From landless to forestless?

Settlers, livelihoods and forest dynamics in the Brazilian Amazon

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Dedicated to Elisângela, Bárbara and Rebecca,

my beloved wife and daughters

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ABBREVIATIONS AND ACRONYMS

ARP	Agrarian Reform Program
CPT	Catholic Church's Pastoral Land Commission
DfID	Department for International Development
EMBRAPA	Brazilian Agricultural Research Corporation
EMATER-PA	Technological Assistance and Rural Extension Corporation of Pará
EMATER-MG	Technological Assistance and Rural Extension Corporation of Minas Gerais
GDP	Gross Domestic Product
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources
IBGE	Brazilian Institute of Geography and Statistics
INCRA	National Institute of Colonization and Agrarian Reform
INPE	National Institute for Space Research
Km	Kilometer
LASAT	Socio-agronomic Laboratory of Tocantins
MDA	Ministry of Agrarian Development
MST	Landless Worker's Movement
II PNRA	II National Plan of Agrarian Reform
PA	Settlement Project
PIN	Program of National Integration
PROCERA	Special Credit Program for Agrarian Reform
PRODES	Amazon Deforestation Monitoring Project
POLAMAZÔNIA	Program of Agricultural and Agro-mineral Centres of the Amazon
PRONAF	National Program for Strengthening Family Farming
UFPA	Federal University of Pará
REDD+	Reducing Emission from Deforestation and Forest Degradation
SLA	Sustainable Livelihoods Approach
SSP	Shared Socio-Economic Pathways
UTM	Universal Transverse Mercator

Preface

In my youth, I looked forward to the holiday period as all young people. However, unlike my friends, I did not intend to spend all my time just having fun. My main goal during my holidays was to help my grandfather with his work on the farm. My grandfather and my grandmother, parents of my father, raised twelve sons and daughters (Mendel's law worked perfectly in this case, since they were six boys and six girls!). Their livelihoods were always based on rural activities, living and working on rented lands. They never had their own plot of land. Their main livelihood activity was milk production. Then, during my holidays, I spent most of my time among cows, heifers, and horses, and also paying attention to the development of corn and bean crops. Irrespective of weather and health conditions, my grandfather had to provide for the livelihood of his family by hand on a day-to-day basis. Despite his daily arduous work, he always stressed to me the importance of preserving the wild animals and the trees. He said sometimes that 'we cannot kill a deer or a wildcat because they are balanced in nature' and 'trees are responsible for the freshness of the soil and for providing water for streams.' I never forgot his teachings and the daily difficulty faced by him then, and still faced by many small farmers in many parts of the country.

This remarkable experience has inspired me throughout my professional (and personal) life. In my professional life, I have had several opportunities to learn from rural people, either in the rural extension service (EMATER-MG) or in the agricultural research corporation (EMBRAPA), where I have been working since 2002. After several years working with traditional small farmers like my grandfather, my attention turned to the people who live in the settlement projects of the Agrarian Reform Program (ARP). In 2004, I had the opportunity to talk with a group of settlers at a presentation that I made. It was interesting because the words 'landless' and 'settled by Agrarian Reform' were (and still are, surprisingly) viewed by some colleagues and also by the Brazilian population as implying 'conflict' and 'disturbance.' However, I was fascinated by their life histories and their persistence in struggling for their own plot of land. I was very curious to understand what they were doing for a living and how they coped with the process of ceasing to be landless and becoming a landowner. In my master's degree, I had the chance to address the relationship between these new small producers and the market, under a specific regulation of milk quality. However, the former curiosity persisted. In 2007, a group of settlers from Eldorado do Carajás, a municipality in the south of Pará state and the place where this study was developed, attended a week-long course in the experimental field at EMBRAPA Dairy

Cattle, in Coronel Pacheco, Minas Gerais State. Thirty-nine persons travelled 2,500 kilometres, spending three days in a bus to reach Coronel Pacheco. It was amazing for me to get to know such enthusiastic people. They were really avid for knowledge, questioning every lecturer about everything. Then, I talked with some leaders of this group about my ideas for understanding their ways of making a living, especially in an area where the environment was such a strong component. They showed their willingness immediately, helping me in everything necessary. I was very excited and I thought: great! I already have the fieldwork location and the main idea to be developed. Now I 'just' have to convince my director about this subject, search for a university also interested in this issue, cope with financing…

The pathway was opened for me when EMBRAPA and Wageningen University came to an arrangement in a program called Competing Claims on Natural Resources. The internal call launched by EMBRAPA to select persons to work on this program in 2007 fitted like a glove into what I was intending to do: to study situations of competition over natural resource access and use, seeking to develop more equitable management options to reduce rural poverty, reduce conflict, and achieve more sustainable use of natural resources.

In December 2007, I and other colleagues from EMBRAPA attended a workshop with the team from the Competing Claims program in Manaus, Amazonas State. On that occasion, I was far from able to participate in the program for bureaucratic internal reasons. However, in the coming months, persevering in my intention and with the crucial support of the heads of EMBRAPA Dairy Cattle, I got the green light to participate in the program from both EMBRAPA and Wageningen University. After all the arrangements and bureaucratic processes, I was ready to start the PhD program at the Forest and Nature Conservation Policy group in July 2009.

The research proposal approved by Wageningen School of Social Sciences was a bit different from the previous idea: the effects on the environment, mainly on deforestation, was expanded from the specific milk production activity to a broader livelihood strategy concept encompassing all kinds of practices and actions that settlers have undertaken to make a living in the real world. This was much more feasible, even though milk production has also played a considerable role in their livelihoods, as shown by this thesis. The proposal also addressed a time perspective to the thesis, analysing alternative development trajectories for the people and for the forest.

My first experience of the people in settlement projects in Eldorado do Carajás was in 2010. This first step of my fieldwork lasted three months. I visited 42 properties and several institutions, talking with settlers and their families, professors, technicians, government

officials, policymakers, and local politicians. I was really surprised by the kindness and willingness of the people with whom I came into contact there, despite their various difficulties. Everyone was enthusiastic about the idea of the research and also willing to support it. Actually, as the vice-mayor at that time, Mrs. Euclides Souza – one of the most enthusiastic men I have ever met – said to me: 'the name of Eldorado do Carajás is nationwide known negatively, always referring to "the massacre of Eldorado"; but when some institutions like EMBRAPA and Wageningen University are interested in issues relating to the people's way of living and forest conservation, it seems a redemption for the people, meaning something like – we can do good things and we are willing to do them.' These words gave me an extra feeling of engagement with the study and also enhanced my confidence in the subject proposed.

My first impression of the settlement projects and the households was very positive. Despite the lack of some basic infrastructure and several other difficulties, most settlers were very happy with their lives, explaining that they were better off than in their previous situation. It is interesting to note how politically conscious they were, knowing their rights and exactly who is responsible for providing these rights. This picture is completely different from the often portrayed traditional small farmers in other regions of the country, who seem not to have too much political consciousness as settlers, even though they have a better social organization of production than the farmers in the settlement projects in Eldorado. Concern about the environment, mainly forest cover at property level and water supply, emerged during all visits. Interestingly, one of the settlers told me that he does not want to be blamed for forest destruction, although he frequently heard people making such allegations on the television.

The second and last step of fieldwork was carried out in 2011. Over a period of almost two months, I visited again some of the same properties that I had visited before, collecting more data about land cover changes and marking points in forest and non-forest areas with a GPS. I organized three workshops aimed at constructing fuzzy cognitive maps relating to the factors that affect livelihood security and environmental sustainability. I was a bit concerned about these workshops, since the literature indicates that such an approach (fuzzy cognitive mapping) is not appropriated for small farmers because of its complexity in linking concepts and attributing weights to these linkages. However, the settlers surprised me positively again: after two rounds explaining how the approach works, they were able to discuss among themselves the links and the best weights to be attributed to them.

In order to better understand market access for settlers in the municipality, I visited a slaughter house where around 450 beef cattle are slaughtered every day and the largest dairy plant in the municipality processing nearly 100,000 litres of milk per day. During these visits, I talked with the local entrepreneurs, who explained to me how the beef and milk chains work in the municipality.

