Maranhão state to the actual property sixteen years ago, with no experience with perennial crop production. This property is located 50 minutes away from Pacajá city; it has electricity, and the road leading to the propriety is in good condition, even during the rainy season. The total area is 90 ha, and 69% is covered with forest degraded by timber exploitation and fire. The total deforested area is 28 ha; 50% is used for pasture, 25% for perennial crops, 7% for annual crops, and 18% is fallow.

Perennial crop production of cacao, banana, and coffee contributes 54% of the household cash income, while 31% is from cattle ranching and livestock, 14%

from maize and manioc flour, and 1% from extraction of “titica” liana and açai fruit. Revenue from these farm activities represents 77% of the total family cash income, while off-farm employment contributes 23%.

Business-as-usual model for perennial croppers: The five-year perennial cropper smallholder production model shows (Table 3-3) that there is a tendency that deforestation will continue at the same rate as the last twelve years, during which time forest stands decreased from 89 ha to 62 ha, at an annual rate of 2%. The model predicted the same rate for the next 5 years. The perennial crop area had an increase of 14%, less than the pasture area, which increased 20%. The annual crop area decreased 76%. Eighty three percent of the area deforested annually was used to grow annual crops and 17% was converted into pasture.

Family cash income (Table 3-4) increased 5% over the five years, reaching US$ 5,004. The household continued to show a preference for perennials. The relative contribution of perennial crops increased from 54% to 59% to the family income. The income from livestock (89% from cattle and 11% from small animals) increased from 31% to 40%. The decreasing relative importance of annual crops in the family income, from 15% to 1%, showed that labor allocation changed from annual crop production to perennial crop and livestock production.

The ELP model solved is consistent in all study cases. It explains satisfactorily the income and land use patterns of householders in Acre and Pará in the business-as-usual scenario. To increase the model accuracy, a larger number of families should be analyzed; however, limited time and financial resources have restricted the amount of fieldwork. In the following sections, the same households are studied to simulate the effects of market prices on income and land use.

First Scenario: Increased Prices of Extractive and Perennial Products

As described in the methodology section, the ELP model was used to simulate the effects of subsidies on forest extractivism and perennial crop production. Over the practiced market price observed during the survey an overprice of 100% was added to simulate a situation where forest products, such as Brazil nut, rubber, liana, *açai*, and *copaiba,* and perennial crops including coffee, cacao, banana, pupunha (*Bactris gasipaes*) had economic stimuli. In this simulation, environmental policies were not enforced. This was only a proposal to subsidize products proceeding from activities that show cumulative evidence of slowing deforestation. Road conditions, demands, and other issues affecting commercialization were excluded in order to simulate good market conditions.

The results were organized to show the effects of product price on land use (Table 3-5) and household cash income (Table 3-6) for extractivists, annual and perennial croppers, and livestock producers, over a five-year period.

All smallholders still lose forest area at an average of 3% (17ha) at the end of the five-year period. Extractivists lose an average of 0.7% of forest area, and annual crop producers lose an average of 11%. The dynamics of fallow and forest areas are a good indicator of household production strategies. In a perfect rotational shifting cultivation system, the fallow area is constant. The reductions of the fallow area mean an increase in crop or pasture production, and vice versa. Yet in the model the fallow area showed an increase of 5 ha as consequence of a reduction of 43% in the annual crop area, while the pasture area increased by 13%. The increase of the pasture area was higher among families primarily engaged in livestock production (31% increment), which already had a cattle ranching tradition. The opposite occurred with producers primarily engaged in perennial crop production, who reduced their pasture area by 16%. The perennial crop area increased an average of 5.3 ha; 44% of it occurred among families primarily engaged in perennial crop production. There was a small increment in perennial crop production among extractivists.

The annual family income increased an average of 11%, from US$ 6,413 to US$ 7,207. The total expenditure to pay the subsidies (adding 100% to the existing market price) was US$ 2,230 per family, up to the fifth year. The relative contribution of annual crop and cattle production to the household income decreased from 24% to 19%. Extractivism and perennial crop production increased the average family income of all households studied by 23%.

Second Scenario: Increased Prices of Annual Crop and Livestock Products

In the second scenario, the effects of commodity price on household income and land use were tested using the ELP model. Nepstad et al. (2006b), when studying commodity markets for the Amazon, found a positive correlation between market price for agricultural products and deforestation. The main commodities in the study sample were rice, maize, beans, cattle, chickens, and hogs. Each of these products had their price doubled in the model. The results of land allocation and income for the five-year models are presented in Table 3-7 and Table 3-8 .

Results from the model showed an increase of 48% in the crop and pasture areas: pasture area increased by 38% and the annual crop area by 50% by the end of the fifth year. Compared with the business-as-usual model, in which the agricultural production area increased by 34%, the high prices had a strong influence on land use decisions in all types of households studied. This influence was significant especially among extractivists for whom the amount of land dedicated to production increased 213%. The result of agricultural expansion on forest stands was astonishing. Forest was cleared and burned at a rate of 2% per year. Producers primarily engaged in annual crops cleared forests at a rate of 4.2% per year, while producers primarily engaged in livestock and perennial crops cleared forests at a rate of 2.8%. Extractivists cleared forests at a rate of 0.5%, the lowest rate among all types of households. Considering the deforestation area, extractivists cleared 11.3 ha, almost the same amount of forest that annual (10.7ha) and livestock producers (10.4ha) had cleared. In general, the average size of the fallow area did not change, but fallow of perennial croppers increased by 13.2% and decreased in the other production systems.

The average increase in income was 57.7%, from US$ 5,673 to US$ 8,948. The annual crop yield per hectare increased 8%. Extractivists had the highest increase in income (119%), and perennial crop producers had the lowest (42%). Livestock producers had an increase in income of US$10,483, an increase superior to the business-as-usual model by 56%. Extractivism and perennial crop production had a less significant participation in the family income in the four households studied, ranging from 55% among families primarily engaged in annual crop production to 19% among families primarily engaged in extractivism.

Conclusions about the Potential of the Ethnographic Linear Program Models to Understand and Predict Land Use Change

Overall, the findings of the study indicated a great potential to use ELP to describe and simulate the main types of land use practiced by smallholders in the

Amazon, and to predict their responses to external interventions. In this paper, we tested different types of smallholders' land use in two Amazonian study sites: the Chico Mendes Extractive Reserve in the State of Acre and the Transamazon in the State of Pará. The model was tested to predict how the payment of bonus for "environmentally friendly" products, in this case extractive and perennial products, could affect land cover and family income. Using the business-as-usual model as a basis, we also tested the effect of increasing prices of agricultural commodities as a result of global food shortage, which is highly predictable due to population growth and a decrease in crop production. The analysis of these two scenarios aims to open the discussion about the future of smallholder production in the Amazon. Both a scenario where forest and other adapted production systems receive stimulus and the business as usual scenario, where forests have no value was considered.

Smallholder Heterogeneity

The first conclusion is that smallholders are a heterogeneous economic category. This study used a cluster statistical analysis to distinguish smallholders by the income from different production systems. Nearly half of the households sampled had livestock production as the main source of income; nevertheless, smallholders primarily engaged in cattle ranching differ from large cattle ranchers in terms of market goals. Smallholders use cattle as savings, selling the product only on special occasions, such as sickness (Muchagata & Brown, 2003). The income originating from smallholders primarily engaged in cattle ranching represents no more than 90% of the production sold and no more than 65% of household production. Cattle production appeared among all types of households, and it is cited as the most important activity for the future of the family. Annual crops are also a common activity among all types of households, and they are a common source of cash for households in their early stages of the life cycle (Walker et al., 2002). These households represent 13% of the sample.

Regarding production specialization, a quarter of the households have forest products as their main source of income, 87% in the Acre study site. Acre and Transamazon extractivists have different realities. In the Transamazon, extractivism is practiced primarily in the early stage of farm occupation, when the family occupies the land covered by forest and has no money. In Acre, extractivism is the main source of income throughout the entire family life cycle, even in places where cattle production is present.

Family cash income is heterogeneous among the different types of smallholders studied. While the average annual family income is US$ 2,800, corresponding to one third of the Brazilian minimum wage, producers primarily engaged in perennial crops have an income 54% higher and producers primarily engaged in annual crops have an income 39% lower than the average. Other important parts of household cash income come from off-farm earnings, which represent about 23% of the total family income, although, statistically, there is no significant difference between clusters. Off-farm income has increased during the last decade due to increments in distributive programs in Brazil (VanWey, D'Antona, & Brondízio, 2007). Further studies about the effects of off-farm income, mainly from social programs such as "*bolsa familia*" (family stipend), could reveal the role of money allocation in the household, and how program requirements have been monitored and enforced. These cash transfer programs could provide clues on how to transfer payments for environmental services to smallholders (Viana, 2009).

The diversity of production systems affects forest conservation. While extractivists in Acre lost 2.1% of forest, producers in Transamazon primarily engaged in livestock production lost 40%. The annual deforestation rate since the extractivist family moved to the land was 0.1%., fifty times lower than the rate among producers primarily engaged in livestock.

The use of ELP as a tool to analyze a baseline household scenario accomplished well the initial goals established for this research. It explained the reality in the four household types. This study offered a good explanation for the household decisions on land allocation, compared to other studies about smallholders that explained household strategies, deforestation patterns, and variations in income composition (Agrawal & C.C.Gibson, 1999; Almeida et al., 2006; Andersen & Barnes, 2004; Angelsen & Kaimowitz, 2001a; Costa et al., 2006; Kaimowitz et al., 2004; Kainer, Schmink, Leite, & Fadell, 2003; Nepstad et al., 2006b; Perz, 2003; Walker et al., 2000). The use of socio economic constraints and demographic variables, such as predicted by Chayanov, and the use of demographic theories (Caldas et al., 2007; Perz, 2001b), have proved to be efficient to observe and predict smallholders' land use.

Smallholder Decisions Linked to Market

The second set of conclusions links smallholders' land use decisions to market signals. Nonetheless, the influence of market on smallholders' decisions does not exert a determinant effect on their production, as it does to agribusiness. Based on Chayanov's theory of peasant economy, the fact that the farm is a unit of consumption and production makes smallholders more willing to avoid risks to family reproduction over time (Costa, 1993; Perz, 2001a), and to be cautious of any proposed change to the production system. This behavioral characteristic is more intense among families less dependent on markets and to which it is difficult to apply a model. Bias was minimized by the use of ethnographic research to compare results from the model with family perceptions about the future. The business-as-usual model was used as a baseline to simulate household reaction to different market conditions.

Two scenarios were developed to simulate the effect of good market conditions (such as higher prices for products and no limitations in commercialization channels) on income and land use. The first model simulated good market conditions for forest products and perennial crops, which are recognized as potential mechanisms to reduce deforestation. The second model for livestock and annual crop production is traditionally associated with an increase in deforestation rates (Nepstad et al., 2006b).

The results were shown in Figure 3-5. Increasing prices of extractivism and perennial crop products led to a 51% decrease in cumulative new deforested area, when compared to the business-as-usual scenario. As expected, deforestation decreased among all households studied, with a greater reduction among extractivists (71%), and a smaller reduction among annual croppers (23%). The different effects of deforestation among smallholders indicated that improved market conditions for extractivist products from extractive reserves, where the forest resource is abundant, can reduce deforestation rates. However, the effect of perennial crop production on reducing deforestation was inferior to the effect observed for forest products. Comparing the three household types with no significant forest resources, newly deforested area was 46% less than observed in the business-as-usual scenario. A plausible explanation is the high cost of implementing perennial crop production, which is always a limitation among smallholders, and the long-term return. For example, the harvest of some forest products, like timber, begins after 20 years.

When we simulated the increase in price of agricultural commodities, agricultural production increased by 44% and boosted deforestation 31% more than the business-as-usual scenario. The phenomenon was more intense among annual crop producers, with a 53% increase; and it was less intense among extractivists, with a 16% increase. Furthermore, the results of a reduction of initial fallow areas by 47%, after five years, indicated a process of agricultural intensification and a continuous decreasing of deforestation rates.

Smallholders respond to changes in market price as predicted in other studies that observe smallholder livelihood strategies. The results indicate that good commercialization channels and prices could lead to forest conservation. An average of US$830 per year given as subsidy to each household was sufficient to avoid a forest loss of 5ha and changed the production system from extensive cattle ranching. In fact, the ELP model is effective to predict land use changes for two market scenarios and it proved to be accurate to understand household behaviors that explain land use decisions.

Market prices changed land use and affected income. As expect, household income increased in both scenarios. It increased by 34% as a result of better prices for perennial and forest products, and 53% as result of better prices for agricultural commodities. If the desirable scenario for smallholder production in the Amazon should focus on expanded forest biodiversity use and an increase in perennial crops areas, households need to have a comparative advantage to change the actual production system from annual crops and cattle. Based on a scenario in which market prices for forest and perennial crops increase, participation of forest and perennial crops production will increase family annual cash income from 41% to 62% (Figure 3-6).

This result was achieved using only forest and perennial production already practiced by producers. It is possible to have better comparative results, if other products are included; however, the introduction of new products will increase the risk that most smallholders try to avoid. To minimize risk, research programs need to be implemented and commercialization channels need to be created, so that biodiversity becomes part of smallholders' livelihood strategies. The ELP model can be compared with other research programs, as a way to understand the socioeconomic effects of research proposals on smallholder livelihoods and to reduce the risk of proposal failure due to family behavior socioeconomic.

Even when the diversity of livelihood strategies is taken into consideration, increasing market prices for forest and perennial crop products can be an efficient mechanism to reduce deforestation, and can contribute to situations where extractivism or perennial crop production previously existed. Another important finding is that deforestation still occurs, due to technical incapacity to produce annual crops without slash and burning.

These results have significant importance when we realize that smallholder production can contribute to reduce carbon dioxide emissions. Considering that smallholders have brought forest biodiversity to consumers and control large amount of forest, substantial efforts need to be implemented to use the potential of smallholders.

Land use change and its effect on the Amazon forest is a current issue in climate change negotiations. Finding ways to reduce deforestation and poverty in tropical areas is a central issue, to which we still do not have answers. This chapter shows the application of a tool that could help decision-makers to plan interventions that are more efficient and interpret effects before they happen. In the next chapter, an ELP model was developed to simulate the carbon baseline for a household and the possibilities to increase carbon stock within a scenario where payment for this environmental service becomes a reality.