In this context, my research examines the interaction between what people do for a living in settlement projects in Eldorado do Carajás and forest dynamics, i.e. deforestation and reforestation in a multi-dimension approach, considering space (municipality, settlement projects, and properties) and time (past, present, and future). In short, I identified the livelihood trajectories adopted by the settlers from time of arrival on their plots until 2010, associating these with forest dynamics over time. On the basis of the settlers' current perceptions about their livelihood security and environmental sustainability, I also identified possible future changes for them and possible effects on the forest. This thesis will hopefully contribute to improving the processes and approaches used by many stakeholders such as policymakers and extension service agencies attempting to achieve both livelihood security and environmental sustainability in the region.

1. General Introduction

Sunset at Moça Bonita settlement project. Photo by the author.

You are thirsty for what?
You are hungry for what?
We do not want only food
We want food
Entertainment and art
We do not want only food
We want a way-out to everywhere
We do not want only money
We want money
And happiness

Comida – Titãs (Brazilian rock band –1987)

1.1 DEFORESTATION IN THE BRAZILIAN AMAZON: AN OVERVIEW OF CAUSES AND AGENTS

The Amazon biome is the largest continuous region of tropical forest in the world. It extends from the Atlantic Ocean to the eastern slopes of the Andes Cordillera and contains parts of nine South American countries. The biodiversity in this biome is unique and one of the highest in the world. The number of species is estimated at one million plants and animals, representing half the number of species registered in the entire world (Chivian, 2002). The Amazon biome also has a large influence on hydrological, climate, and global biogeochemical cycles (Rodrigues et al., 2009; Skole & Compton, 1993). Amazonian forests have been an important and continuous part of the functioning of the earth's system since the Cretaceous (Maslin et al., 2005).

Most of the Amazon biome (69%) lies within Brazil. It comprises 40% of the world's remaining tropical rainforest (Laurance et al., 2001). The Brazilian government has defined this area as the Legal Amazon[1] (Figure 1.1). The area covers approximately 5.1 million km^2 or 61% of Brazil's territory and is home to 24 million people or approximately 13% of the country's population in 2010 (IBGE, 2011a).

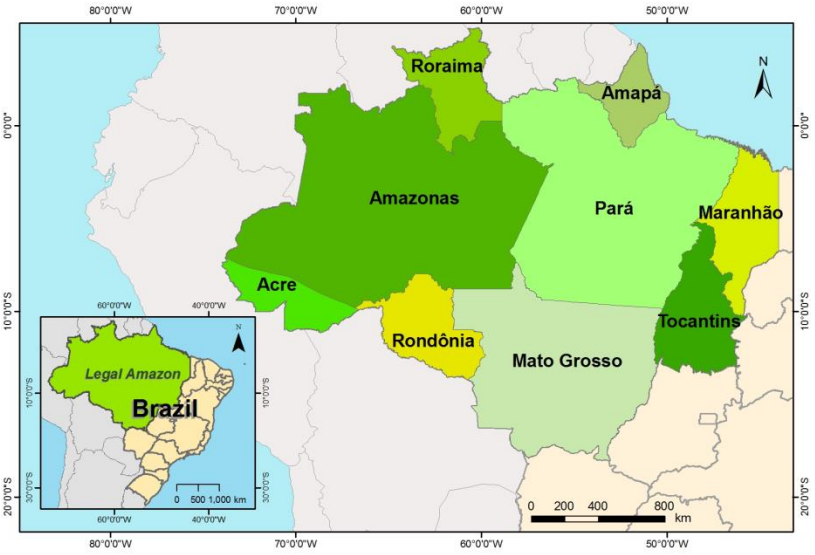


Figure 1.1 Legal Amazon: (A) Country view and (B) States in Legal Amazon area
Source: IBGE, 2011b

[1] Created by Law 1.806 of 06.01.1953, the Legal Amazon is a geopolitical concept used to plan and to promote the development of the region. It comprises the entire Brazilian Amazon biome and some transitional areas bordering *Cerrado* (Brazilian savanna) (INPE/PRODES, 2008). The terms Legal Amazon and Brazilian Amazon are used interchangeably in this thesis.

The process of occupation of the Brazilian Amazon in the last fifty years has stimulated lots of activities, such as cattle ranching and agriculture, logging, the building of new roads, mining exploitation, construction of dams, establishment of settlement projects, regional population growth, and land speculation, among others (Becker, 1997; Homma et al., 1993; Moran et al., 2005; Walker et al., 2009). However, the implementation of these activities has also brought deforestation,[2] which has been reported as the most serious environmental consequence of the occupation process in the region (Ângelo & de Sá, 2007; Fearnside, 2005; Hecht & Cockburn, 2011). The cumulative deforested area in the region amounted to approximately 750,000 km^2 in 2012, or 18.7% of the forested area (INPE/PRODES, 2012). Although the annual deforestation rate has been decreasing over the past ten years from about 27,000 km^2 to less than 5,000 km^2 in 2012, with an average of about 12,000 km^2 in this period, deforestation is still the major environmental problem (Hecht, 2012; INPE/PRODES, 2012). The deforestation is not spread evenly in the Legal Amazon. Rather, most deforestation has been concentrated along the so-called Arc of Deforestation (Figure 1.2), within the boundaries defined by the southwest of the State of Maranhão, the north of Tocantins, the south of Pará, the north of Mato Grosso, the entire State of Rondônia, the south of Amazonas, and the southeast of Acre (INPE/PRODES, 2008). For Becker (2005), this arc depicts a consolidated occupied area, representing the human pressure of land occupation and agricultural expansion into the Brazilian Amazon biome.

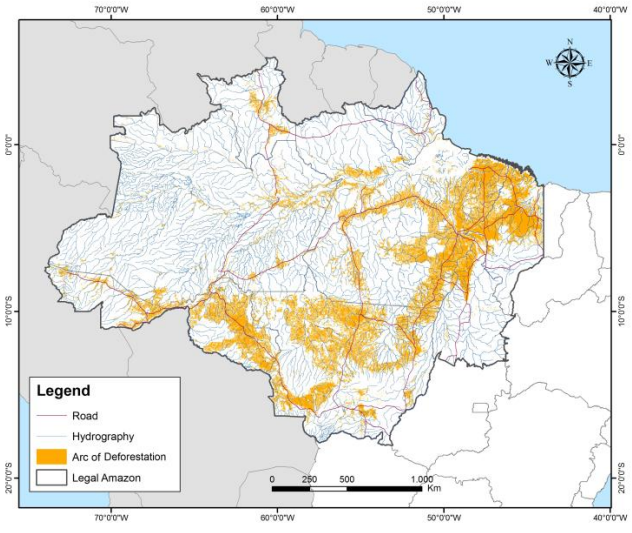


Figure 1.2. The limits of the Legal Amazon and the Arc of Deforestation
Source: Adapted from IMAZON, 2010

[2] Deforestation is defined as 'the complete clearing of areas of primary forest by anthropogenic activities, such as ranching, farming, and infrastructure construction, as detected by orbiting satellites' (INPE/PRODES, 2008).

Deforestation in the region has been driven by many different and sometimes reinforcing causes, resulting from direct drivers, such as infrastructure extension (road construction, hydropower development, and mineral exploitation) and agricultural expansion (cattle ranching and crop expansion) among others, and from more indirect driving forces, such as market and commercialization structures (rapid market growth and market accessibility) and property rights regimes (land distribution and land tenure issues) among others, as shown in Table 1.1.

Table 1.1 Summary of relevant studies about causes and drivers of deforestation in the Brazilian Amazon

Author	Level of analysis	Causes and drivers
Fearnside (2001)	Regional	Land tenure, migration, agrarian reform
Laurence et al. (2001)	Regional	Roads, infrastructure projects, migration, logging, and mining
Perz (2002)	Multilevel	Household demography, timber extraction, cattle ranching, property rights, infrastructure projects, national and international policies, international demands
Margulis (2004)	Regional	Cattle ranching, existence of roads, low production cost of cattle breeding
Aguiar et al. (2007)	Regional	Agrarian structure, productive system, distance to roads and to urban centres
Soler & Verburg (2010)	Multilevel	Property size, year of establishment of the settlement, soil fertility, and accessibility
Hargrave & Kis-Katos (2012)	Regional	Commodity prices (meat, soybean, and wood) and credit policies

These studies are relevant to highlight causes and drivers of deforestation in the Brazilian Amazon. However, deforestation is a complex phenomenon and cannot be explained by one single dominant factor or by simple causal patterns; rather, deforestation results from different combinations of conditions where the influence of a given condition at a given time depends on its interaction with other conditions (Geist & Lambin, 2002; Scouvart et al., 2008; Young et al., 2006). Moreover, in human–environment interactions research, simple causal explanations have recently been replaced by more complex, systemic approaches allowing the complexity of causal interactions to be taken into account (Young et al., 2006). Thus, this thesis approaches deforestation as a complex process resulting from the multi-causal interactions of factors over time.