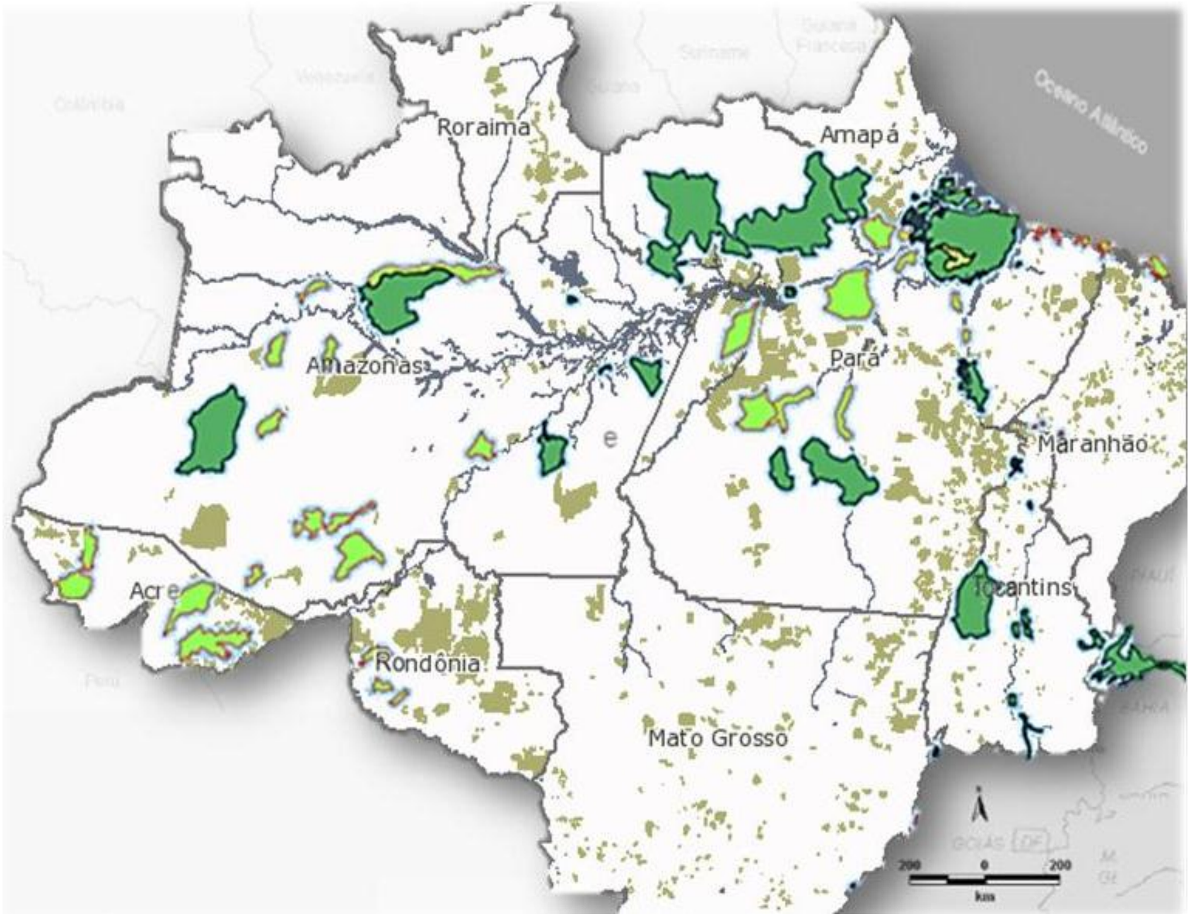

Figure 3-1. Distribution of smallholders in the Brazilian Amazon. Brown represents smallholder settlement. Dark and light green represent direct use conservation units with residents. (Source: www.mma.gov.br/servermap)

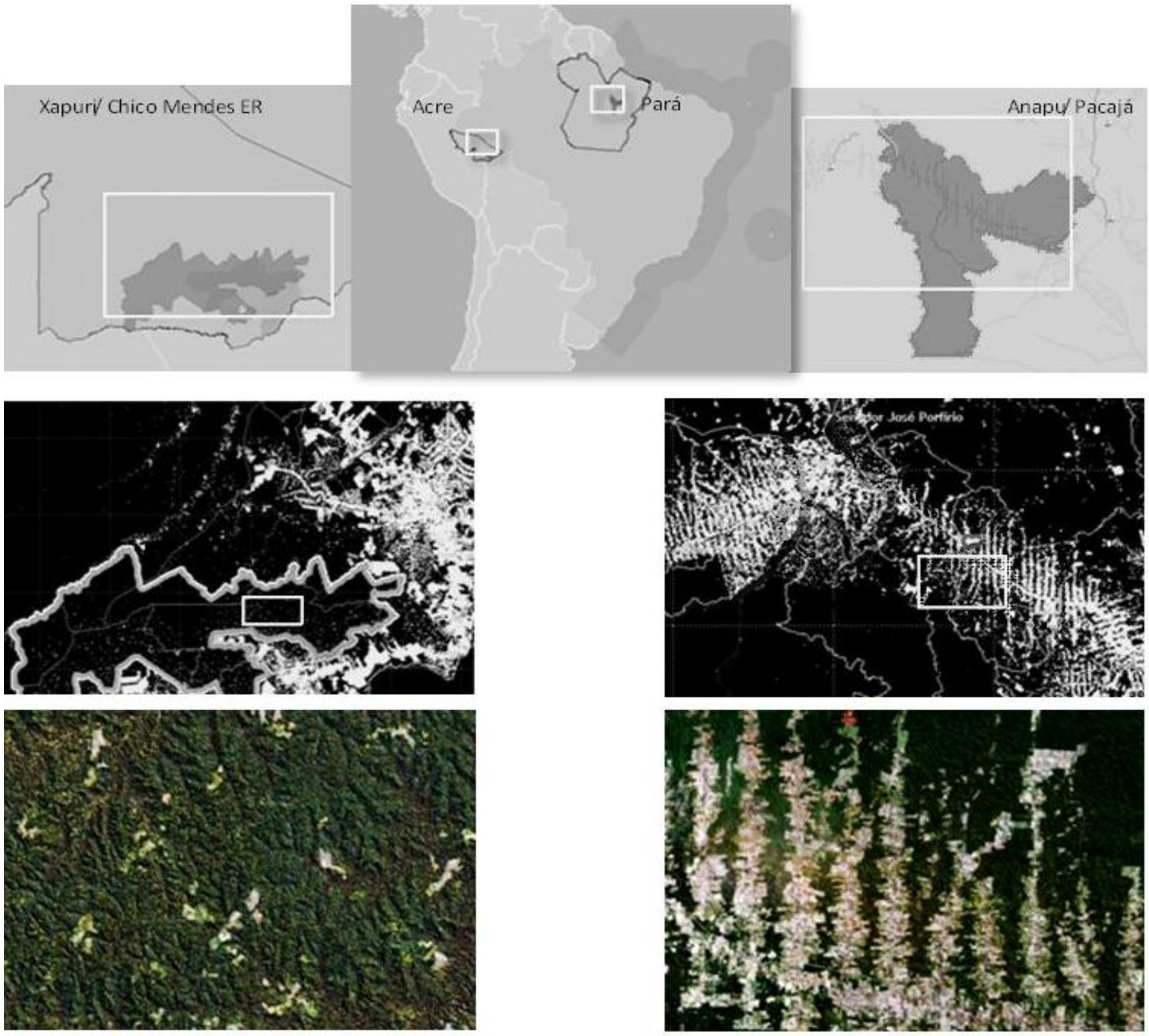

Figure 3-2. Study sites location showing the difference in deforestation pattern.

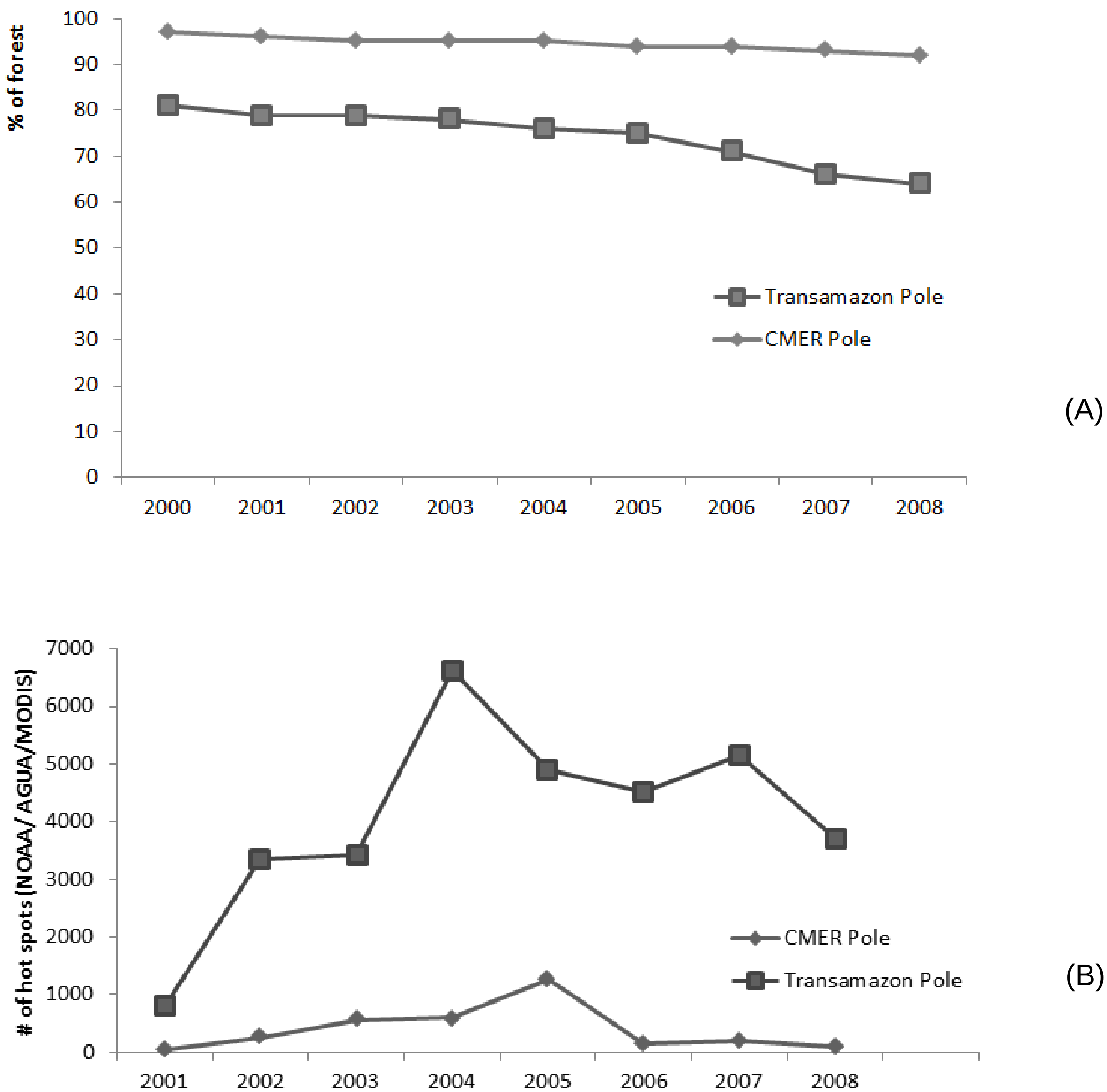

Figure 3-3. Two indicators of carbon emission from the study sites. (A) Percentage of total study area covered by forest. Deforestation higher in Transamazon area and intensifying during the second half of 2000.(B) Number of hotspots in the same area. Indicate the amount of area burning. Source: Brazilian National Aerospatiale Research Institute (INPE/DETER). Accessed: 08/09/2009 from http://www.obt.inpe.br/deter.

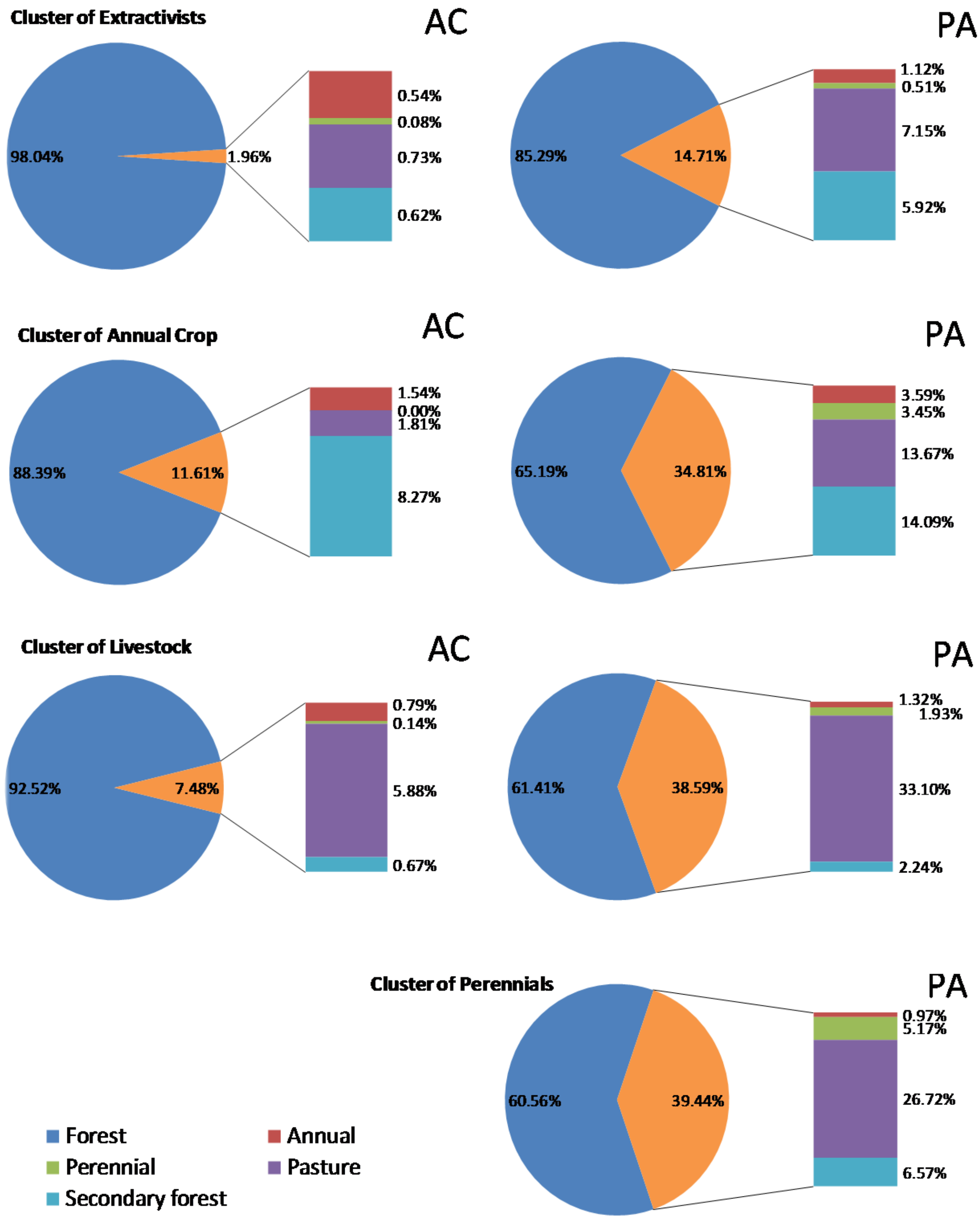

Figure 3-4. Land use patterns in Acre and Para study sites. Values are percentage of study site total area. Yellow area in the graph represents deforested land.

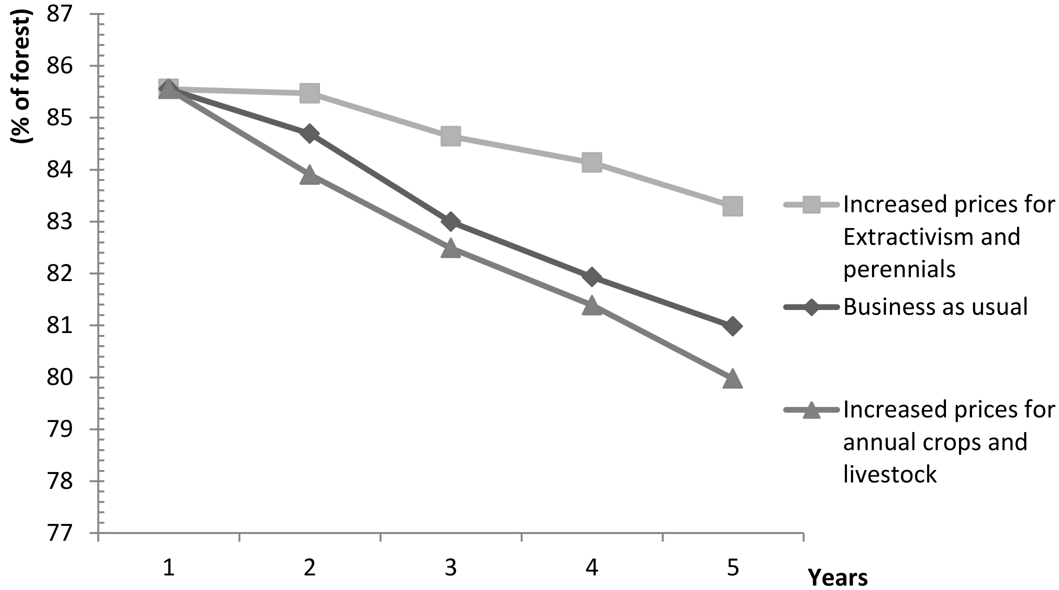

Figure 3-5. Deforestation patterns for a five-year model. Values are a percentage of smallholder's forest cover.

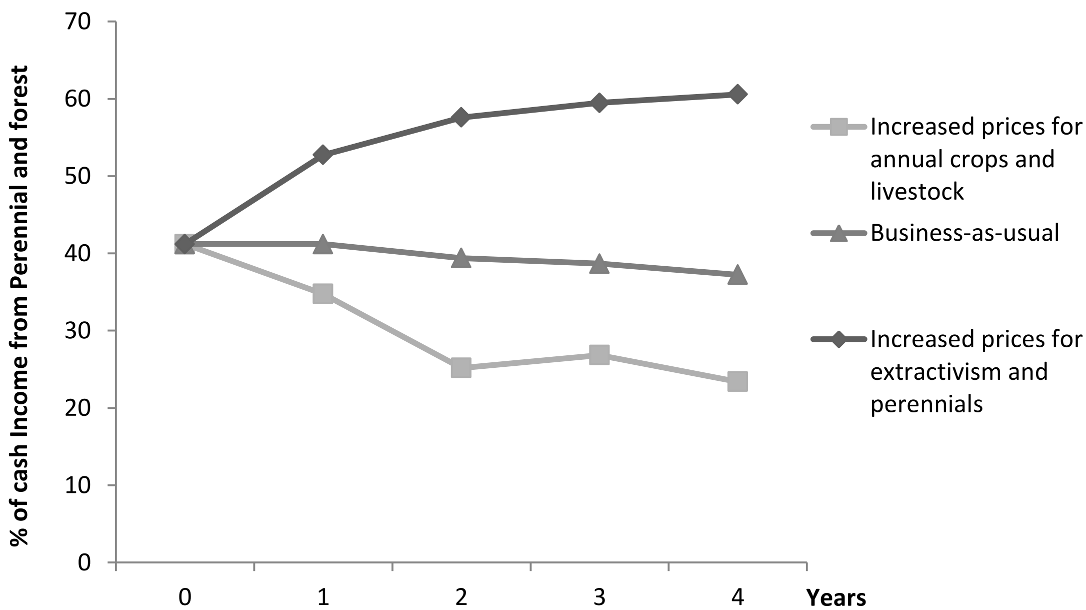

Figure 3-6. Cash income proportion that comes from forest and perennial crops in the five-year modeled families.

Table 3-1. Characteristics of smallholders' sampled in the Acre and Pará sites, clustered by main cash production.

Smallholder characteristics	Cluster 1 Extractivist (E)		Cluster 2 Annual crop (A)		Cluster 3 Perennial (P)		Cluster 4 Livestock (L)	
	Acre	Pará	Acre	Pará	Acre	Pará	Acre	Pará
n=	46	7	4	26	0	37	8	101
Area (ha)	519.9 (124.8)	97.8 (0.2)	221.3(32.0)	72.4 (28.3)		92.8 (55.7)	418.3 (102.3)	98.2 (37.9)
Forest (ha)	509.7 (190.3)	83.5 (2.4)	195.6 (36.9)	47.2 (21.3)		56.2 (34.8)	387.0 (87.3)	60.3 (33.8)
Annual (ha)	2.8 (1.0)	1.1 (0.4)	3.4 (1.2)	2.6 (2.7)		0.9 (1.2)	3.3 (1.9)	1.3 (1.9)
Perennial (ha)	0.4 (0.5)	0.5 (1.2)	0.0 (0.0)	2.5 (2.4)		4.8 (4.9)	0.6 (1.9)	1.9 (2.1)
Pasture (ha)	3.8 (1.3)	7.0 (3.4)	4.0 (1.1)	9.9 (9.5)		24.8 (22.2)	24.6 (20.3)	32.5 (27.0)
Secondary forest (ha)	3.2 (1.1)	5.8 (2.6)	18.3 (2.8)	10.2 (4.9)		6.1 (3.0)	2.8 (2.3)	2.2 (4.2)
Extractivism income (%)	67.4 (15.1)	89.4 (2.1)	36.5 (6.7)	0.0 (0.0)		0.0 (0.0)	18.9 (8.3)	0.0 (0.1)
Annual crop income (%)	26.0 (12.7)	10.2 (3.5)	55.3 (6.5)	84.0 (16.8)		3.0 (7.2)	29.1 (11.3)	2.8 (7.3)
Livestock income (%)	8.7 (2.5)	0.4 (0.2)	8.2 (3.5)	12.9 (15.5)		15.7 (17.6)	51.7 (19.4)	91.2 (15.9)
Perennials income (%)	0.9 (0.3)	0.0 (0.0)	0.0 (0.0)	3.0 (9.6)		81.3 (18.4)	0.3 (0.7)	6.0 (11.4)
Family size (number)	6.2 (2.1)	1.8 (0.6)	4.0 (1.1)	2.1 (0.9)		2.4 (0.7)	4.3 (2.7)	2.2 (0.8)
Years in area	16.1(4.6)	2.1 (1.5)	15.0 (8.7)	7.1 (5.2)		9.4 (3.9)	14.1 (2.1)	8.7 (4.1)
Distance market (hours)	1.8 (0.7)	3.9 (5.7)	1.2 (0.4)	2.8 (2.5)		1.8 (1.1)	1.3 (1.2)	2.2 (3.9)

Note: Values represent means (standard deviation).

Table 3-2. Smallholder cash income for each productive cluster. Values indicate mean annual household cash income in dollar.

Household Income ($)	Cluster 1 Extractivist (E)		Cluster 2 Annual Crop (A)		Cluster 3 Perennial (P)		Cluster 4 livestock (L)	
	Acre	Pará	Acre	Pará	Acre	Pará	Acre	Pará
n=	46	7	4	26	0	37	8	101
Extractivism	2657	1276	709	0	0	0	734	0
Annual crop	930	143	972	847	0	38	1130	64
Livestock	236	57	126	220	0	745	2007	2233
Perennials	28	0	0	46	0	3533	12	174
Total	3852	1477	1807	1113	0	4316	3882	2471

Table 3-3. Model results for business-as-usual scenario. Values are in percentage of total household area.

Parcels		Year 1	2	3	4	5
Extractivist	E (450ha)					
Annual croppers	A (85ha)					
Perennial croppers	P (90ha)					
Livestock producers	L (110ha)					
Forest	E	97.9	97.3	96.4	95.7	94.9
	A	60.0	56.8	56.4	53.2	51.8
	P	69.4	68.8	62.6	63.2	62.7
	L	68.0	67.8	65.6	63.2	61.5
Secondary forest	E	0.9	1.2	2.1	2.1	2.8
	A	17.6	19.8	15.1	12.8	14.2
	P	5.6	3.6	8.7	8.7	9.2
	L	2.7	2.6	2.7	2.7	1.8
Annual	E	0.3	0.3	0.3	0.4	0.4
	A	5.9	6.4	5.8	5.9	5.9
	P	1.7	1.2	1.2	0.6	0.6
	L	0.9	2.0	0.5	0.8	0.8
Perennials	E	0.0	0.0	0.0	0.0	0.0
	A	2.4	2.4	1.5	1.5	1.5
	P	7.8	7.8	8.9	8.9	8.9
	L	1.1	1.1	1.1	1.1	1.1
Pasture	E	0.9	1.2	1.2	1.8	1.8
	A	14.1	14.7	21.3	26.6	26.6
	P	15.6	18.7	18.7	18.7	18.7
	L	27.3	26.5	30.0	32.2	34.7

E- Extractivist; A- Annual Croppers; P- Perennial Croppers ; L - Livestock Producers

Table 3-4. Model results for business-as-usual scenario. Values are in percentage of total household cash income.

Types	Productive system	Year 1	2	3	4	5
Extractivists	Extractivism	75.1	72.5	71.1	63.5	63.5
	Annual crops	15.2	14.7	14.4	18.9	18.9
	Perennial	0.0	0.0	0.0	0.0	0.0
	Livestock	9.6	12.8	14.5	17.5	17.5
	Total Income (US$)	*4100*	*4247*	*4331*	*4881*	*4881*
Annual croppers	Extractivism	0.0	0.0	0.3	0.3	0.3
	Annual crops	60.3	63.7	57.3	53.5	53.4
	Perennial	15.3	13.6	8.8	8.1	8.1
	Livestock	24.4	22.6	33.6	38.2	38.3
	Total Income (US$)	*4516*	*5073*	*5080*	*5558*	*5568*
Perennial croppers	Extractivism	0.6	0.6	0.5	0.6	0.3
	Annual crops	14.7	9.0	8.0	0.7	0.7
	Perennial	53.8	53.4	54.3	58.6	58.8
	Livestock	31.0	36.9	37.2	40.1	40.3
	Total Income (US$)	*4787*	*4816*	*5419*	*5017*	*5003*
Livestock producers	Extractivism	0.0	0.0	0.0	0.0	0.0
	Annual crops	8.8	22.5	3.1	6.6	6.3
	Perennial	20.0	17.4	19.7	17.9	16.9
	Livestock	71.2	60.1	77.2	75.4	76.8
	Total Income (US$)	*5049*	*5805*	*5121*	*5625*	*5960*

Table 3-5. Model results for increased prices of extractive and perennial products. Values are in percentage of total household area.

Types		Year				
		1	2	3	4	5
Extractivists	E (450ha)					
Annual croppers	A (85ha)					
Perennial croppers	P (90ha)					
Livestock producers	L (110ha)					
Forest	E	97.9	97.8	97.6	97.2	97.2
	A	60.0	60.0	58.7	56.8	53.6
	P	69.4	67.7	67.1	66.8	65.2
	L	68.0	69.3	66.1	66.1	64.2
Secondary forest	E	0.9	1.2	1.2	1.4	1.4
	A	17.6	19.8	19.1	19.9	21.5
	P	5.6	3.6	3.6	4.2	4.8
	L	2.7	2.6	2.7	2.7	3.1
Annual	E	0.3	0.2	0.2	0.2	0.2
	A	5.9	3.8	5.8	6.2	4.9
	P	1.7	1.2	1.2	0.9	0.9
	L	0.9	0.5	0.5	0.5	0.5
Perennials	E	0.0	0.0	0.2	0.2	0.2
	A	2.4	2.4	2.4	2.9	3.4
	P	7.8	8.9	9.4	9.4	10.4
	L	1.1	1.1	2.0	2.0	2.0
Pasture	E	0.9	0.9	0.9	1.1	1.1
	A	14.1	14.1	14.1	14.1	16.5
	P	15.6	18.7	18.7	18.7	18.7
	L	27.3	26.5	28.6	28.6	30.2

Table 3-6. Model results for increased prices of extractive and perennial products. Values are in percentage of total household cash income.

		Year				
Type	% of Income	1	2	3	4	5
Extractivists	Extractivism	83.8	90.9	91.0	89.9	89.9
	Annual crops	10.8	3.3	3.3	3.2	3.2
	Perennial	0.0	0.0	0.0	0.0	0.0
	Livestock	5.4	5.8	5.8	6.9	6.9
	Total Income (US$)	*7350*	*6843*	*6878*	*6961*	*6961*
Annual croppers	Extractivism	0.0	0.5	0.4	0.7	0.8
	Annual crops	52.8	40.1	52.1	50.8	40.8
	Perennial	25.8	32.4	26.0	29.1	35.0
	Livestock	21.4	26.9	21.6	19.3	23.4
	Total Income (US$)	*5151*	*4094*	*5112*	*5706*	*5151*
Perennial croppers	Extractivism	0.4	0.4	0.3	0.4	0.3
	Annual crops	11.0	6.3	6.0	3.5	3.2
	Perennial	67.7	70.5	71.8	73.7	75.6
	Livestock	20.9	22.8	21.9	22.5	20.8
	Total Income (US$)	*7093*	*7789*	*8133*	*7917*	*8536*
Livestock producers	Extractivism	0.0	0.0	0.0	0.0	0.0
	Annual crops	7.3	2.8	2.1	2.1	2.0
	Perennial	33.3	35.6	48.4	48.4	47.2
	Livestock	59.4	61.6	49.5	49.5	50.8
	Total Income (US$)	*6057*	*5662*	*7629*	*7629*	*7833*

Table 3-7. Model results for increased prices of annual crop and livestock products. Values are in percentage of total household land.

Type	Parcel	Year 1	2	3	4	5
Extractivist	E (450ha)					
Annual croppers	A (85ha)					
Perennial croppers	P (90ha)					
Livestock producers	L (110ha)					
Forest	E	97.9	96.8	97.0	96.0	95.4
	A	60.0	55.2	54.6	51.8	47.4
	P	69.4	67.3	62.2	60.7	59.9
	L	68.0	67.0	61.5	61.5	58.5
Secondary forest	E	0.9	0.8	0.7	0.9	0.7
	A	17.6	19.8	15.8	11.4	15.8
	P	5.6	3.6	8.7	8.7	9.2
	L	2.7	2.6	1.9	1.9	1.9
Annuals	E	0.3	0.7	0.7	0.9	0.7
	A	5.9	6.4	6.8	6.4	6.4
	P	1.7	2.7	2.7	2.7	2.9
	L	0.9	2.0	2.0	2.0	2.0
Perennials	E	0.0	0.0	0.0	0.0	0.0
	A	2.4	2.4	1.5	1.5	1.5
	P	7.8	7.8	7.8	7.8	7.8
	L	1.1	1.1	1.1	1.1	1.1
Pasture	E	0.9	1.6	1.6	2.2	3.2
	A	14.1	16.4	21.3	28.9	28.9
	P	15.6	18.7	18.7	20.2	20.2
	L	27.3	27.3	33.5	33.5	36.5

Table 3-8. Model results for increased prices of annual crop and livestock products. Values are in percentage of total household cash income.