The type of agent in a forest area is of primary importance in determining the rate of spread of deforestation (Fearnside, 2008; Godar et al., 2012a; Margulis, 2004). Apart from deforestation caused by the infrastructural projects from federal government in the last decades, several types of deforestation agents have been identified in the Brazilian Amazon,

such as large, medium, and small landholders (Aguiar et al., 2007; Caldas et al., 2007; Fearnside, 2008; Godar et al., 2012a; Ludewigs et al., 2009; Margulis, 2004). Large and medium landholders tend to develop extensive beef cattle ranching in Amazonia because of the favourable environmental conditions for raising livestock, the structured market, and the high rates of return on this activity (Margulis, 2004). Cattle ranching developed by these agents has led to significant forest conversion to large tracts of pasture (about 60% of the deforested total area of the region), and this is the main direct cause of deforestation in the Brazilian Amazon (EMBRAPA & INPE, 2011; Fearnside, 2008; Margulis, 2004; McCracken et al., 2002; Rivero et al., 2009). Although soybean production has expanded on large farms in Mato Grosso, some studies have indicated the minor role of this activity as a direct cause of deforestation, since the farms occupy large areas previously used as pasture (Barona et al., 2010; Rosa et al., 2012).

Next to the large and medium landholders, small farmers[3] have also been named as important deforestation agents. Their agricultural activities based on the slash-and-burn technique and fallow rotation in itinerant agriculture, and also cattle ranching, have been highlighted as important direct causes of deforestation (Angelsen & Kaimowitz, 2001; Fujisaka et al., 1996; Hall, 1989; Tourrand et al., 2004), although other authors point out that these agents and their activities have a minor role in Amazonian deforestation, compared with large and medium landholders (Campari, 2005; Pacheco, 2009a). However, models of fallow cycle and itinerant agriculture offer a limited explanation of deforestation by small farmers. These models link the role of small farmers in deforestation to the expansion of agricultural systems, with a combination of other factors, such as household dynamics, credit, market, and infrastructural conditions, also influencing deforestation (Brondízio, 2006; Caviglia-Harris, 2004). Moreover, the contribution of these agents to deforestation is controversial, varying by data source, year of analysis, and level of analysis (see Godar, 2012b). For instance, Margulis (2004) indicated two percent of deforestation caused by small farmers in the entire Brazilian Amazon up to 1999, whereas the figure is 54% using the Brazilian Institute of Environment and Renewable Natural Resources' (IBAMA) dataset and 37% using the National Institute for Space Research's (INPE) satellite imagery. In another study, using the agricultural census

[3] Small farmer or family farmer is defined by Federal Law Nº 11.326/2006. Among several characteristics relating to structure of labour and source of income, the law states that the majority of labour used in on-farm economic activities has to be provided by the family, and the size of the property cannot exceed four fiscal modules. The size of each fiscal module ranges from 50 to 100 hectares in the Legal Amazon, depending on the region and municipality. Therefore, people who hold 20 hectares (0.2 module) or 400 hectares (4 modules) in some regions in the Legal Amazon can be technically considered small farmers or family farmers.

(1995/1996) of the Brazilian Institute of Geography and Statistics (IBGE) and INPE satellite imagery, Pacheco (2009a) found that small farmers were responsible for 35% of total deforestation in the Brazilian Amazon up to 2003. Recently, Godar et al. (2012b), using time series of satellite imagery from 1986 to 2007 and fieldwork data, indicated that small farmers were responsible for 23% of the deforestation on properties within four municipalities along the Transamazon highway. Therefore, the debate about small farmers' role in, and contribution to, deforestation in the Brazilian Amazon is not yet settled. This thesis hopes to contribute to this debate. In addition, a specific group of small farmers settled in a large number of settlement projects (*projetos de assentamento*: PAs) established under the Agrarian Reform Program (ARP) are also deemed to be noteworthy agents of Amazonian deforestation (Brandão Jr. & Souza Jr., 2006; Fearnside, 1984, 2008; Machado, 2002; Pasquis et al., 2005; Santos, 2010; Soler et al., 2009; Tourrand et al., 2004). However, the debate about these specific agents' role in, and contribution to, deforestation has also been controversial (Brandão Jr. & Souza Jr., 2006; Godar et al., 2012b; Pacheco, 2009a). Furthermore, the link between their activities and practices – including associated factors at household level – and deforestation has scarcely been addressed. Understanding agent-specific roles in and contributions to deforestation in the Brazilian Amazon is key to adjusting policies and resource allocation in the face of forest destruction (Godar et al., 2012b). Therefore, focusing on these specific agents, this thesis seeks to contribute new insights into the debate about the complexities and specificities involved in the deforestation process within settlement projects under the ARP in the Brazilian Amazon. The next section gives a brief overview of agrarian reform in Brazil, linking it with the activities and practices developed by small farmers within settlement projects and their controversial effects on forest cover in the context of environmental regulation.

1.2 AGRARIAN REFORM, SETTLEMENT PROJECTS, AND DEFORESTATION IN THE BRAZILIAN AMAZON

The first national agrarian reform law (Land Statute) was, paradoxically, approved under the dictatorship that followed the military coup in 1964. The Land Statute defined agrarian reform as a combination of measures that seek to promote improved land distribution through modification of land tenure systems, in light of principles of social justice and enhanced productivity (Bruno, 1995; Fernandes et al., 2012). The government apparatus was completed

in 1970 when the National Institute of Colonization and Agrarian Reform[4] (INCRA) was created. INCRA's actions have focused on legalizing plots occupied by squatters and expropriating large private areas for establishment of new settlement projects. Although the Land Statute was the first law to establish a process of intervention through land expropriation, indicating 'priority areas,' very few expropriations occurred throughout the 1970s (Heredia et al., 2005). During the last six years of the military government (1979–84), emphasis was placed on granting legal titles to land in already established pasture areas for cattle ranching instead of creating new settlement projects. During this period, the dynamics of invasions at local level were organized and carried out by the squatters[5] themselves, unrelated to formal organizations, since the only previously existing social organizations, Unions of Rural Works, were extremely weak and had strong relationships with landowners (Intini, 2004). Social movements that have supported the struggle for land, such as the Catholic Church's Pastoral Land Commission (*Comissão Pastoral da Terra*, or CPT) and the Landless Workers' Movement (*Movimento dos Sem-Terra*, or MST), only emerged in the mid-1980s, after the demise of the military regime. In the first year after the return of democracy (1985), the government prepared the first National Agrarian Reform Plan (*Plano Nacional de Reforma Agrária* – PNRA), authorized in the Land Statute. This plan aimed to give effective application to devices in the Land Statute and the ARP, with regard to better distribution of land, setting targets and deadlines, and seeking the practical process of agrarian reform, indicating complementary programs of land tenure, colonization, and taxation of land (Heinen, 2004). As a result, several mechanisms to support agrarian reform emerged in the 1990s, such as the Threshold Project (*Lumiar*[6]), the Special Credit Program for Agrarian Reform (PROCERA) and, later, the National Program for Strengthening Family Farming (PRONAF[7]). In 2004, a new agrarian reform national plan (II PNRA) was elaborated, aiming at providing settlers with the conditions to assure local sustainable development, with

[4] INCRA is 'responsible for implementation of agrarian reform policy and national land ordering' (MDA/INCRA, 2004). In practice, INCRA is responsible for the establishment, support, and monitoring of the settlement projects.