		Year				
		1	2	3	4	5
Extractivists	Extractivism	62.5	40.6	53.4	40.5	50.7
	Annual Crops	28.5	49.2	38.1	49.1	35.3
	Perennial	0.0	0.0	0.0	0.0	0.0
	Livestock	9.0	10.2	8.5	10.4	13.9
	Total Income (US$)	4388	6921	8307	8891	9636
Annual croppers	Extractivism	0.0	0.4	0.3	0.3	0.3
	Annual Crops	61.1	66.0	66.2	58.6	58.6
	Perennial	15.0	11.8	7.1	6.8	6.8
	Livestock	23.9	21.8	26.3	34.3	34.3
	Total Income (US$)	4610	5852	6315	6592	6592
Perennial croppers	Extractivism	0.4	0.3	0.3	0.3	0.3
	Annual Crops	33.2	45.6	45.6	45.0	47.3
	Perennial	46.9	36.0	36.0	35.5	34.0
	Livestock	19.5	18.0	18.0	19.2	18.4
	Total Income (US$)	6588	8569	8569	8698	9081
Livestock producers	Extractivism	0.0	0.0	0.0	0.0	0.0
	Annual Crops	11.6	27.7	24.3	24.3	23.1
	Perennial	14.2	11.6	10.2	10.2	9.6
	Livestock	74.2	60.7	65.5	65.5	67.3
	Total Income (US$)	7107	8693	9907	9907	10483

CHAPTER 4
MODELING EFFECTS OF CLIMATE CHANGE POLICIES ON SMALLHOLDERS

Introduction

Importance of the Brazilian Tropical Forest to Global Climate Change

As primary causes of climate change, the Intergovernmental Panel on Climate Change (IPCC) report (UNFCCC, 2005) highlights fossil fuel use and land use change, the latter accounting for roughly one-fifth of total anthropogenic greenhouse gas emissions. Forests play a double role in climate change: sequestering large quantities of carbon as growing trees absorb carbon dioxide from the air, and storing carbon. Thus forests can become a major source of carbon emission when the stored carbon is released into the atmosphere by means of fire, forest degradation and deforestation activities.

Brazil is the fourth largest carbon emitter in the world. Annual emissions in the Brazilian Amazon are estimated at 200 million tons per year from deforestation (Houghton, 2005) plus the accidentally burned area that emits from 10% to 150% more carbon than deforestation alone (Nepstad et al., 1999). Studying 152 cases in tropical areas with high deforestation rates, Geist and Lambin (2002) found that carbon emissions in the Amazon are mostly due to anthropogenic activities of converting forests to non-forested area. The actors vary over time depending on internal and external factors such as currency exchange rate, commodity prices, and subsidies. In the 1980s and 90s, smallholders and cattle ranches emitted almost the same amount of carbon; however, since 2000, emission from deforestation for large farms producing soybeans for export increased (Nepstad et al., 2006b).

The main international forum about climate change was organized by the United Nations in the Framework Convention on Climate Change (UNFCCC), which was adopted at the Earth Summit in Rio de Janeiro in 1992. The main agreement negotiated as an amendment to the convention was the Kyoto Protocol, under which industrialized countries agreed to reduce their collective emissions of greenhouse gases by 5.2% compared to the year 1990. Yet credit for forest maintenance was excluded in the agreement until 2012 (UNFCCC- United Nations Framework Convention on Climate Change, 2005). This spawned the voluntary market for carbon stocked in tropical forests, though still in a limited scale.

Because of emerging knowledge about global warming, and the urgency felt by governments, the role of tropical forests to alleviate global warming is attracting more attention as a target of international financial flows for conservation than are other environmental services such as biodiversity maintenance. During the UNFCCC 13th Conference of Parties -COP13- held in Bali in 2007, the “Road Map” to the next commitment period after 2012 was established. This included tropical forests in Brazil, which holds the greatest area of tropical forest in the world and could potentially gain carbon credit in this new, currently negotiated system. This carbon credit can compensate tropical countries for their nationwide reduction in emissions from deforestation and degradation (REDD) (Moutinho et al., 2005).

Forest-Based Carbon Trade for Smallholders

There are two major reasons to consider smallholders as the main actors to be involved in the REDD mechanism. One is the socioeconomic importance of this social segment. Between a half million (IBGE- Instituto Brasileiro de Geografia e Estatística, 2006) and two million (CONTAG- Confederação Nacional dos Trabalhadores na Agricultura, 2004) smallholder families live in the Amazon biome. Excluding Mato Grosso transition forest, they control 31% of the land, generate 71% of total rural production aggregate value, and grow 89% of the daily food (IBGE- Instituto Brasileiro de Geografia e Estatística, 2006). They also produce about 93% of the cassava flour, 95% of the rice, 100% of the beans, and 58% of the cattle in the Amazon region (Costa, 2000). On the other hand, most of the smallholders in the Amazon live on less than two dollars per person per day: the poverty line established by the Word Bank.

The other and the most important reason for the importance of smallholders in carbon trade is the linkage between production and carbon emissions from deforestation. This is due to the intense use of fire as the widespread tool of clearing forests for farming (Hedden-Dunkhorst et al., 2003). Nepstad *et al.* (1999) found equal contributions of small and large farms to total deforestation, although such an estimate typically varies with the methodology used. For example, Pacheco (2003), using census data and satellite imagery, estimated that deforestation by small farmers constituted only one percent of the total area deforested between 1985 and 1995. On the other hand, Sawyer (2001) theorized that if each of the two million families living in forested rural areas deforested one hectare, carbon emissions by smallholder farms could reach 65% of the total carbon emitted by land use change in the Amazon.

Many researchers see that an effective way of reducing deforestation rates of smallholders is to make agriculture more productive and sustainable, and forests more valuable. Agriculture will continue to be an important activity for large populations in the tropics. An increase in productivity through intensification, for example, can lessen the pressure on the agricultural frontier and thus reduce deforestation. Von Ambsberg (1988) argues that agricultural improvements will reduce deforestation only if they do not increase the profitability of agricultural activities in newly cleared areas. Yet it has been suggested that livelihoods of many settlers arriving in the Brazilian Amazon region as poor colonists have improved and that some achieved it at markedly higher rates than other populations in Brazil (Braz et al., 1988; Reynal et al., 1995; Vosti, Witcover, & Carpentier, 2003). This suggests that the most profitable strategy for farming may be to clear forest for agriculture and ranching. Still, with increases in the intensity of land use, it may be possible to reduce these incentives to clear forest (Vosti, Gockowski, & Tomich, 2005).

It has been also argued that technologies for intensifying agriculture could slow deforestation; however, the link between the two is ambiguous. In the Amazon, the main possibilities for agricultural intensification for smallholders include cultivation of perennial crops, pasture management, silvopastoral systems, forest management, and fire management and control (Carpentier, Vosti, &

Witcover, 2000; Mello & Pires, 2004). All of them can potentially lessen the pressure on conversion of forests.

Other researchers suggest that deforestation in poor tropical communities will be reduced if forests become economically attractive to local populations. Timber forest management practices (FAO- Food and Agricultural Organization of the United Nations, 2005) and management of forests for non-timber forest products (Nepstad & Schwartzman, 1992) have been considered the best ways to raise forest-based incomes of local people (Perez & Byron, 1999). More recent views have documented that forests with high biodiversity——such as tropical forests— are not ideal for commercial harvesting, because harvesting is difficult and yields are seldom economically viable (Neumann & Hirsch, 2000). In contrast, the REDD mechanism can achieve both an increase in the value of forests through payments for carbon stored in biomass, and reduction in carbon emission through a shift from the slash-and-burn agricultural system to low carbon emission systems such as agroforestry and rotational cropping. It is thus seen as a new, potential method to control deforestation in the tropics.

A carbon market for forest is yet to be regulated, and there are still methodological issues that make implementation difficult. For the purchaser of carbon offsets, it is essential to be able to monitor and measure the net reduction in carbon emissions, to enforce the agreements. The problems of measurement revolve around calculation of the net emission effect: the difference in carbon emissions over time between the ‘‘project scenario" and the “baseline scenario” (without project) (Moutinho et al., 2005; UNFCCC- United Nations Framework

Convention on Climate Change, 2008). Another measurement problem stems from the Kyoto Protocol's "additionality" principle: initiatives to mitigate greenhouse gas emissions must be considered additional to existing practices and governmental environmental laws. For smallholders, this implies the necessity to define carbon emissions for each parcel of land use on the property (Achard, Eva, Mayaux, Stibig, & Belward, 2004).

This chapter contributes to the REDD discussion by evaluating the potential costs and benefits when smallholders change their production systems to those of low carbon emission. This study was carried out in an eastern Amazon smallholder area, in which the first governmental project of payment for environmental services started in 2004. We simulated the effect on land use and family income over a five-year period from the start of the payment. Our focus was on evaluating the effectiveness of the new carbon income on reducing deforestation and improving family welfare.

We hypothesized that participation in the carbon market affected the smallholder system in two ways: 1) the extensive agricultural system will lose economic competitiveness to higher carbon systems such as perennial crops and forest management; and 2) livestock and agricultural systems will be intensified, due to reduced availability of land for agricultural expansion plus funds available through the carbon market to invest in technological improvements.

Methods

An ethnographic linear program (ELP) was used to analyze the potential effects of REDD policies on land use decisions and farm income of small-scale farmers in the Transamazon settlement project near Altamira, in the eastern Brazilian Amazon. The model is briefly described below, and the effects of REDD policies on land use, farm income and carbon stocks were simulated.

Linear programming can be mathematically described as:

Max (or Min): $Z = \Sigma_j C_j X_j$ (j = 1 . . . n)

Subject to: $\Sigma_i A_{ij} X_j <= R_i$ (i = 1 . . . m)

And $X_i >= 0$

Z is the variable objective to be minimized or maximized; C_j is the cost (debit) or returns (credit) of each of the n activities X_j; A_{ij} is the set of input or output coefficients for each activity j and resource or constraint i; and R_i is the set of m minimum or maximum constraints or restrictions.

Study Area

This study was conducted in Anapú County, State of Pará, in a settlement area located near the Xingu River in the eastern part of the Brazilian Amazon, 600 km or 12 hours by car from Belém, the state capital (Figure 4-1). The area receives annual precipitation exceeding 1,700 mm with five dry months a year with less than 50 mm precipitation (ANA- Agencia Nacional de Águas, 2006). This seasonal rain pattern defines the agricultural cycles and the high inflammability of the forest in the dry season (Nepstad et al., 2004). This area was colonized in 1972, when the Transamazon highway was opened in the heart of the Amazon tropical rain forest. The settlement was designed as a “fish-bone” with secondary roads (*travessão*), each of which is 5 km long and running perpendicular to the highway. The total population of Anapú is 9,407 and the demographic density is less than 0.79

inhabitants/km². Most of the population (67%) lives in smallholder. According to the Brazilian Institute of Geography and Statistics (IBGE, 2006) census, 62% of the population older than 10 years is involved in some kind of agriculture, animal husbandry, forestry, and fishing activities. The smallholders living within 10 km from the Transamazon highway had been settled by the government 20 years ago, while migrants farther from the highway moved in without official permits. The former received subsidies and technical assistance to grow cacao and develop pasture, and deforested more area than the latter (Rocha, 2003).

Economic Analyses of the Reducing Emissions from Deforestation and Forest Degradation Project Using Ethnographic Linear Programming

Studies of smallholder systems require an understanding of the complexity of their livelihood production and reproduction activities. The conceptual framework to study small farmers places a family at the center of decision making in resource allocation and consumption (Hildebrand et al., 2003). All fluxes of inputs and outputs associated with production converge at and diverge from the family. The effect of carbon policies and their constraints on the livelihood system is added. To work on this dynamic and complex multi-year scenario, we chose ELP as a tool. As opposed to traditional linear programming, this method incorporates socio-cultural parameters, changing nutritional requirements, evolving household composition, and other factors to enhance the dynamism, representing a real-world livelihood system (Hildebrand et al., 2003).

Our model was created in Microsoft Excel© with the standard Frontline System Solver© add-in, which maximizes the sum of the gross margins for all activities included in the model, following the objective function $Z = \sum_j c_j X_j$; where the X_j are the production or other activities; c_j is the forecast gross margin of *X*. Each activity is subjected to constraints R_i: the use of the resource *i* needed to operate an activity *j* cannot exceed the available amount of the resource held by the household (Mudhara & Hildebrand, 2004). The equation form of constraints in the model is $\sum_j a_{ij} X_j \leq b_i$; where b_i is the amount of resource *i* available.

The objective of this model is to maximize the sum of annual cash available for discretionary spending over five years. Each year is subdivided to account for seasonal household activities. The mixture of products sold in the market, non-farming activities, such as social security benefits and temporary work, and consumption requirements, such as purchase of food, clothes, or spending on leisure define the cash flow. The ELP model keeps track of sizes of forested areas and areas of other land uses on a farm in any year, as well as the length of time of different land-uses. Using this information, the carbon stock in a farm is calculated for each year, providing a basis for evaluating the impacts of REDD policies. In this scenario we assumed annual payments of REDD during the project period.

This model has four main constraints: 1) farm size: the area used for all farm activities cannot exceed the farm size; 2) labor: the labor needed for activities varies by semesters and gender, and households use primarily family labor, but can hire people if cash is available, or to work for others to earn cash.; 3) cash: a household must have money for farming operations and for the necessary household expenditures each year. The surplus generated in any semester is transferred to the next semester; and 4) consumption requirements: some staple crops grown primarily for household consumption require a minimum level of production to meet family needs.

Two special constraints were introduced to simulate household livelihood changes in a REDD project. The first constraint is that deforestation is not allowed. All activities related to deforestation were adjusted to incorporate new technologies developed locally by small farmers and experimentation systematized by the Amazon Institute for Environmental Research (IPAM) and the Brazilian Agricultural Research Corporation, (EMBRAPA) (Mello, 2008; Veiga & Serrão, 1990). The other constraint is that fire is not allowed without rigid control and management, which increases production cost. The equation for the cost and efficiency of fire prevention and control techniques was defined by the IPAM fire project (Carvalho, Mello, Assunção, & Souza, 2008; Mello & Pires, 2004) for each type of vegetation and area where fire will be used. For this study, we included the cost to control accidental forest fires while building firebreaks around the forest area.

The model was validated to a set of initial conditions that define the model's starting point in terms of available resources (land, labor, and capital), existing land uses, and prevailing technology and prices.

Data Collection

Development of an ELP requires input and output details for all the livelihood activities. The aggregate data available from the Brazilian demographic census were inappropriate to the lot level, thus we used the database generated by the Brazilian Ministry of Environment, Fundação Viver Produzir e Preservar (FVPP), a grassroots organization with a program of payments for environmental services, and IPAM, an NGO with experience in climate change policies. This dataset contained information for 307 lots collected in 2004 and 2007 (Figure 4-1). The data were collected in a one-day period for each lot. The procedures of data collection included structured interviews, vegetation sampling along transects to survey main land uses, and handwritten diagrams to collect information about production strategies and plans. The data included information on land use, family life history, livelihood activities, and prices.

Due to the high variability of smallholder land use dynamics, calculating the carbon stock using a direct measurement is expensive and not viable for carbon trade on a large scale (Pagiola et al., 2005). Remote sensing methods are becoming more accessible and accurate to measure carbon stocks through new algorithms. They can detect landscape changes with less interference from clouds, and estimate the amount of carbon in the landscape (Nepstad et al., 2007).

In this study, carbon stock was estimated based on the type of land cover by associating a carbon value for each land parcel. The land cover was defined using a combination of satellite imagery interpretation and field survey, in which the smallholders delineated their property in printed satellite images. The regional deforestation baseline was defined using the Brazilian official deforestation monitoring system (INPE- Instituto Nacional de Pesquisas Espaciais, 2009), which was freely available and had classifications of forest and non-forested area.

The values of carbon stock in the biomass used in this study were obtained from the studies conducted in eastern Amazonia by the Center for International

Forestry Research (CIFOR) and the International Center for Tropical Agriculture (CIAT) (Braz et al., 1988; Palm et al., 2000). The aboveground carbon stocks in tons are defined as follows: primary forest: 160 ton/ha; managed timber forest: 130 ton/ha; agroforestry systems: 55 ton/ha; young fallow: 15 ton/ha; old fallow: 25 ton/ha; pasture: 5 ton/ha; and annuals: 5 ton/ha.