[5] Most squatters had worked on the infrastructural projects and in the gold mine. However, there was a continuous flow of people from other regions (especially smallholders from the northeast) looking for new opportunities. Despite the fact that squatters (*posseiros*) were also landless (*sem-terra*), the concepts are quite different: squatters are people who invade and establish their families in an area of which they are not sure who the owners are (Martins, 1981), being more disorganized and individualists, whereas the landless are much more organized, with invasions with political overtones, and always connected to some social movement, such as Union, CPT, or MST (Otsuki, 2007).

[6] Despite some criticism, the *Lumiar* (Lighting) Project is considered by settlers and technicians as the best experience in technical assistance and professional training teams so far (see Moreira, 1995).

[7] There is a special subsidized credit for settlers called PRONAF A with an annual interest rate of 1.15%. The loan is split over seven years with three years' grace and a 40% discount of the total amount lent (INCRA, 2012).

unprecedented attention being paid to the environment, agricultural prices, and marketing policy (Deere and Medeiros, 2007). This plan is still in force to the present day.

The II PNRA, as an effective application of the ARP, defines agrarian reform as 'the set of measures to promote better distribution of land by changes in tenure and use in order to achieve the principles of social justice, sustainable rural development, and increased production' (MDA/INCRA, 2004). The beneficiaries of the agrarian reform program (called settlers) are landless rural workers and small squatters/colonists. The primary goal of the ARP is to provide a living to landless people by the establishment of settlement projects, mainly by redistributing large from private landholders (Fearnside, 2001; MDA/INCRA, 2004). By providing land for landless people, the government aims to help poverty alleviation and to promote socio-economic development. The premise of the ARP is that farms within settlement projects are considered units of agricultural production from where settlers can earn their living by small-scale commercial farming, producing an agricultural surplus for the market (MDA/INCRA, 2004).

The Brazilian Amazon region is the main place where settlement projects have been established under the ARP. From the start of agrarian reform in Brazil (1964) until 2011, roughly 750,000 families, corresponding to around 60% of all families that participated in the ARP in the entire country, were settled in the region, occupying approximately 70 million hectares (INCRA, 2012). However, the establishment of settlement projects is a process also associated with a large number of direct and indirect drivers of deforestation (Fearnside, 2001; Van De Steeg et al., 2006). For instance, agricultural land availability is fundamental to settlers to provide their livelihoods by cultivating crops (annuals, perennials) and/or by establishing pasture to raise cattle (beef, milk) (Alves et al., 2009; Fujisaka et al., 1996; Marquette, 1998; Tourrand et al., 2004; Vosti et al., 2003; Walker & Homma, 1996). In turn, the need for agricultural lands may imply negative effects on forest cover. Futemma & Brondízio (2003) indicate that credit policies, broad infrastructure (e.g. roads), and the market are key components of agrarian reform, but they are also considered drivers of the rapid advance of deforestation in the settlement projects (Brandão Jr. & Souza Jr., 2006). Moreover, some studies have pointed out that the establishment of settlement projects in some regions has entailed serious environmental and social consequences because of the indirect driving forces of deforestation coupled with the lack of state planning, lack of infrastructure, large distance to markets, profile of the settlers, lack of technical support, lack of credit, etc. (Batista, 2009).

The Brazilian Forestry Code (Federal Law 12.727/2012)[8] entails not being allowed to deforest more than 20% of forest on properties located within the Legal Amazon, so 80% of the total area of each property must remain a legal reserve. However, according to Brandão Jr. & Souza Jr. (2006), the average deforestation was 49% of the total area within 1,123 settlement projects mapped by INPE in 2004 in the Legal Amazon region, most of them located within the Arc of Deforestation. Furthermore, Soler & Verburg (2010) indicate that deforestation can be similar inside and outside settlement projects in Rondônia, but, inside them, deforestation can exceed 50% of the total property areas within 10–14 years of establishment. In another study, taking two municipalities as study sites in Pará State, Pacheco (2009a) estimates that settlers contributed to between 70% and 10% of total deforestation within these municipalities up to 2001/2002. Although these situations cannot be generalized for the entire region and all settlement projects, these studies reinforce the perceived impact of agrarian reform on deforestation. Other authors, however, have indicated that the impact of agrarian reform on land use change in the Brazilian Amazon is only minor, since only about one tenth of total deforestation has occurred within INCRA settlements (Godar et al., 2012b; Machado, 2002; Pacheco, 2009a). Even optimistically, considering the latter studies, 10% on the Amazonian scale still represents a lot. Therefore, the fundamental questions addressed in this thesis are why deforestation takes place in settlement projects, what drivers are behind it, and why it is so much in excess of the requirements of the Forestry Code.

1.3 DEFINING THE RESEARCH PROBLEM

Apart from the infrastructure necessary for the establishment of the settlement project and its impact on forest cover, settlers need agricultural lands to make their living, to reach the ARP goals. It is clear, therefore, that livelihood decisions and landscape changes at local level are interrelated (Arts et al., 2012). Thus, as expected, the need for agricultural lands to provide for livelihoods in a densely forested region like the Brazilian Amazon has driven most of the settlers to deforest. The government's assumption in the ARP is that deforesting up to 20% of the total property area within a settlement project is enough for a household to have a

[8] After ecological–economic zoning, properties in some regions in the Legal Amazon can be allowed to deforest up to 50% of their total area, respecting the limits of riparian areas and permanent preservation areas in line with the Forestry Code.

sustainable living, balancing agricultural development and forest conservation. However, figures show that in many settlement projects throughout the Brazilian Amazon settlers have deforested larger areas than the Forestry Code permits, as already mentioned. The reasons behind this process are not completely clear.

Some studies have pointed out that the combination of a high rate of abandonment of properties and a high rate of deforestation at the same time indicates a lack of economic and environmental sustainability within some settlement projects (Ludewigs et al., 2009; Pasquis et al., 2005). Others studies, such as that of Brondízio (2005), have indicated that the variation in rate, extension, and direction of deforestation might be associated with the different agricultural activities undertaken as part of households' livelihood strategies. However, there is little empirical evidence of the effects of the different livelihood strategies and livelihood trajectories on deforestation over time. Consequently, specific questions about whether the activities developed by settlers are, at the very least, providing their livelihoods and about the effects of these choices on deforestation over time have been hardly addressed. Answers about human–environment interactions are fundamental to better understand the process that results in higher or lower deforestation in Amazonian settlement projects (Moran, 2005). In this context, there is a need to examine the complexity and multi-causalities involved in settlers' activities and practices at the household level over time and the consequences for forest cover changes. Identifying and understanding the link between livelihood strategies and trajectories and their effects on forest cover changes would contribute to more useful and efficient approaches for researchers, development agencies, and policymakers in realizing more sustainable farming systems, in enhancing the well-being of settlers, and in developing policies that address specific activities that are less harmful to the forest, respectively.

Therefore, this thesis addresses the specific problems in relation to competing claims on natural resources (Giller et al., 2008), i.e. making a living and forest conservation in the Brazilian Amazon agrarian settlements.

1.4 RESEARCH OBJECTIVES AND KEY QUESTIONS

The objective of this research is to investigate in more detail how settlers have made their living; how their activities and practices have affected forest cover changes within the settlement projects; and how future prospects for both, i.e. people and forest, are to be envisioned. Based on this general objective, the following four research questions were formulated:

1) What livelihood strategies are adopted by settlers in Amazonian settlement projects?
2) To what extent are forest cover changes occurring in areas where settlement projects were established?
3) To what extent have different livelihood strategies and trajectories led to different effects on forest cover changes?
4) How do settlers perceive the factors that affect their current livelihood security and environmental sustainability in their area and what are the future prospects?
Each research question generates other specific sub-questions that are addressed in each chapter of the book.