Even though the average production system used by small farmers generally leads to a decrease of forest area, the pattern is heterogeneous. Thus, smallholders with similar income composition were aggregated to reduce variability of land use, making possible generalizations from the model. The smallholders were classified into three categories: cattle-dependent farms, perennial crops-dependent farms, and annual crops-dependent farms. The aggregate results were used to categorize and create a descriptive statistic of the sample.

To solve the model, one smallholder was chosen among the category that had a higher rate of deforestation and large area of forest stands, two of the most significant characteristics for implementation of REDD program. Within the households in the category, there were six that were willing to participate in the research and that had deforestation rate, income and pasture area close to the average for the farms in the category. Among the six, the model smallholder was selected for the easiest access.

Complementary data were collected to deepen information about family composition and history, market conditions, productive system, and forest degradation. The data collected and the model solved were validated with the family to confirm the simulations.

Five-Year Model Estimation of Carbon Balance in the Smallholder

The goals of REDD projects in relation to carbon emission are, in essence, to reduce deforestation and degradation in comparison with the past. Thus, what is to be negotiated is the difference in carbon emissions between the projection from the past and the actual value achieved. Establishing a carbon baseline for small farmers is difficult due to the small size and diversity among farms. In addition, each farm has different patterns of deforestation and degradation and will have different strategies to reduce deforestation and degradation during a project period.

To meet the diversity of smallholders, a three-step process based on ELP was proposed as a method to calculate the carbon to be traded. This method first determined the current land cover and land use of a lot, to estimate the existing carbon stock. Validity of the model was tested by simulating the land use change in the recent past and comparing the result with the actual change that occurred on the land. Second, two ethnographic linear programming scenarios were created to calculate projected carbon emissions with and without the project. The former assumed the conventional livelihood strategies of households in the study area and calculated carbon emissions without carbon trade. The latter scenario incorporated the expected effects of payment for the aboveground carbon stock. Both were solved for five years. Third, the amount of carbon to be sold was calculated as the difference between the carbon emission in the business-as-usual (baseline) scenario and that in the new production system. Then the value of payment was calculated with two different prices for carbon.

Results

Land Use and Deforestation Patterns in the Study Area

As of 2007 when the data were collected, the surveyed land was mainly used for cattle ranching and subsistence agriculture. Fifty-seven percent of the land was classified as standing forest, 16% fallow (of various ages), 21% pasture or crop fields, and 6% as “other”. This landscape was shaped by the loss of 30% of the standing forest over the previous 15 years. The remaining forests were highly vulnerable to forest fires, due to logging activities that make forest more flammable, and frequent use of fire as a major tool for land management. About 30% of the remaining forests had been burned at least once by 2004. Between 1986 and 2004, 5,743,858 tons of carbon per year was emitted from deforestation of 240,000 ha of forests alone. This figure equals an average of 20.5 ha of deforestation per farm, including accidental forest fires, in 164,000 ha of land in total.

The typical smallholder in Anapú had 88 ha. The average annual family cash income was US$ 970 from the combination of perennial crops - mainly cacao and banana - (US$ 446); annual crops - primarily cassava and rice - (US$ 174); and other (off-farm) employment (*e.g.* teacher, retirement and other governmental sources) (US$ 350). Cattles were sold only on special occasions, such as family deaths or weddings, and the number was increasing in this area to an average of 26 head per family, indicating an increase of deforestation. This region is a perfect place to start a REDD project because it has a large forest area with high deforestation pressure, serious problems of poverty, and a very well organized social movement.

Similar to the third chapter, but using a smaller sample, smallholders were categorized in three types of farms based on sources of cash income. Type- I (cattle-centered farms) farms had 46 % of the annual income from cattle. Thirty-two percent of the farms belonged to this type, and they are mostly located within 10 km from the main road. They generally had poor soils. The average farmland consisted of 33% pasture, 8% annual crop, 2% perennial crops, 12% fallow, and 45% forest.

Type- II farms (perennial crop-centered farms) had the more diverse annual income, of which 38% came from perennial crops. They were situated in areas with the same level of accessibility as the former type and with good basaltic soils, and constituted 19% of the total number of farms. The main crops were coffee, cacao, and banana. Land cover was more diverse than the other types with 17% pasture, 4% annual crops, 5% perennial crops, 8% fallow, and 66% forest on average.

Type- III farms (annual crop-centered farms) were mostly located more than 10 km from the main road and constituted 49% of the total farms. They had problems of accessibility in the rainy season and land tenure was typically not consolidated. These families had the lowest income that was mainly from annual crops, and characterized by a subsistence economy. Land cover consisted of 2% pasture, 6% annual crop, 1% perennial crop, 14% fallow, and 77% forest.

The three classes had different deforestation rates; the rate was highest in Type- I, where pasture expansion was needed to accommodate increasing numbers of cattle and to make up for a decline in pasture productivity. Between 2001 and 2005, the deforestation rate for this type measured by Real Time

Deforestation Detection (DETER) coordinated by the Brazilian National Institute for Space Research, was 4.3% per year, while the rate was 2.1% per year for Type- II. Type- III had an intermediate rate of 2.8%, mainly due to a lack of financial resources and more difficult market access factors that limit development. Thus, Type- I farms had the most suitable characteristics for REDD projects because they had the highest deforestation rates and a large area of highly threatened forest.

The Family-Level Model of a Type- I Smallholder

The modeled farm was selected from the 207 properties in the database based on three criteria. The first was that it had deforestation rates above the average. The first selection reduced the sample to 98 Type-I smallholders. The second criterion was smallholders with deforestation, income and pasture area near the average of the Type-I, which theoretically have the higher transactional costs to change their production system. This reduced the sample to 11 smallholders. The last criterion was family interest in participating in the research, resulting in six households. The household selected had the easiest access.

The holding selected was acquired in 1990 and the total area was 110 ha, consisting of 95 ha of forest, 3 ha of annual crops (rice) and 12 ha of fallow. The main production strategy was to produce large areas of annual crops (principally rice) together with pasture. After rice was harvested, the land was converted to pasture. At the same time, they took out a loan to grow cacao because this region had a profitable and well-established market for cacao. They also purchased cattle with a subsidized loan. The household had nine cattle, some fences, and a pen.

The pasture had fences only on the boundaries of their property, and its management involved slash-and-burn practices. The cattle received vaccines and salt throughout the year. The family raised chickens and pigs for consumption. Today, after 18 years since the family moved in, the family has 22 head of cattle and the forest area has been reduced to 66 ha, with a deforestation rate of 4.3% per year in the last five years.

The family was composed of six members, but only four work on the property (one adult female and one adolescent female live in the city two hours away on foot). The family had one additional adult male, who was considered a family member, living with them for the last 10 years. One adult female received a wage for her work as a community health agent. Men worked eight hours; 288 days a year, and women and children between 8 and 13 years provided 6 hours of labor per day. The annual family income was US$ 4,310: 36% from off-farm activities; 18% from annual crops; 24% from cacao; and 22% from cattle and dairy products.

Modeled land cover change is presented in Figure4-2.The comparison between the observed land use change and the modeled results confirmed the tendency of forest losses for the next five years. The predicted forest area in the year 2012 is 59 ha, a reduction of 10.7% since 2007. The annual crop area was stable at 0.5 ha per year (ranging from 0.3 ha to 0.7 ha), only half of the average size for the Type-I properties. Seventy-five percent of the land for annual crop was in forest. The biggest change in the area was an increase in pasture, growing from 29% to 35% of the total smallholder area. The fallow area was reduced and perennial crop area did not change, staying at 3% of the area. The model reproduced the loss of forest to pasture, a common situation for this type of producer.

In the business-as-usual scenario, income increased from US$ 4,310 per year to US$ 6,758 due to the increase in cattle sales. Cattle revenue surpassed cacao and became the main income source by the third year. The present value of total income discounted 6% for a five-year period was US$ 22,974. The income consisted of 29% from off-farm activities, 11% from annual crops, 27% from cacao, and 31% from cattle and dairy products. Forest products were collected sporadically, mainly fruit (*açai* (*Eutherpia* sp.) and *buriti* (*Mauritia flexuosa*)),which contributed two percent of the family cash income. Family labor was not sufficient at the end of the third year, so the family had to hire the equivalent of four percent of the total available family labor..

*Carbon stock payment scenario***-** Under this scenario, the smallholder receives an annual payment equivalent to the difference in carbon retained on the farm in comparison to the baseline (scenario 1). The payment is added to the model as beginning year cash, and has no restriction on its use. With the constraints of no deforestation, fire management, and no burning of pasture, the production cost increased by 18% on average. The model was solved with a ton of carbon valued at US$ 5 and again at US$ 10, the average market price for forest carbon projects (Nepstad et al., 2007). The results are presented in the Figure 4-3 and Figure 4-4.

The payment of US$ 5 per ton of carbon resulted in carbon emission reductions of 291 tons in five years as the result of preservation of 5.1 ha of forest compared with the business-as-usual scenario. The carbon credit received by the householder in five years was US$ 835.69. However, even with carbon payment, family income was reduced to US$ 19,806.86: 14% less than the business-as-usual scenario. Thus, the payment for carbon emission reduction would be insufficient for a family to change the production practices using fire. The model gives the option for the family to choose between annual crops with fire and without fire, and the transition to annual crop without fire occurred only on 35% of the crop area.

With the scenario of an annual payment of US$ 10/ton, 501 tons of carbon emission would be avoided and an income of US$ 2,745.34 would be generated. The payment for carbon sequestration in only five years reduced deforestation from 9ha to 1.8 ha and increased carbon stocks by 1.2% from the start of the project, owing to a 15% increase in the fallow area. Compared to the business-as-usual and US$5 scenarios, carbon stock would increase in the last year of the model, in spite of persistent carbon stock decline in the first two years, mainly due to the period of production system changes (Figure 4-3).

The effect of carbon payment on family income and land use was significantly different at this carbon price. Family income increased to US$ 25,150.98, or 9.4% greater than the business-as-usual scenario. The family could reduce fire dependence on the production system without a loss in income. At the end of the five years of this analysis, the primary income continued to be provided by cattle, but the new production system provided additional income, which is low in the first two years but became greater thereafter. Fire control enabled the use of *açai* and the collection of lianas viable in the riparian area, diversifying income sources.

The contribution of these non-timber forest products to the total income increased from 2% to 18%. Other forest uses were not incorporated in the model because of the previous timber extraction in the area, and in a five-year model it would be impossible to change the forest condition to allow more intense forest management. However, this is an important element to consider in longer term models.

The labor deficit increased from 4% to 9% in this scenario, and cash income was reduced by US$ 917 during the first two years due to the investment needed to change the system in the short term. However, after the third year the income became 24% greater than the business-as-usual system (Figure 4-4).

Discussion and Conclusions

During the last decade, local smallholders, rural extension efforts, and national and international research centers developed new land management techniques, which are now adopted to a limited extent by smallholders in the tropics in the absence of carbon trade. These techniques had the goal of reducing deforestation while increasing forest value (Perz, 2003). Despite the relative success of these techniques, they have never been adopted widely to reduce deforestation. Part of the failure has been due to their high implementation costs, which are particularly a burden to poor farmers (Almeida et al., 2006). The carbon trade can become an important source to finance this change on a large scale.

This work simulated the effects of carbon trade as a means of achieving a low carbon emission system for small producers in Anapú, in the eastern part of the Amazon. The region is classified as a high potential area for REDD projects because of relatively well defined land tenure, well-structured social organization, and a highly threatened forest with the loss of 30% of forest cover, mainly in the last 15 years (Soares-Filho et al., 2006b; Wunder et al., 2008).

We used ethnographic linear programming to seek answers to the effects of potential carbon trade on a smallholder's livelihood system. This chapter showed that carbon trade could be economically viable, improve food security, and simultaneously increase carbon stock in livestock-based smallholders. Such smallholders that are dependent on livestock constitute 32% of the smallholders in this region and have the highest deforestation rate among the types analyzed. However, if carbon prices are not high enough to cover the transition costs to an intensive production system and good environmental protection practices, the model predicts a negative effect on the family livelihood. This result suggests the risk to smallholder farmers when Brazil enforces environmental laws to reduce deforestation without implementing policies to change the production system. This trend became evident in Brazil with recent efforts to reduce deforestation, where fines for violation of environmental regulations increased and credit was restricted to farmers who complied with environmental laws.

In our single farm model at a fixed carbon price of US$ 5 per ton of carbon, a REDD project will reduce agricultural production and collapse the livelihood system with a negative cash flow. The value of US$ 10 per ton of carbon, a value twice as much as those found in other studies of smallholders (Börner et al., 2007; Wunder et al., 2008), was sufficient to compensate the cost of adapting the production system. Such differences in opportunity cost to reduce carbon emission from smallholders arise from the different methodological approaches used. In our case, the opportunity cost is defined for the whole property, not for each activity that is affected by limiting deforestation. This accountability is complex and is only possible using models such as ELP. Additional new forest uses, such as vegetable oil extraction, fruit collection or any other forest-related production can lead to new profit that reduces the adaptation cost for carbon projects. The opportunity cost as defined here is linked with the introduction of new technologies to reduce forest conversion rather than mechanisms of compensation for preserving the forest.

An ELP model must capture changes in established production systems as a consequence of an intervention, in our case REDD policy, as its main objective. It is possible to use ELP output to generate regional tendencies, but it was not done in this chapter, as it was not the objective here. A quick simulation using the results for cattle-centered smallholders showed that the emission of 501 tons of carbon was avoided on 110 ha of land during the five years. Since the study area has 2,000 type-I producers (cattle specialists) holding an average of 100 ha, the simple calculation from the result yields 182,000 tons of avoided carbon emission per year in the total area of 200,000 ha.

Regardless of how the carbon market will be established - whether at a project level as the volunteer market is supposed to operate, or at the national level, as Brazil proposed - the effective transformation of production systems from high to low carbon emission will happen when incomes of families living in forest areas increase. Our model can help carbon contractors decide how to elaborate the contract clauses, such as the definition of yearly goals for a household, changes in the production system, the cost and revenues, as well as carbon stored in the property.

The results show that it is possible and feasible to establish a new level of discussion about REDD with small landholders in the Amazon by conditioning payment for carbon on change in productive systems. ELP models, once refined with better data, could be incorporated in programs like ProAmbiente, one of the most advanced Payment for Environmental Services (PES)-like schemes that includes the effect of deforestation and other environmental services such as fire control and water quality (Hall, 2008). Yet this PES program has been failing to attract buyers, mainly due to the difficulty of the certification process that does not clearly show the amount of services generated (Wunder et al., 2008). Nor does it have a monitoring system to ensure that the services are being processed and a new low carbon emission system has been developed. Both limitations can be minimized with the ELP method.

Another good case where the methodology could be applied is the Amazonas state "*bolsa floresta*" program, that makes a fixed payment of US$25 per month per family for not deforesting, as well as for community improvements such as building schools and health center, and providing training. However, when understanding of family livelihood system is insufficient, a disconnection between environmental service rendered and payments can reduce success due to lack of comprehension about family livelihood strategies. The application of ELP methodology can facilitate the negotiation of a common platform between program managers and communities. ELP model data collection and output of the simulations are helpful in planning and implementing production system changes needed to reduce deforestation and increase income. This way, the remuneration for environmental service could be better estimated.

These two Brazilian PES programs are examples where ELP can be used to improve results of the REDD program to reduce carbon emission. The methodological tool used in this chapter could be applied, with small adjustments, to the rural extension system in order to reduce uncertainty about the carbon transaction.