1.5 THEORETICAL BACKGROUND

1.5.1 Land use and land cover change studies in the Brazilian Amazon

As stated by Browder et al. (2004), most land use and land cover studies on the Amazon biome are based on three theoretical perspectives: (1) the neoclassical economic tradition (NET), (2) the Chayanov theory, and (3) political ecology. The NET approach, based on the concepts of rationality and utility maximization of land use supported mainly by Von Thünen's original theoretical work (Norton, 1979), postulates that farmers manage the landscape to maximize utility, forced by exogenous (market and environmental) and endogenous (household labour) characteristics, shifting from subsistence-oriented polycultures to more commercial agriculture (Browder et al., 2004; Browder et al., 2008; Dickinson, 1969; Norton, 1979; Vosti et al., 2003). An example of the use of the NET perspective in Brazilian Amazon studies is that of Vosti et al. (2003). Their study identifies several socio-economic and biophysical factors influencing land use patterns, taking into account smallholder land use decisions (when and how much to deforest and for what purpose). The study also addresses how such factors influence land use over time, taking into account soil fertility shifts and exploring policy and technology options that give farmers incentives to slow deforestation without decreasing farm household income. However, one important limitation of the NET-oriented literature highlighted by Browder et al. (2004) is a tendency to treat the household as a homogeneous entity, whereas households should be considered as a heterogeneous and more fluid entity. This thesis tackles this limitation by considering that people are different, with different backgrounds and different perspectives (Scoones, 2009).

The Chayanov theory is about the operationalization of units of production based on family labour (Abramovay, 1998). According to this theory, there is a logical balance in the relationship between work and consumption within the household. In Chayanov's view, effort on the family labour farm was designed to satisfy a locally homogeneous acceptable standard of consumption; when that was achieved (at the intersection of the curves of marginal utility of labour and marginal disutility of effort), the 'self-exploitation' of the peasant labourer ceased. Thus, peasants worked no harder than they had to and stopped when consumption demand was satisfied. They neither saved nor invested (Hammel, 2005). This relationship does not follow the logic of capitalism in its formal context, but economic choices about what, when, and how to produce, for example, are determined by the rationality of family needs, emphasizing the role of family dynamics in farming system changes (Abramovay, 1998; Herrmann, 2005). For instance, Caldas et al. (2007) stated that deforestation in the Amazon biome is not an autonomous process, but rather is linked to household structures. The authors, from a Chayanovian perspective, identified that household labour (the number of men), distance from the property to the highway, and market factors induced higher deforestation along Transamazon Highway (BR 230) in Uruará County, Pará State. However, as pointed out by Browder at al. (2004), studies using the Chayanov theory have focused on the 'domestic life cycle' and elaborate trajectories of land cover change with the same disadvantages as the NET, considering the peasantry to be locally homogeneous (Hammel, 2005). This thesis deals with this criticism by assuming that households are heterogeneous in their livelihood choices, and, consequently, change the landscape differently.

The third perspective, political ecology, embraces studies of the relationships between political, economic, and social factors and environmental issues and changes, offering powerful analytical tools to understand social and environmental problems more comprehensively (Walker, 2005, 2006). Political ecology focuses on the intersections of structural as well as political forces and ecological dynamics at the local level, linking them to more macro-structural issues, as pointed out by Scoones (2009). Some studies in the Brazilian Amazon have used this theoretical approach to discuss deforestation and human consequences (Moran, 1993) and how choices are made about land use and how these choices are themselves structured by policy (Walker et al., 2009). Despite being an important theoretical framework to study human–environment interaction, political ecology has been criticized for its lack of a careful analysis of scale (Christopher Brown & Purcell, 2005) and also for not balancing political and ecological questions in more than a glancing manner (Walker, 2005, 2006). This thesis attempts to tackle these criticisms, taking into account the multiple-scale

driving forces present in the study area (Giller et al., 2008), and also the trade-offs between livelihood security and environmental sustainability achieved under the ARP.

Despite the pros and cons of these three approaches, significant differences do exist among land use types, but those types are not reliably or consistently differentiated by conventional predictors emanating from the NET, Chayanov, and political ecology literatures (Browder et al., 2004; Scoones, 2009). Other unspecified factors, such as social and cultural issues, also play a role in determining land use patterns. As pointed out by Geist & Lambin (2002), ranges of other underlying driving forces and proximate causes of deforestation, such as livelihood strategies, individual and household behaviour, policy and institutional factors, rural settlements, etc., are not included in these models. Moreover, rural livelihoods and their interplay with the environment are not just about economics or ecology but also about social relations (Bernstein et al., 1992). For instance, as indicated by Faminow (1998), the NET approach that analyses the performance of pasture expansion is based on technological fixes that are unsuitable to ranching in the Amazon biome. This approach almost always fails to take into account other perspectives, such as agronomy and the environment. The variety of cattle production systems (dairy cattle, beef cattle, and dual-purpose cattle production) involve different handling of breeding, different processing methods, different marketing techniques, different social organization of production, and a variety of investment, cost, and turnover strategies (Faminow, 1998).

Accordingly, an alternative theoretical approach is proposed to support this thesis, aiming to broaden the perspectives of analysis to socio-economic and political aspects of deforestation in the Brazilian Amazon settlement projects. Different from most of the previously discussed studies, this thesis focuses on people and how their practices, linked to several existing factors, local and external, influence deforestation. The sustainable livelihoods approach (SLA), which emphasizes the diversity of ways in which people make a living, emerges as a suitable theoretical perspective to make an in-depth analysis of the complex web of activities and interactions in settlement projects (Scoones, 2009).

1.5.2 Sustainable livelihoods approach: an overview

Livelihood perspectives have gained a central position in the debate and thinking on rural development in the last decade, looking at the reality of the rural world and trying to understand socio-ecological events and processes from a local perspective (Scoones, 2009). As the core approach used in this thesis, livelihood perspectives draw on diverse disciplinary

perspectives and cut across sectorial boundaries, providing an essential counterpoint to mono-disciplinary approaches, such as the economic, anthropological, agricultural, and ecological approaches that have dominated development enquiry and practice (Scoones, 2009).

One of the central theoretical approaches of a livelihood perspective is conceptually and intellectually inspired by the influential paper published by Chambers & Conway in 1992. The SLA, with its comprehensive outlook and its emphasis on the social, economic, and environmental dimensions of rural life, endeavours to explain key causal relationships and their influences on daily life but in such a way that the information remains manageable (Carney, 1998). Overall, it is an analytical and heuristic tool, providing a way to order and understand the links between different aspects of people's livelihoods (Clark & Carney, 2008).

The central concept in this approach is the sustainable livelihood, defined by Carney (1998: 2) as follow:

> *A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.*

As pointed out by Ellis (2000), the important feature of this livelihood definition is the way in which it directs attention to the links between assets and the options people possess in practice to pursue alternative activities that can generate the income level required for survival. Moreover, in this definition, the author has expanded the livelihood perspective, integrating three fundamental terms to conceptualize sustainable livelihood: capability, equity, and sustainability.

The term *capability* refers to the ability of human beings to lead lives they have reason to value and to enhance their choices (Sen, 1997). It reflects a person's ability to achieve a functioning, meaning what a person is capable of doing and being (Chambers & Conway, 1992). Such capabilities enhance resilience, enabling one to cope with and adapt to stresses and shocks, and to be able to find and make use of livelihood opportunities (Chambers & Conway, 1992). The principal of *equity* is of pivotal importance in the sustainable livelihood framework. It is about the improvement of the distribution of assets, capabilities, and opportunities, enhancing those of the most deprived, involving not just income distribution but also personal, social, environmental, and political aspects (Chambers & Conway, 1992). The term *sustainability* refers to social and environmental sustainability, impacting and being

impacted by livelihood choices at multi levels. At local level, impacts of livelihood activities can maintain and enhance or deplete and degrade the local natural resource base (forest, soil, water, biodiversity). For instance, deforestation is a negative side of agricultural livelihood activities, whereas reforestation is a positive side. At regional and global levels, livelihood activities contribute to net positive or negative effects on the long-term environmental sustainability of other livelihoods, focusing on, for instance, loss of biodiversity and climate change (Chambers & Conway, 1992).

Together with these fundamental concepts, other terms are part of the approach, aiming at capturing the multi-dimensionality and multi-causality of different forms of livelihoods for different people in different environments over time (Chambers & Conway, 1992). The livelihoods framework (Figure 1.3) thus helps to 'organize' the various factors that constrain or provide opportunities for people's livings and to show how these relate to one another (DfID, 1999).