In this preliminary work, we only examined the effect on one household. In the future, a number of different and diverse households should be analyzed to improve the validity of the model to measure potential effects of carbon trade on smallholders living in tropical forests. Additional smallholders can be modeled with relatively few changes in the model, mainly to account for smallholder size, current land use, and household composition. This work showed promising fields of study that can help decision makers see the impact of a carbon market on small households and the effectiveness of REDD projects. In the whole Brazilian Amazon region, there are nearly two million smallholders with high emission production systems. With a little support, such a system can be changed to systems with less carbon emissions.

The next chapter focuses on using model developed and presented in this chapter to simulate the effects of introducing a REDD program in a smallholder system, using an innovative approach to determine the project carbon baseline and to establish targets to reduce emissions from land use change.

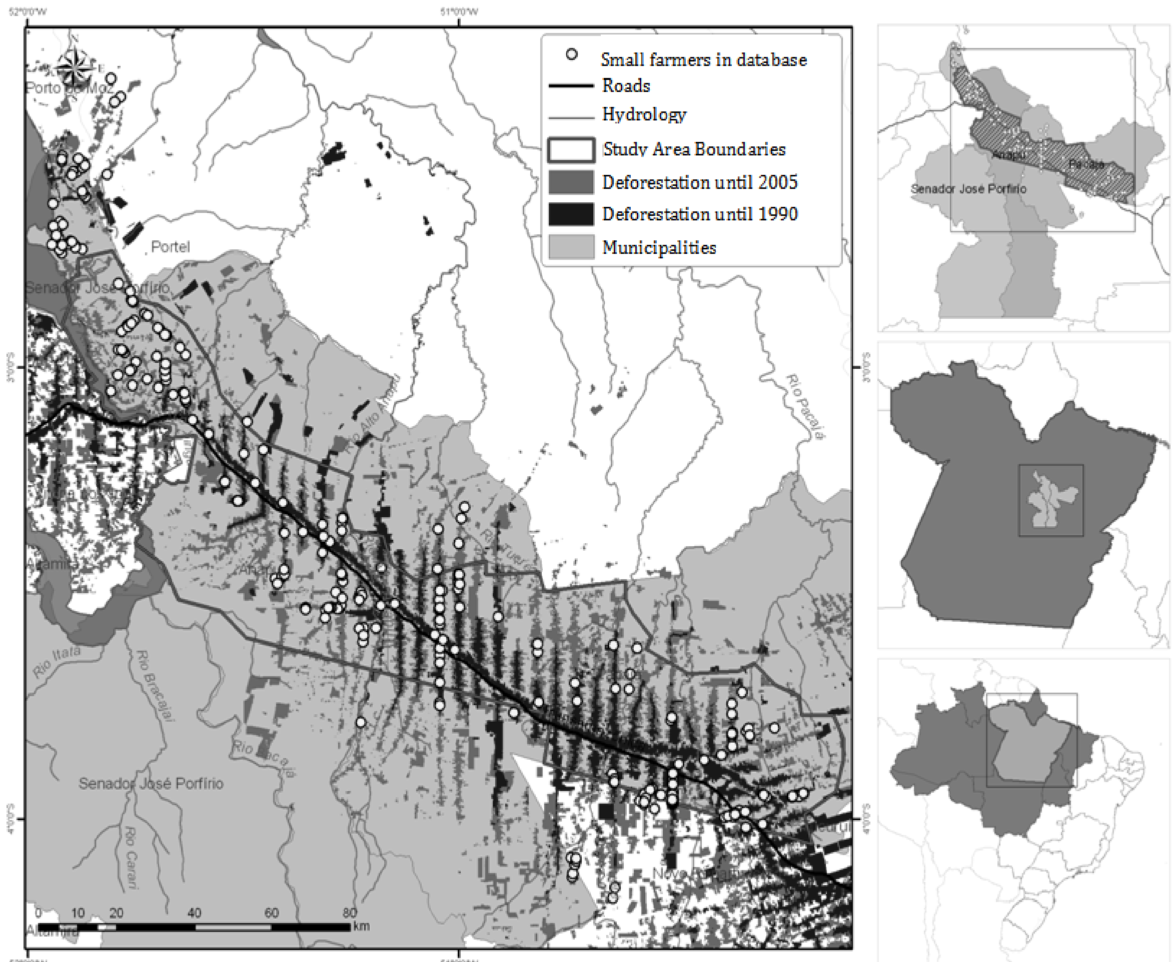

Figure 4-1. Location of the rural settlement area in Anapú, Pará State. The dots are the interview locations. Source: Instituto de Pesquisa Ambiental da Amazônia (IPAM) remote sensing lab.

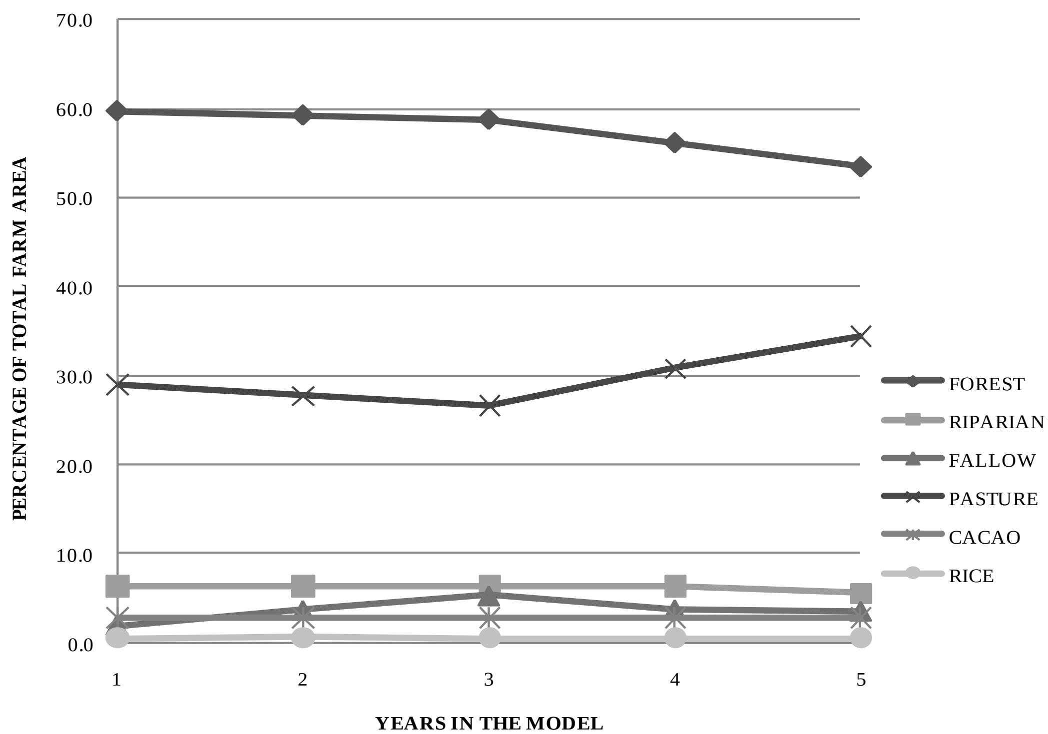

Figure 4-2. Changes in land use cover during the five-year model for a type-I farm, in the business-as-usual scenario

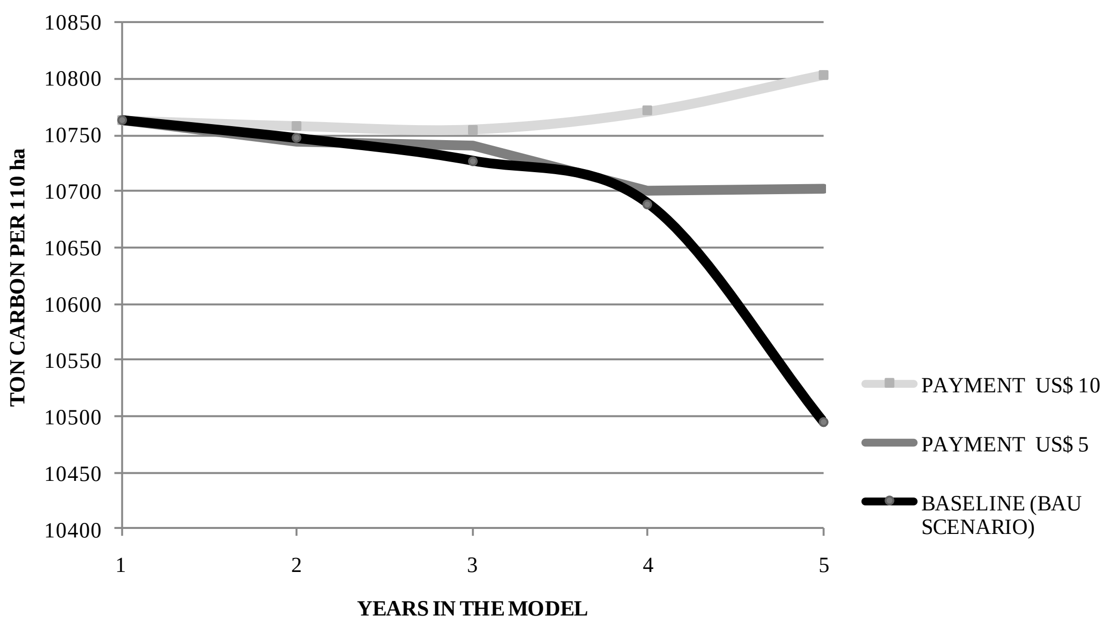

Figure 4-3. Five-year model using the business-as-usual and carbon payment scenarios. The difference between the businesses as usual carbon scenario and the carbon stock in the carbon payment scenarios is the avoided emission.

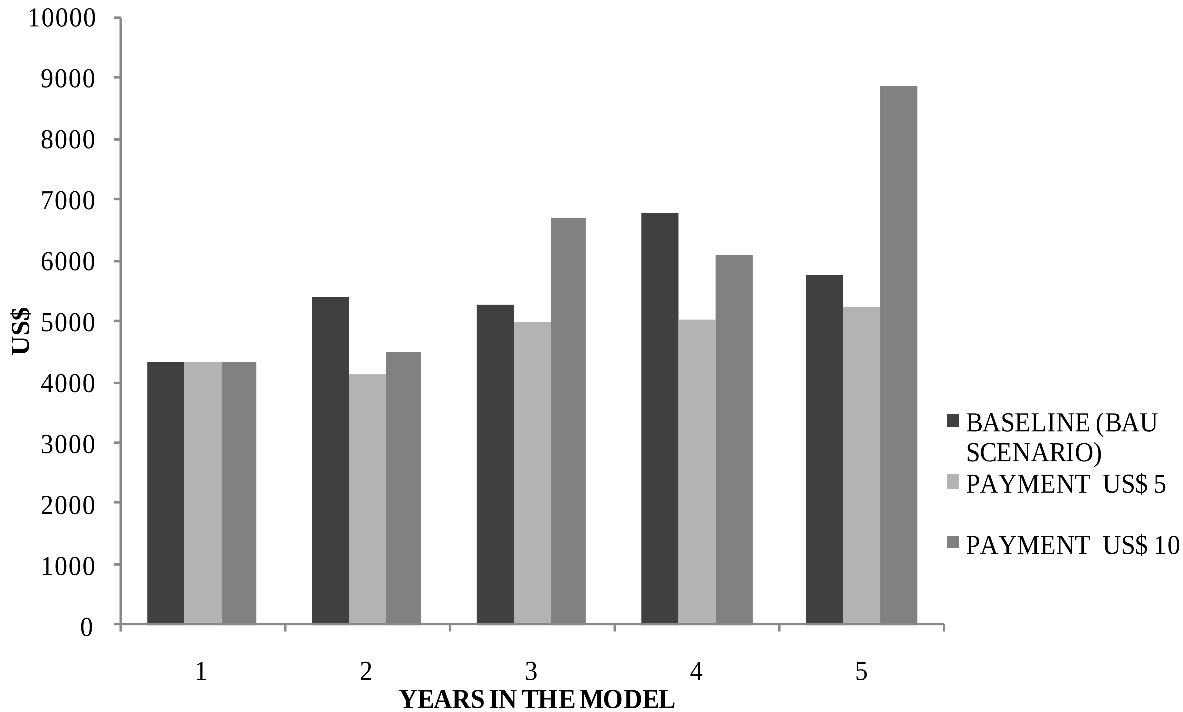

Figure 4-4. Change of annual income during the five years of simulation for the models with and without carbon payment to type-I farm in Anapú, Pará.

Table 4-1. Simulation results for carbon stock payments and business-as-usual scenarios.

Scenario		Business-as-usual	Carbon payment US$ 5	Carbon payment US$ 10
Family income[a]	(US$)	22,974	19,807	25,151
Deforestation in 5 years	(ha)	9.0	4.9	1.8
Fallow area change in 5 years	(ha)	- 0.3	0.8	1.9
Avoided carbon emission[b]	(Ton)	-	291	501
Increase in labor demand	(% hired)	-	4	14
Carbon credited[c]	(US$)	-	835.69	2,745.34

a- Present Value; b- Included changes in all land use; c- Present Value

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

Arguments about the importance of tropical forest conservation for climate change mitigation have been dictating the tropical environmental agenda during the past years. Although these are likely to become stronger in the years to follow, two points are still unresolved: first, a consensus on how to trigger a global scale initiative that stops deforestation and degradation has not yet been established. In addition, it is not yet clear how effectively tropical forest conservation initiatives mitigate climate change.

Large-scale programs to stop deforestation in the Amazon will need to address the issue of smallholders. Part of the challenge is how to deal with some millions of smallholder families dispersed all over the Amazon who use a widespread production technique: the slash and burn of small forest plots every year. Finding ways to change a production system from extensive agricultural dependence, mainly cattle and annual crops, to more intense use of forest products and the adoption of better agricultural practices is the challenge associated with reducing deforestation by smallholding families, agents that produced nearly 40% of the cumulative deforestation in the Amazon. Now that the Brazilian government and the world aim to reduce greenhouse gas emission at a low cost and in a short time through reduced deforestation, a key requirement is the design of Reducing Emissions from Deforestation and Forest Degradation (REDD) policies that support production initiatives which have already been developed by smallholders, but that historically have had no support. In this way, converting locally developed initiatives for better use of forest into large-scale production systems, and at the same time reducing regional inequality, is the most politically, ecologically, and economically adequate option to achieve not only immediate reduction of deforestation, but a permanent trend in how human society looks at the forest.

This research contributes to this discussion by analyzing the effects on smallholder land use of the implementation of REDD climate change policies. It aimed to answer three main specific questions: 1) Are smallholders really an important social group to implement a program on reducing carbon emissions from deforestation and forest degradation in the Amazon? 2) Is it possible to develop a tool that helps smallholders to reduce risk associated with the implementation and management of carbon projects? 3) Is payment for avoided carbon emissions an attractive business for smallholders to change production systems and increase family income? Research to answer these questions was conducted in Pará and Acre states using Ethnographic Linear Programming models to simulate livelihood strategies of diverse households and to evaluate effects of implementation of carbon payment schemas in smallholder livelihood systems.

The goal of any researcher is to provide a contribution, even a small one, to support decision makers and qualify their interventions through findings based on well-qualified methods of research. This research is not an end in itself. It is but a step towards the comprehension of the social dynamic involved in climate change, illuminating issues about smallholders, maybe one of the most complex solutions. If I have been successful, these findings should lead to a better understanding of the constraints and possibilities of including the Brazilian Amazon smallholders as active agents in the new “Amazon scenario.” This concluding section identifies and illuminates a number of contributions emerging from this research, as well some of its limitations.