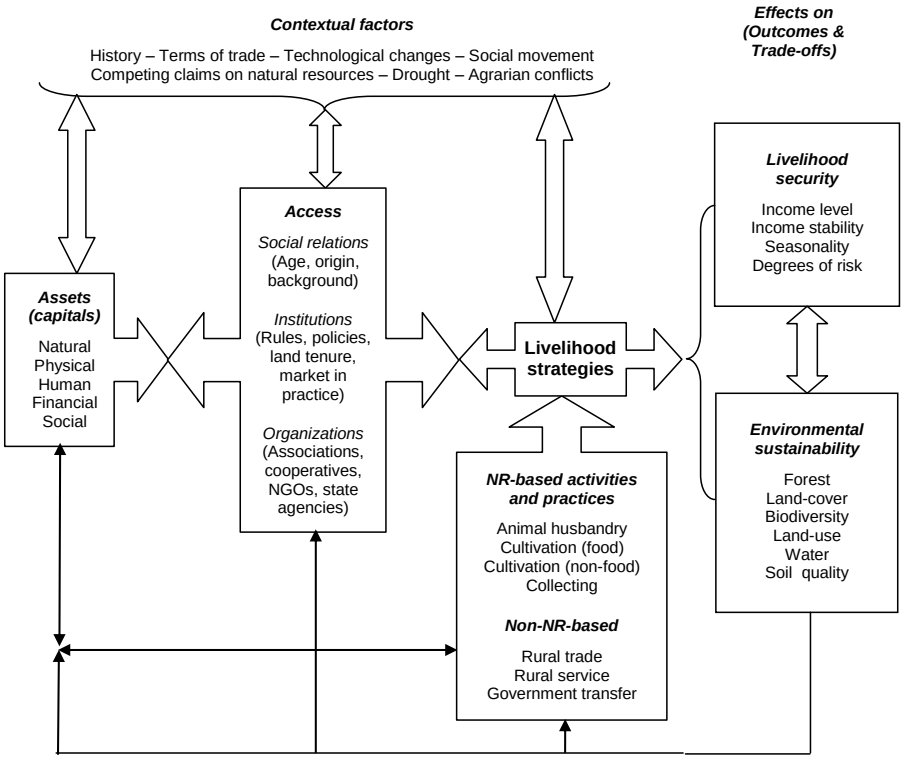


Figure 1.3 Sustainable livelihoods framework
Source: Based on Scoones, 1998; Ellis, 2000

However, it is regarded not just as an analytical tool (frameworks and checklists), but also as a normative position (Scoones, 2009). It is defined in the DfID guidance sheets (1999) as follow:

> *Firstly, the approach is 'people-centred', in that the making of policy is based on understanding the realities of struggle of poor people themselves, on the principle of their participation in determining priorities for practical intervention, and on their need to influence the institutional structures and processes that govern their lives. Secondly, it is 'holistic' in that it is 'non-sectorial' and it recognizes multiple influences, multiple actors, multiple strategies and multiple outcomes. Thirdly, it is 'dynamic' in that it attempts to understand change, complex cause-and-effect relationships and 'iterative chains of events'. Fourthly, it starts with analysis of strengths rather than of needs, and seeks to build on everyone's inherent potential. Fifthly, it attempts to 'bridge the gap' between macro- and micro-levels. Sixthly, it is committed explicitly to several different dimensions of sustainability: environmental, economic, social and institutional.* (DfID, 1999)

As a people-centred approach, SLA excellently suits the objectives of this thesis: understanding forest land dynamics by the comprehension of what people do to make their living and the effects on the forest.

Contextual conditions, as part of the SLA, involve factors that affect different claims, such as the distribution of property (especially but not exclusively land), work, income, consumption, and accumulation. However, these may be perceived differently among settlers (Bernstein et al., 1992). Contextual factors include the effects upon rural people of external trends (historical, social, political, technological, economic, etc.) and shocks (competing claims on natural resources and drought). At the same time, contextual factors also have an influence upon other sets of factors in the framework (Carney, 1998). These are so-called vulnerabilities (Carney, 2003), factors outside the control of a person but which influence access to an asset (Allison & Ellis, 2001).

The livelihood framework recognizes five categories of assets/capital: human capital (formal and informal education, local ecological knowledge, the skills and ability to labour, health of household members); physical capital (including productive assets held by the household such as farm equipment, herds, and land) as well as communal assets to which they have access (roads, communication infrastructure such as community phone); social capital (social networks, associations to which people belong, and access to wider institutions of society); financial capital and its substitutes (savings, credit, pensions, subsidies, cattle, etc.); and natural capital (the natural resource base endowment such as water, soil, and forest resources) (de Sherbinin et al., 2008; Ellis, 2000; Scoones, 1998).

Access to these assets is determined and mediated by a large number of structures and processes (factors that either prevent people from gaining, or support people to gain, access to

the livelihood assets), such as rules, policies, organizations, state agencies, etc. (Ellis, 2000). As shown by Ellis (2000), this social positioning comprises such factors as gender, age, origins, and religion. Institutions are the formal rules, conventions, and informal codes of behaviour that constrain human interaction such as land tenure arrangements (property rights). Organizations, as distinguished from institutions, are groups of individuals bound by some common purpose to achieve objectives.

The livelihoods concept takes an open-ended view of the combination of assets and activities that eventually constitute a viable livelihood strategy for the rural family (Ellis & Biggs, 2001). Livelihood strategy is influenced by context factors, assets, and access, but it is determined by the set of natural and non-natural resource-based activities and practices (Ellis, 2000a). Natural resource-based activities can include agriculture (livestock rearing, forestry, cropping, etc.) through processes of intensification (more output per unit area through capital invested or increase in labours inputs) or extensification (more land under cultivation), as proposed by Scoones (1998). Non-natural resource-based activities are related to rural trade (marketing of farm outputs, inputs, and consumer goods), rural services (sale of labour), and other social transfers such as pensions (Ellis, 2000).

Livelihood strategies are supposed to achieve certain material livelihood outcomes, interpreted in a comprehensive way as well-being (de Haan, 2006). The DfID (1999) interprets the outcomes as more income, increased well-being, reduced vulnerability, improved food security, and more sustainable use of natural resources. In the framework adopted in this thesis, the outcomes are interpreted as livelihood security, meaning that people obtain and maintain access to essential resources to ensure their immediate and long-term survival, improving their livelihood condition over time (Chambers & Conway, 1992), and environmental sustainability, meaning the sustainable use of natural resources, with forest cover as the indicator.

The effects of livelihood strategies on livelihood security and environment sustainability are twofold, as indicated by (Ellis, 2000): 1) the first effect leads to people becoming less vulnerable or more vulnerable in terms of their capability to manage adverse trends or cope with shocks, and 2) the second effect refers to changes in the resilience and stability of resources such as soils, water, and forest, and the environment may be improved, stabilized, or degraded. These effects depend on the opportunities available and the strategies adopted by local agents to respond to those opportunities, and they may obviously have different effects on the local environment (Ellis, 2000).

Therefore, livelihood strategies result from the interplay and mutual influence of actions and practices at household level and contextual conditions. In turn, household structure is based on various assets (types of capital), characterized by a dynamic process through access to social relations, institutions, and organizations, and on-farm and off-farm activities. The outcomes and trade-offs of livelihood strategies can be seen as livelihood security and environment sustainability. In turn, livelihood security and environmental sustainability are not stable outcomes, influencing back upon assets, access, on-farm and off-farm activities, and contextual conditions, constantly affecting and inducing changes in livelihood strategies.

The way in which this process unfolds, and the stresses and strains that result in the emergence of new patterns of activity, are influenced by trends and events that are in varying degrees exogenous to households and to local circumstances (Ellis, 2000). In the course of time, livelihood strategies may change in association with natural resources use, interpreted here as forest use in the Amazonian landscape. This association is classified by Sunderlin et al. (2005) in three different stages: hunting and gathering populations, using the forest as a source of food (capture and collection of forest fauna and flora); shifting cultivation, where forest lands serve as a source of agricultural lands whose fertility is maintained and restored by forest ecosystems in a system of rotational fallow; and permanent agriculture at the forest frontier, where forest lands tend to serve as a source of new agricultural lands that are not part of forest fallow systems. It is assumed that the last stage, as found in most Amazonian agrarian settlements, is more harmful to the forest, since it depends on continuous forest clearing to establish agricultural systems, entailing a competing claim on natural resource (Giller et al., 2008).