The second chapter shows the wrong focus that has been given to smallholders in the Amazon and the necessity of repositioning them to the center of the REDD debate. This statement is supported by two factors: first, smallholders are largely the most numerous and widely spread agent in forest areas; they have constructed the most effective and efficient capacity of interaction with forest biodiversity and, from this capacity, produce more economic outputs than any other agent does. Second, this agent could be transformed into a deforester under certain socio-economic environments, as the discussion on credit availability proved. Such characteristics make smallholders the primary agent to be dealt with through a coherent payment policy for environmental services that aims to reduce deforestation and increase forest value.

The next chapters were dedicated to understanding the effects and potentials of implementing REDD programs within a smallholder’s context. The first observation is that inclusion of smallholders in the REDD mechanism does not guarantee that the family will change to a less carbon intensive productive system. In chapter four, the household modeled responded by applying most of the income generated by carbon trading to promote agricultural intensification and not to intensify forest use or change to an agroforest system or reforestation. Intensification is seen as one of the possibilities to reduce deforestation. However, the model does not capture behavior change in relation to the forest use. Understanding the causal agent of this behavior is key to promote long-term forest conservation. One hypothesis is related to model limitation. I used only a 5year model, which is a short period of time for the family to implement long-term changes. Further studies need to develop models that at least capture the project timeline, which in this study was limited by the software analytical package used. Another possibility is that the production options might not be technically adequate to household constraints, such as labor, land use, or market. Increasing the number of households modeled could help identify behavioral patterns that promote intensification of forest and agroforest production even for models within the 5 year limitation.

A second observation, the limitation of markets to leverage REDD permanent effectiveness, in other words, to guarantee that land use changes will be permanent when payments for carbon finish. In the third chapter, the application of models simulating market stimuli to traditional deforestation drivers – cattle and annual crops – shows a tendency to increase deforestation in all household types, even extractivists. The response to market stimulus for implementation of forest products and agroforest systems that reduce deforestation, however, was less intense than expected. Addressing this weak correlation between the increase in credit supply for forest products and the increase in use of forest opportunities is crucial to improving the permanence of deforestation reduction.

In this sense, it is important to stress that market options for forest products are limited, and the model did not find good possibilities to optimize forest use and perennial crops due to these limitations. These research results suggest as urgent need of research focusing on improving forest management for timber and non-timber products, as well as devoted to agroforestry and reforestation technical and marketing improvements. In Brazil, less than 3% of the available research resources are applied on the Amazon region (Ministério de Ciência e Tecnologia, 2008). It is important to stress that this kind of result could present some bias resulting from the same model limitations presented above; however it does not reduce the importance of the result for REDD implementation.

A third observation is the importance of deconstruction of the generic use of "smallholder" as a homogeneous agent in the landscape, which has been creating a bias in large-scale analyses and policy design and implementation. The third chapter shows how different smallholders are that share the same geographic region. In the same vicinity, the deforestation patterns differ, as well as the drivers behind deforestation. Using the household, the study shows that is possible to find some well-defined patterns of family cash income composition, which defines some common land use strategies as a unit of analysis. However, others factors show influence in deforestation patterns such as time since occupation, which has a positive correlation with deforestation in settlement areas, while a negative correlation in Extractive Reserves. The households modeled reflected this heterogeneity, reacting differently to the same policy. The results of these policies in deforestation prove the point that the more efficient unit of intervention is the household, where the land use decisions take place.

However, acting at this level could represent a constraint to establishing large-scale projects. The accuracy and flexibility of Ethnographic Linear Programming (ELP) models indicates that this methodology has the potential to describe land use change at the household level. With some adaptations, such as the development of a friendly interface that works with Microsoft Excel©, this model could be used by rural extension systems to define a project's carbon baseline based on past use, but also the projected trajectory. The sum of household independent baselines could be used to collectively negotiate carbon resources. The high initial costs of defining a household level baseline needs to be internalized during project preparation, and this additional initial cost could represents a gain in efficiency during the implementation phase, for having individual projects, with individual targets, anchored in a large-scale community project. This design, developed in the ProAmbiente "pole" idealization, that failed to quantify the environmental service produced, could make use of this method to design future carbon projects. Further development of model-friendly interfaces should include flexibility, taking into account project specificities as well as different production systems in order to facilitate its application on a large scale. To be used as a valid tool to define the carbon baseline, the ELP model should be validated in a larger sample of smallholders.

A fourth observation, and one of the most challenging and important research topics to the implementation of REDD on smallholders, is how to define the amount of carbon credit and the value of this remuneration. The methodology developed with the use of ELP models, presented in chapter four, calculates the opportunity cost differently from most of the studies. These studies define accountability as the opportunity cost to change from the deforester system to another that preserves the forest. This methodology biases the real opportunity cost to the family, by not considering the loss in food security; nor considering the parcel land use evolution. One parcel that today is planted in manioc; in the subsequent years could be maize, or cattle. The methodological option to solve this bias was to calculate the resources needed to transform the productive on system in an environment restricted by REDD policy.

The use of this methodology changes the unit of analyses from “hectare” to “household”. To the household, the cost of conserving the forest means not only the income lost with the not-use option, but also the cost of the marginal increment of production in other areas inside the property. This means that the concept of REDD ++ (including deforestation, forest degradation, and land use change) could be implemented using this methodology to households, which can account for carbon balance on the whole property as the sum of each parcel balance. This approach is incorporated in the livelihood production system better than just accounting for avoided deforestation.

Programs such as ProAmbiente, described in the previous sections, could fit better in this carbon accountability than those intended only to immobilize forest as a property asset, which does not directly link carbon balance with changes in the production system. The model developed here could prove to be a good tool to simulate property level carbon accountability, including the flexibility needed to accommodate the full spectrum of livelihood production systems found in the

Amazon. Further studies need to be developed to improve the model accuracy to link carbon with land parcel uses; nevertheless, the precision level in the model was more accurate than that based on remote sensing analyses alone today, and they could be used together. The debate about the level of precision acceptable to measure carbon to REDD projects is still at the beginning, and this study could represent a new perspective from which to look at this topic from a property level.

This research brings important insights to a variety of concerns involving REDD programs. While at the international level institutions and economic agents see forest carbon as the cheapest and quickest solution for the reduction of global carbon emission levels, seeming to be a good bargain. However tropical forest dwellers have another perspective. Millions have the perspective that REDD money could supply part of their necessities that were never attained, such as credit, technical assistance, governance, land rights, infrastructure, etc. If REDD policies can integrate these two perspectives, so much the better. Otherwise… but this is a topic for other theses.

APPENDIX A
QUESTIONNAIRE USED AT HOUSEHOLD LEVEL

UNIVERSIDADE DA FLORIDA
INSTITUTO DE PESQUISA AMBIENTAL DA AMAZÔNIA
Adaptado do Projeto Bom Manejo de Fogo do IPAM

QUESTIONÁRIO N°:
Comunidade:_____________________________ Data:____/____/2008.
Entrevistador:____

DADOS GERAIS:

I – Entrevistado e família:

1 - Qual o seu nome (completo)?____
2 - Onde o Sr(a) nasceu (município/UF)?____
3 - Caso não tenha nascido aqui, em que ano o Sr(a) chegou a este município?
____
4 - O Sr(a) é o(a) dono(a) desta propriedade? ( )sim ( )não
5 - Caso não, qual o nome do proprietário?____
6 - Caso não, qual sua relação com a propriedade?
( )meeiro ( )arrendatário ( )posseiro ( )filho ( )irmão ( )outros____________________
7 - Caso não, quem toma as decisões sobre as atividades produtivas de sua propriedade?
( )o proprietário ( )o Sr.(a) ( )os dois ( )outros____________________________________
8 - Caso sim, qual a forma de acesso a propriedade?
( )compra ( )herança ( )ocupação ( )outros____
9 - O Sr.(a) possui documentos da propriedade? ( )sim ( )não
10 - Caso sim, qual ou quais?
( )Titulo definitivo em seu nome ( )Recibo de compra ( )Procuração ( )Escritura Pública
( )Carta de Posse ( )Outros ____
11 - Qual o tamanho de sua propriedade?____
12- O Sr. mora nesta propriedade? ( )sim ( )não
13 - Caso sim, a quanto tempo ? ____
14 - Caso não, onde o Sr.(a) mora?
( )Outra propriedade rural ( )Cidade ( )Vila ______________ ( )Nos dois ______________
15 - O Sr. possui propriedades urbanas? ( )sim ( )não
16 - Caso sim, quais e onde se localizam?
( )Casa _________________ ( )Comércio _________________ ( )Terreno ________________
( )Outro ____
17 - O Sr. possui outras propriedades rurais? ( )sim ( )não
18 - Caso sim, especificar ano de acesso, tamanho, localidade, natureza do morador e situação legal do imóvel?

Ano de acesso	Tamanho (ha, m², etc.)	Onde fica (comunidade/município/UF)	Tipo de morador(1)	Situação legal do imóvel(2)

Notas:

1 - Tipo de morador:

Família (1) Ninguém (4)

Meeiros (2) Outros (5)

Empregados (3)

2 – Situação Legal:

Não tem título(1) Escritura pública(4)

Título definitivo(2) Carta de posse(5)

Recibo de compra(3) Outros(6).

19 – Qual dessas propriedades o Sr(a) considera mais importante (onde ele desenvolve a maioria de suas atividades de cultivo, plantio, criações de animais e extração de produtos do mato)?
____

20 - O Sr(a). sempre trabalhou com agricultura( )/pecuária( ) ? ( )sim ( )não

21 - Caso não, o que o Sr.(a) fazia antes? ____

22 - Caso não, há quantos anos trabalha com agricultura _________ / pecuária _________ ?

23 – O Sr(a) já recebeu algum tipo de financiamento? ( )sim ( )não

24 – Caso sim, qual o tipo de financiamento (especificar a linha de crédito, o ano em que recebeu ou vai receber, se foi para a agricultura, pecuária ou os dois, já recebeu as parcelas e se esta endividado ou não?

Tipo de financiamento	Ano em que:		Finalidade(*)	
	Recebeu	Vai receber	Agricultura	Pecuária

(*)Marcar com um X, e no caso de ter recebido para os dois, marcar ambos.

25 – Composição familiar:

NOME /Parentesco(em relação ao entrevistado)	Idade	Estado civil	Escolaridade	Participa de organização?				Quais suas fontes de renda?	Diárias (quant.) *itens 3, 4, 5
				S	N	Qual?	Nível da Participação em: reuniões, assembleias, cursos, etc...		
ENTREVISTADO									

II – Caracterização da propriedade:

26 - Como estão distribuídas as áreas em uso e ociosas de sua propriedade (no caso de mais de uma propriedade, utilizar os dados daquela que o entrevistado considera mais importante)?

Cobertura vegetal	Área quando chegou	Área hoje
Mata		
Mata sapecada (atingida pelo fogo)		
Capoeira		
Roças (cultivos temporários/anuais)		
Outros plantios (1)		
Pasto		
Quintal		
SAFs (2)		
Total		

Obs.: A área pode ser em hectares (ha), tarefas (tf), linha (ln), metros quadrados (m²), alqueires(alq.), etc.

(1) São os plantios de culturas perenes e semi-perenes, como banana, caju, pimenta, etc.

(2) Sistemas agroflorestais.

28 – De onde é retirada a água utilizada no consumo doméstico ou no trabalho?.

Fontes de água	Usos				Distância/tempo gasto	
	Doméstico		Agropecuário		Fonte/casa	Fonte/trabalho
	sim	não	sim	não		
Rio						
Igarapé						
Poço comunitário						
Poço particular						
Grota						
Açude						

29 - Existe alguma área na sua propriedade que apresente dificuldades em ser utilizada para plantações ou para pasto ? ( )sim ( )não

30 - Caso sim, quais são essas áreas (identificar a área, o tipo de vegetação, tipo de solo e tamanho da área e as causas da área ter se tornado inaproveitável para plantio ou pasto)?

Tamanho	Vegetação	Solo	Causa(1)

III – Infra-estrutura da propriedade:

31 - Quais as benfeitorias, meios de transporte, equipamentos e máquinas existentes em sua propriedade?

Construções, máquinas e acessórios	Quantidade	Tipo
Casa		
Casa de Farinha		
Curral		
Cerca		
Caminhão		
Outro carro		
Moto		
Trator		
Pulverizador		
Carroça		
Canoas		
Barco motorizado		
Motosserra		
Motor		

32- Existe energia elétrica em sua propriedade? ( )sim ( )não

33 - Caso sim, de que tipo? ( )elétrica pública ( )elétrica particular ( )outros ______________

34 - Quais destes serviços existem próximos a sua propriedade (Especificar a distância e o tempo gasto entre a propriedade e o serviço) ?

Serviços	Distância(casa/serviço)	Tempo gasto(em hs ou min)
Escola		
Posto de saúde		
Posto policial		
Estrada asfaltada		

PRODUÇÃO:

I – Atividades Produtivas:

35 - Quais os tipos de produtos o Sr(a) planta em sua roça (cultivos anuais, temporárias) e qual a produção da ultima safra (área usada, produção, compradores, local de venda e tipo de transporte) ?

Roça (Cultivos anuais)	Área usada (*)		Produção/preço		Tipo de Comprador (1)	Local da venda (2)	Tipo de transporte (3)
	Mata (ha)	Capoeira (ha/idade)	Consumo	Venda			
Arroz( )							
Feijão( )							
Milho( )							
Mandioca( )							
- Farinha	-	-					
- Tucupi	-	-					
- Goma	-	-					
No caso de outras roças							
Arroz( )							
Feijão( )							
Milho( )							
Mandioca( )							
- Farinha							
- Tucupi							
- Goma							

(*): A área pode ser em hectares (ha), tarefas (tf), linha (ln), metros quadrados (m^2), alqueires(alq.), etc.

Notas:

1 - Tipo de comprador:
Indústria (1)
Cooperativa (2)
Consumidor direto (3)
Comerciante (4),
Feirante (5),
Atravessador (6)
Outros (7)

2 - Local da venda:
No município (1)
Vila (2)
Na Comunidade (3)
Outra Comunidade (4)
Outro município(5)
Na propriedade(6),
Outros (7).

(3) Tipo de transporte:
Caminhão (1)
Outro carro (2)
Ônibus (3)
Bicicleta (4)
Carroça com tração animal (5)
Barco(6)
Outros (7).

37 – Por quanto tempo o Sr.(a) deixa uma área descansar para voltar a plantar?_________________

38 – Quais destes procedimentos o Sr.(a) adota no preparo e cultivo das áreas de plantio e de pasto (anotar o mês da atividade e o número de dias gasto na atividades por hectare ou tarefa) ?

FASES	ROÇA(ultima vez)				PASTO			
	Área	Mês	Dias gastos	N.º de pessoas	Área	Mês	Dias gastos	N.º de pessoas
Broca					-	-	-	-
Derruba					-	-	-	-
Aceiro								
Queima								
Coivara					-	-	-	-
Plantio					-	-	-	-
Capina 1					-	-	-	-
Capina 2					-	-	-	-
Colheita					-	-	-	-

39 - Quais os outros plantios (banana, pimenta-do-reino, coco, açaí, etc.) que o Sr(a) possui em sua propriedade e qual a produção da ultima safra (nº de pés, totais consumidos e vendidos, tipo de comprador, local de venda e tipo de transporte) ?