The combination of activities and practices at rural household level occurs in several dynamic ways over time, responding to pressures and opportunities of internal and external circumstances (Ellis, 2000; Scoones, 1998). The internal circumstances involve many other different kinds of activities and practices – producing food for home consumption and sale, raising children, negotiating different kinds of social relations with and between households, depending on the availability of resources at household level (labour capacity, land, and capital) and the family's set of goals and priorities (Crehan, 1992; Zoomers, 1999). In turn, the external circumstances refer to the agro-ecological situation, market access, infrastructure, agrarian change or social and political upheaval, and the presence of development institutions (Zoomers, 1999). As a result, many decisions about livelihood strategy choice do not result

from systematic or conscious planning; rather, they reflect adaptation to internal and external changing circumstances (Zoomers, 1999).

A detailed analysis of livelihood strategies is a prerequisite for a better understanding of the role of the multi-dimensional and multi-causal factors that have affected, positively or negatively, livelihood choices (Preston, 1994). However, as already mentioned, livelihood strategies change in response to internal and external circumstances, given the temporariness of livelihood activities. In this context, livelihood strategy analysis is expanded to include livelihood trajectory analysis. Livelihood trajectory is an appropriate 'methodology for examining individual strategic behavior embedded both in a historical repertoire and in social differentiation' (de Haan & Zoomers, 2005: 43). This analytical concept shows the direction that a household is taking, since households with a similar combination of practices can go in very different directions (Zoomers, 1999). This thesis focuses on a multi-temporal analysis of livelihood changes, examining past livelihood trajectories, livelihood strategies adopted in the present, and the factors that will potentially affect livelihoods in the future.

1.5.3 Sustainable livelihoods approach: advantages and drawbacks

Scoones (2009) states that the SLA has been applied successfully across sectorial areas, such as fisheries (Allison & Ellis, 2001) and natural resource management (Hoogstra et al., 2006). Several advantages of using the SLA to identify constraints to livelihood development and poverty reduction have been highlighted, such as: 1) it focuses on people, supporting them to build upon their own strengths and realize their potential; 2) it takes a comprehensive view of rural livelihoods, recognizing multiple influences on people's choices, multiple agents involved, multiple livelihood strategies adopted, and multiple livelihood outcomes; 3) it aims to do away with preconceptions about what rural people are seeking and how they are most likely to achieve their goals, and to develop a more accurate and dynamic picture of them in their environment; and 4) it stresses the importance of sustainability, recognizing that sustainable rural livelihoods can only be achieved if natural resources themselves are used in sustainable ways (Carney, 1999; Farrington et al., 1999).

However, as with all theoretical approaches, some drawbacks to the SLA have also been noted. Scoones (2009) suggests four drawbacks in the livelihood perspectives. Firstly, livelihood perspectives fail to address aspects of economic globalization. With its origins in complex disciplines and emphasizing the local, the SLA has difficulty in dealing with big shifts in the state of global markets and politics. Secondly, there are only marginal debates

about power and politics, and there is a failure to link livelihoods and governance debates to development issues. In this situation, an intellectual articulation with both political sciences and more radical agrarian studies is missing. Thirdly, the SLA does not deal with long-term environmental changes. Despite the use of the term *sustainability*, studies based on the SLA have ignored, for instance, the impacts of climate change on poverty and livelihood development. Fourthly, little effort is made to debate long-term shifts in rural economies and agrarian changes. Although a rich description of livelihood complexities in the present has been presented in many studies, questions about what livelihoods will look like in the future have hardly been addressed. In order to respond to these drawbacks, Scoones (2009) has identified four challenges, both intellectual and practical, that offer opportunities to extend, expand, and enrich livelihood perspectives:

1) Knowledge – livelihood analysis frameworks and methods offer a way of uncovering complexity and diversity in ways that have not often been revealed before, but livelihood analysis can be made to serve multiple purposes and ends. As a flexible concept, on the one hand, it opens up such a rich diversity in empirical description; on the other hand, it can equally be squashed down into the narrow instrumentalism of log frames and planning formats, or be deployed by particular political interests. Moreover, livelihood knowledge can be used as a normative assumption, contrasting ideal types (or classes) of livelihoods with alternatives with pejoratives ascriptions. Important questions, such as, firstly, which option is best, and for whom? and, secondly, what happens next?, emerge from this challenge. This thesis addresses livelihood knowledge in two ways. Firstly, it regards livelihood as a dynamic process (de Haan, 2006), using the SLA to understand and to describe the current reality (Chapter 2), to describe and to analyse livelihood trajectories (Chapter 4), and to indicate future changes in the system (Chapter 5), expanding the limited instrumentalist use of the framework, taking account of the dynamics involved in livelihoods. Secondly, there is no normative 'ideal' livelihood strategy predefined or indicated in this study; rather, livelihood knowledge is used to analyse the trade-offs between livelihood security and environmental sustainability (Chapter 5). Thus, livelihood knowledge is not used in this thesis as a normative assumption.

2) Politics – discussions on power and politics must move beyond the local level to examine wider structures and inequality. Attention to how livelihoods are structured by relations of class, gender, origin, and background is central. Understanding agrarian structures requires, as Bernstein et al. (1992) point out, asking the basic questions: who owns what, who does what, who gets what, and what do they do with it? The ARP is deemed to be a political instrument

and so its goals are the focus of analysis and not just considered as context. This thesis deal with this challenge, linking the rationality behind the ARP with local practices (Chapter 2). The power issue is touched upon in this thesis in terms of the historical struggle for the land (this chapter), the market, and the relative loss of organizational power after being settled (Chapter 2).

3) Scale – livelihood analysis is challenged to examine networks, linkages, relationships, flows, and chains across scales, going beyond a mechanistic description of them but remaining firmly rooted in place and context. Such approaches must also illuminate the social and political processes of exchange, extraction, exploitation, and empowerment, and so explore the multiple contingent consequences of globalization on rural livelihoods. In such a view, the global and the local are not separated – either physically or analytically – but intimately intertwined through relationships, linkages, relations, and dynamics between diverse locales. Giller et al. (2008) have pointed out that major tensions exist between global values regarding nature conservation, national and sub-national interests in agricultural production, and the socio-cultural values and livelihoods of local populations that characterize competing claims on natural resources from local to global level (Figure 1.4). On the one hand, there is pressure on environmental resources to provide a sustainable livelihood at local level; on the other hand, there is pressure to promote a sustainable environment at global level.

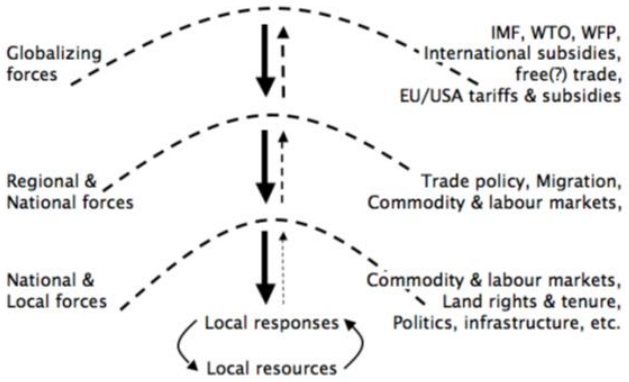


Figure 1.4 Multi-scale driving forces model
Source: Giller et al., 2008

Scales issue are considered in this thesis in Chapters 3 and 5, addressing multi-scale forest dynamics and the effects of high-scale policies, such as credit and market access, in individual livelihood trajectories.

4) Dynamics – long-term change has been a challenge for the SLA. In long-run livelihood change, specific dynamic drivers, operating over decades, are highlighted as important. These include demography, regional economic shifts and urbanization, migration, and land use. Livelihood analysis that identifies different future strategies or pathways provides one way of thinking about long-term change. These future changes characterize livelihoods in a dynamic way, considering possible and plausible descriptions of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces (Kok, 2009). In this thesis, future analyses (Chapter 5) are built on the most recent set of global scenarios available from the Intergovernmental Panel on Climate Change, the Shared Socio-economic Pathways (SSP). This analysis also addresses the scale challenge since global scenarios are downscaled to local realities.

1.6 METHODOLOGY

Given that this research focuses on a contemporary phenomenon in a real-life context, the case study was chosen as the methodological research design (Yin, 2009). This section introduces the study area selected to carry out this research. The set of methodologies, both qualitative and quantitative, from data collection to data analysis are also described in this section. Each chapter of this thesis used a specific set of methodologies that are only explained in this section in general terms. The specific details of each methodological approach are explained later, within each chapter.