Outros Plantios (Permanentes, etc)	Nº de pés		Produção (*) (ultima safra)/preço		Tipo de Comprador (1)	Local da venda (2)	Tipo de transporte (3)
	Total	Produtivos	Consumo	Venda			
Banana							
Cacau							
Café							
Caju							
Coco							
Cupuaçu							
Laranja							
Açaí							
Pimenta-do-reino							
Pupunha							
Mogno							
Paricá							
Cedro							
Andiroba							

Obs.: Permanentes envolve plantios em capoeiras e roças antigas, sistemas agrolflorestais, e cultivos de quintais.
(*) Unidades(unid.), quilos(kl), sacos de 60 kl(sc), litros (l), etc.
<u>Notas:</u>

40 - Quais os principais produtos da pecuária e pequenas criações produzidos por esta propriedade e quanto o Sr(a) vendeu ou consumiu na ultima safra (quantidade, consumo familiar, total comercializado, tipo de comprador, local da venda e tipo de transporte) ?

Pecuária e Pequenas Criações	Quant hoje.	Consumo ()	Venda (prod/preço	Comercialização		
				Tipo de Comprador(1)	Local da venda(2)	Tipo de Transporte(3)
Boi(unid.)						
Leite(l)						
Queijo(kg)						
Carne(kg)						
Massa de queijo(kg)						
Porcos(unid.)						
Carne(kg)						
Galinhas(unid.)						
Ovos(unid.)						
Patos(unid.)						
Ovos(unid.)						

Notas:

1 - Tipo de comprador:
Industria (1)
Cooperativa (2)
Consumidor direto (3)
Comerciante (4),
Feirante (5),
Atravessador (6)
Outros (7)

2 - Local da venda:
No município (1)
Vila (2)
Na Comunidade (3)
Outra Comunidade (4)
Outro município(5)
Na propriedade(6),
Outros (7).

3 - Tipo de transporte:
Caminhão (1)
Outro carro (2)
Ônibus (3)
Bicicleta (4)
Carroça c tração animal (5)
Barco(6)
Outros (7).

41 - Quanto tempo por dia costuma gastar com as atividades pecuárias(criações, pasto, etc)?
____

42 - O Sr. utiliza produtos de sua propriedade para alimentar suas criações? ( )sim ( )não

43 - Caso sim, quais são os alimentos retirados de sua propriedade que o Sr(a). utiliza para alimentar suas criações? ____

44 – Quais os principais produtos extrativos (madeiras, frutas nativas, ervas e plantas medicinais, caça, peixe, mel de abelhas, fibras, cipós, e outros) desta propriedade (identificar tipos de produtos, total extraído e vendido, período de extração, local de venda, tipo de comprador e transporte utilizado para levar o produto ao mercado) ?

Extrativismo	Consumo ()	Venda Prod/preço	Local da venda(1)	Tipo de comprador(2)	Tipo de transporte

Notas:

1 - Tipo de comprador:
Industria (1)
Cooperativa (2)
Consumidor direto (3)
Comerciante (4),
Feirante (5),
Atravessador (6)
Outros (7)

2 - Local da venda:
No município (1)
Vila (2)
Na Comunidade (3)
Outra Comunidade (4)
Outro município(5)
Na propriedade(6),
Outros (7).

3 Tipo de transporte:
Caminhão (1)
Outro carro (2)
Ônibus (3)
Bicicleta (4)
Carroça com tração animal (5)
Barco(6)
Outros (7).

45 - O Sr(a) faz carvão? ( )sim ( )não
46 - Caso sim, quantos fornos( ) ou gaiolas( ) tira por ano?________________________________
47 - Como é feita a retirada da madeira da mata?
( )tração animal ( )caminhão ( )trator ( )arraste manual( )outros ______________________
48 - Quando não vende o Sr.(a) troca madeira por outra coisa ? ( )sim ( )não
49 - Caso sim, o que(abertura de ramal, rancho, etc.)? _____________________________________
____
50 - Quais os tipos de utensílios que o Sr(a) costuma utilizar para pescar?_____________________
____
51 - Quantos vezes por mês o Sr(a). costuma ir pescar?____________________________________
52 - Quantas horas por dia costuma ficar pescando?_______________________________________
53 - Quantos dias por mês o Sr(a).costuma caçar?____
54 - Quantas horas por dia costuma caçar?_____________________________________
55 - Qual o período do dia que o Sr(a). costuma caçar? ( )manha ( )tarde ( )noite
56 - O que o Sr(a). utiliza para caçar (cães, armadilhas, facão, espingarda, bota, lanterna, etc)?
____
57 - Quantos vezes por mês o Sr(a) costuma ir tirar fibras ou cipós no mato?____________________
58 - Cada vez que o Sr(a) vai tirar fibras ou cipó no mato, quantas horas demora?_______________
59 - Quantos vezes por dias por mês o Sr(a). costuma ir colher ou coletar frutas no mato?________

60 - Quantas horas o Sr(a) costuma ficar colhendo frutas no mato? _____________

II – Mão-de-obra e tecnologia:

61 - O Sr(a) contrata mão-de-obra para ajudar nas atividades? (   )sim (   )não
62 - O Sr.(a) tem ou já teve meeiros em sua propriedade?
(   )sim, tem   (   )sim, já teve   (   )não
63 - Caso tenha ou tenha tido meeiros, eles moram(vam) no lote? (   )sim   (   )não
64 - Quais as atividades que o Sr.(a) tem em meia ultimamente?____________________________
65 - O Sr(a) trabalha em mutirão?   (   )sim   (   )não
66 - Caso sim, quais as atividades que são realizadas em regime de mutirão?__________________
____
67 - Caso sim, depois de realizado o mutirão em sua propriedade quantos diárias o Sr.(a) tem que trabalhar em outras propriedades? ____
68 - O Sr(a) utiliza adubo químico?   (   )sim   (   )não
69 - Caso sim, de que tipo?____
70 - O Sr(a) utiliza defensivos agrícolas?   (   )sim   (   )não
71 - Caso sim, de que tipo?____
72 - No último ano, o Sr.(a) contratou diaristas para realizar as atividades listadas (especificar número de diaristas, remuneração e dias gastos?

Diaristas	Quantidade de diaristas	Valor da diária	Total de dias gastos
Derrubada			
Aceiro			
Plantio			
Colheita			
Limpeza de roça			
Limpeza de pasto			
Cuidar do gado(vaqueiro)			

III – <u>Trocas não-monetárias</u>:

73 - O Sr(a). costuma dar alguma coisa(produtos de consumo ou de uso domestico) que é retirada de sua propriedade a seus vizinhos?   (   )sim   (   )não
74 - O Sr(a)., costuma trocar alguma coisa(de consumo ou uso doméstico) que é retirada de sua propriedade com seus vizinhos?   (   )sim   (   )não

75 - Caso o Sr(a). dê ou troque alguma coisa com seus vizinhos, quais são aqueles que o Sr(a). dá ou troca com maior frequência com seus vizinhos, e em caso da troca, que produtos o Sr. costuma receber (no ultimo ano/2000)?

PRODUTOS TROCADOS	PRODUTOS RECEBIDOS	PRODUTOS DADOS

Obs.: Os produtos alvo da troca são aqueles retirados do mato (madeira, lenha, cipós, plantas medicinais, caça, frutas, etc.), das plantações (banana, coco, café, pimenta, maracujá, caju, etc.), da roça (mandioca pura, farinha de mandioca, milho, feijão, arroz, etc.), das criações (bovinos, porcos, galinhas, patos, etc.) e outros.

FOGO:

I – Perdas:

76 - É frequente a ocorrência de perdas com o uso do fogo em sua comunidade? ( )sim ( )não

77 – Caso sim, quais as ocorrências de fogo descontrolado em sua propriedade que o Sr(a) consegue lembrar ?

Ano	Causa(*)	Quantos lotes afetou?	Quantos dias durou?

(*) Tipos de causa: Fogo na roça do vizinho, fogo na pastagem do vizinho, fogo na derrubada do vizinho, fogo de caçador, fogo na própria pastagem, fogo na própria derrubada, e outros.

78 – O que o Sr.(a). perdeu em benfeitorias e equipamentos ?

Perdas	Quant.	Tipo
Casa (material com que foi construída e tamanho)		
Utensílios domésticos (redes, colchões, fogões, etc.)		
Cercas (tamanho em metros e quantos fios)		
Curral (material com que foi construído e tamanho)		
Casa de farinha (n.º de fornos e acessórios perdidos)		
Carroça (tipo de material com quer foi construída)		
Paiol(quantas sacos de arroz, de feijão estavam dentro, etc:)		

79 – O que o Sr.(a). fez para repor o que perdeu em benfeitorias e equipamentos ?

Perdas recuperadas	Quant.	Tipo
Casa (material com que foi construída e tamanho)		
Utensílios domésticos (redes, colchões, fogões, etc.)		
Cercas (tamanho em metros e quantos fios)		
Curral (material com que foi construído e tamanho)		
Casa de farinha (n.º de fornos e acessórios perdidos)		
Carroça (tipo de material com quer foi construída)		
Paiol(quantas sacos de arroz, de feijão estavam dentro, etc:)		

80 - O Sr(a) já teve áreas derrubadas, queimadas antes do período correto ? ( )sim ( )não
81 - Caso sim, qual a área queimada?____
82 - Houve aproveitamento da área derrubada atingida pelo fogo? ( )sim ( )não
83 - Caso sim, qual o tipo de aproveitamento? ____
____

84 - Quais as perdas que o Sr teve em suas roças atingidas pelo fogo (a perda de roça que ele considera mais importante)?

ESPÉCIES	ÁREA PERDIDA(*)	PRODUÇÃO PERDIDA(se tiver)
Mandioca		
Arroz		
Milho		
Feijão		

(*) Em tarefas(tf), hectares(ha), linha(ln), alqueire(alq.), metros(m), etc.

85 - Quais as perdas que o Sr(a) teve em suas plantações (banana, pimenta-do-reino, coco, açaí, etc...) por causa do fogo?

ESPÉCIES	N.º DE PÉS	PRODUÇÃO PERDIDA (se tiver)

86 - O Sr(a) já perdeu algum animal (gado, cavalo, porco, galinha , etc..) por causa do fogo (espécie e quantidade)?____
____

87 - O Sr(a) já teve pasto queimado fora de época em conseqüência de fogo acidental?
( )sim ( )não
88 - Caso sim, qual a área de pasto atingida pelo fogo?____________________________________

89 - O Sr(a). já teve que alugar pasto em conseqüência de fogo acidental? ( )sim ( )não
90 - Caso sim, qual o valor do aluguel por cabeças de gado, quantas cabeças foram colocadas no pasto alugado e por quanto tempo?____

____
91- O Sr(a) já teve áreas de mata atingidas pelo fogo? ( )sim ( )não
92 - Das espécies de madeira de seu mato que o Sr(a) vende ou utiliza, quais as mais atingidas pela ocorrência de fogo(espécies e quantidade perdida)?___________________________________

____
93 - Das árvores frutíferas de seu mato(bacuri, cupuaçu, açaí, etc.), cujos frutos o Sr(a) vende ou consome, quais as mais atingidas pela ocorrência de fogo(espécies, quanto colhia por safra antes do fogo e quanto colhe depois do fogo)?____

____
94 - Das fibras ou cipós que o Sr(a) retira de seu mato, quais as mais atingidas pela ocorrência de fogo(espécies, quanto retirava antes do fogo por ano e quanto retira depois do fogo)?___________

____
95 - Dos tipos de caça (tatu, paca, veado, cutia, etc...) que existem em seu mato, quais aqueles que se tornaram mais escassos após a ocorrência do fogo descontrolado no mato(espécies, quanto caçava de cada espécie antes do fogo por ano e quanto caça depois do fogo)?________________

____
96 - Depois da ocorrência do fogo, demora mais para o Sr(a) conseguir caçar algum animal?
( )sim ( )não
97 - Caso sim , quanto tempo?____
98 – Os problemas de saúde aumentam na época das queimadas? ( )sim ( )não
99 - Caso sim, quais?____

____
100 - O Sr(a) já teve algum benefício em consequência da ocorrência do fogo descontrolado?
( )sim ( )não
101 - Caso sim, quais ? ____

____
II - <u>Uso e prevenção do fogo</u>:
102 - Para que atividades de seu lote o Sr(a). utiliza o fogo? ____________________________

____
103 - Quem é responsável em sua família pela organização da queima e por medidas de controle do fogo?____
104 - Considera importante utilizar técnicas de prevenção e controle de queimadas?
( ) sim ( )não
105 - Caso sim, Porque ?____

____
106 - O Sr(a) discute com alguém sobre a preparação da terra ou sobre a queima? ( )sim ( )não
107 - Caso sim, quem?
( )sindicato ( )vizinhos ( )IBAMA ( )comunidade ( )Ongs
( )igreja ( )família ( )não discute ( )outros__________________________
108 - Como o Sr(a). decide a época e o dia certo para fazer a queima de sua área?_____________

____
109 - Caso o Sr(a) faça aceiro com trator quantas horas gastou e quanto pagou pela diária do trator?

____
110 - Seus vizinhos tomam precauções para evitar a ocorrência do fogo acidental em suas propriedades?
( )sim ( )não

111 - O Sr(a) já teve problemas com vizinhos em consequência do fogo acidental? ( )sim ( )não
112 - Caso sim, quais? ____
113 - A comunidade tem algum tipo de organização para as queimadas? ( )sim ( )não
114 - O Sr(a). participa das atividades comunitárias de prevenção e controle de fogo?
( )sim ( )não
115 - Caso sim, quais são essas atividades? ____
____
116 - O Sr(a) precisa de autorização de algum órgão para fazer queimadas? ( )sim ( )não
117 - O Sr(a) acha que a existência de grupo organizado de controle e prevenção do fogo influência em sua praticas de uso do fogo?____
____
118 - Na sua comunidade, quais os órgãos do governo ou da sociedade civil que orientam os agricultores sobre o uso do fogo?
( )IBAMA ( )EMATER ( )EMBRAPA ( )IPAM ( )STR
( )outros____
119 - Quais as técnicas que utilizou na ultima roça queimada?
Fazer um desenho da área mostrando:
Que tipo de vegetação tinha no entorno da queimadas?
Onde foi feito aceiro e ou varrida e tamanho?
De que lado começou o fogo e qual a direção do vento?
Tinha paus-secos ou for?a derrubados?
Levaram água para o local e onde deixaram?

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BIOGRAPHICAL SKETCH

Ricardo de Assis Mello was Born in Rio de Janeiro, Brazil. He attended the Federal University of Viçosa where he graduated as Agronomist in 1990. He moved to the Amazon to study at the Federal University of Pará where graduated as specialist in “Small Farmers and Sustainable Development in the Amazon”. His first work with smallholder was with Rubber Tappers in Xapuri, Acre State, in 1992. He worked also with riverines at low Xingu River, organizing community forest management plans. He have been working in IPAM (Amazon Institute for Environmental Research) since 1999 researching effects of fire use on rural smallholder livelihood productive system, and building institutional alliances to support strategies of fire reduction. In the last years, he works as advisory of Amazon social movements to incorporation of environmental services concept in Brazilian politics directed to rural smallholders. He was councilor of ProAmbiente program from 2004 to 2007 and Para State Environmental Council in 2004/2005. He comes to the University of Florida where he was part of the Amazon Leadership Initiative Program, and where he pursued his Master of Arts in the Center for Latin American Studies. He pursued a minor in tropical conservation and development. He did his fieldwork in 2008, in the Anapú, Pacajá and Xapuri, areas of different land use and colonization histories. His research was related to the use of Ethnographic Linear Programming Models to understand the effects of climate change agreements to smallholder’s livelihood.