1.6.1 Study area

Two main criteria determined the selection of the study area: the area should be within the Arc of Deforestation to contribute towards understanding forest dynamics, and the area should encompass as many settlement projects as possible, to contribute towards a specific understanding of forest dynamics in settlement projects. The southeast of Pará State was chosen as the broad area from which to select the case for this thesis as it is considered to be one of the most important ARP areas in the Legal Amazon (da S Martins and da S Pereira, 2012). This importance is explained by the history of land occupation and agrarian reform in the region, briefly described in the next section. Specifically, the municipality of Eldorado do Carajás was selected because it meets the prerequisites in relation to the large number of settlements (about 67% of the municipal area was occupied by settlement projects in 2010) and it is located within the Arc of Deforestation. Moreover, as the location of the most violent

conflict between landless people and the government in the recent past, Eldorado do Carajás has a symbolic connotation in relation to the struggle for land in Brazil. Furthermore, prior contacts with key people in the municipality who could support the study played a crucial role in the selection.

1.6.1.1 Southeast Pará: land occupation and agrarian reform

The massive process of occupation of the region began in the mid-1950s with the official concession by the Pará government of vast areas of land to exploit Brazil nut forests (*castanhais*). These areas, sized between 2,000 and 9,000 hectares, were granted to a few private holders (one private holder could take more than one area); this resulted in a land concentration process that became a cause of tensions and conflicts in the region some years later (Otsuki, 2007). Requiring hand labour to harvest the Brazil nuts in their areas, landholders brought people from other regions, mainly the northeast, to work in their Brazil nut forests (Girardi, 2008).

Moreover, migration into the region increased between the early 1960s and the late 1980s, pushed by several federal government development projects, such as the Program of National Integration (PIN – 1970) and the Program of Agricultural and Agro-mineral Centres of the Amazon (POLAMAZÔNIA – 1974). These programs were mainly aimed at alleviating social problems in other regions, especially the northeast, where drought was an intermittent problem, and at promoting the development of the region. This period was also remarkable for great infrastructure projects and mineral exploitations, such as the BR-230/Transamazônica (1972) highway, the Serra Pelada gold mine (1980), and the Serra de Carajás iron ore mine (1985), respectively (Homma, 2001). An illustration of this massive migration process: around 100,000 men were working in the gold mine of Serra Pelada in that time (Araújo, 2010). However, these projects were not perennial, meaning that at the end of these activities thousands of people were unemployed and without opportunities in the region. This situation increased tension over land access, reflecting the fact that most of the workers and miners had originally been small farmers in their homelands (Intini, 2004; Girardi, 2008). Meanwhile, the Pará State government was still conceding large portions of land to a few families in the region to exploit the Brazil nuts trees. In 1980, just three families had 200,000 hectares under their control in the southeast of Pará (Emmi and Marin, 1996).

Brazil nut exploitation declined in the late 1970s because of low prices and labour shortages (due to the major projects underway in the region), making way for the rise of new

economic activities, such as logging. After the most valuable timber in the region had been logged in the mid-1980s, especially mahogany (*Swietenia macrophylla*), the next option was to establish large pasture areas for beef cattle breeding, supported by road building, official credit, and tax exemptions (Hecht, 1985; Ozorio de Almeida & Campari, 1995; Muchagata & Brown, 2003).

Meanwhile, social movements had already organized, such as the Workers' Union, CPT, and MST (see section 1.2), and began to carry out actions of invasion and land tenure in the region, becoming politically empowered as the interlocutors of the demands of the agrarian reform process with the government. Despite this, the social movements continued to press the government to accelerate the process through the establishment of new settlement projects and increase the support to families that were camped and newly settled, culminating in the infamous episode that occurred on 17 April 1996 when 19 landless people died in a conflict[9] with police in Eldorado do Carajás. As a result of this remarkable conflict and under intense pressure from national and international organizations, the government established, in the same year as the conflict, a regional INCRA office in Marabá (SR-27/MB – the first one outside a state capital), aiming to accelerate the agrarian reform and, consequently, reduce conflicts in the region. It is important to point out that, historically, every single expropriation happened under pressure from a social action, such as a land invasion or, more usually, camping along roads (Schneider et al., 2004). These efforts are reflected in the number of settlement projects established (by legalization and by expropriation) and the area in which they are located in southeast Pará: up to 1996, 96 settlement projects had been established on 842,968 hectares, whereas from 1997 to 2010, roughly 220 new settlement projects were established on about 1,256,336 hectares in the area covered by SR-27/MB (INCRA, 2012).

1.6.1.2 Eldorado do Carajás

The municipality of Eldorado do Carajás was created in 1991, divided from the municipality of Curionópolis. The name, Eldorado, is not a coincidence, referring to the legend of *El Dorado*, a place of immense wealth searched for by Spanish conquerors in South America in the sixteenth century. Eldorado was chosen as the name of the municipality because of the gold rush boom in the region (the Serra Pelada gold mine is about 40 km from Eldorado do Carajás), representing a new hope for thousands of Brazilians, driven by the chronic

[9] According to MST members in Eldorado do Carajás, the movement was aiming to do a walk to Brasilia to seek more support for agrarian reform. Early in the walk, still in Eldorado, with the discontinuance of food baskets provided by the government via INCRA, the protesters decided to close the PA-150 road to raise money to buy food for the walk by charging tolls to passing drivers. The state government then sent police to clear the road, triggering the conflict.

unemployment resulting from the economic crises of the 1980s and 1990s and the drought in the northeast (Pará, 2011). The complement, Carajás, originated from the indigenous people, Karajá, who lived in the region, and it was also influenced by the proximity of the municipality of Parauapebas (about 80 km away), the location of one of the big projects in the region, the Serra do Carajás iron ore mine (Pará, 2011).

Eldorado do Carajás is located at geographical coordinates 06º 06'12" South latitude and 49º 22'18" West longitude, covering an area of 2,956.70 km^2 in the southeast of Pará (see Figure 1.5). The predominant soil in the municipality is oxisol, with small areas of entisols. The original vegetation is characterized by dense forest with valuable species, such as cedar (*Cedrela odorata*), mahogany (*Swietenia macrophylla*), and Brazil nut tree (*Bertholletia excels*), and open mixed forests presenting the same set of valuable species. The municipality is classified as Aw, according to the Koeppen classification, with dry winters (May/September) and rainy summers (November/March). The temperature ranges from 23ºC to 32ºC, with 26ºC on average. Humidity is high, roughly 80%, and precipitation is about 2,000 mm/year (IBGE, 2011b).

According to Census 2010 (IBGE, 2011a), the total population in the municipality is 31,786, with a population density of 10.75 *per* km^2; 16,578 people live in urban areas, 15,208 in rural areas. Eldorado do Carajás is occupied by people from several parts of the country, mainly northeast, generating great heterogeneity in population composition. The dynamic of occupation in the area where the municipality was created followed the same logic as the entire region, as broadly summarized in Table 1.2. In 2010, two-thirds of the municipality, or approximately 2,000 km^2, was occupied by 21 settlement projects, creating about 4,600 farm plots. In turn, deforestation affected roughly 92% of the municipality's total area in 2011 (INPE/PRODES, 2012). Eldorado do Carajás is defined as a post-frontier municipality because of its deforestation rate and land use consolidation (Becker, 2001; Rodrigues et al., 2009).

Table 1.2 Characteristics of land occupation in Eldorado do Carajás

Period	Main rural economic activity	Characteristic of land occupation
From 1950s to 1970s	Brazil nut exploitation	Large area dominated by few families
From 1970s to mid-1980s	Timber exploitation, beginning of cattle ranching Rice production	Large and medium farms Some squatters
From end-1980s to mid-1990s	Cattle ranching, rice and cassava production (in the settlement projects)	Large and medium farms Beginning of the establishment of settlement projects (1988)
From end-1990s to the present	Milk and beef cattle, cassava flour, corn, beans	2/3 of the municipality occupied by settlement projects

1.6.1.3 Settlement projects

The historical process of land occupation in the selected case study settlement projects is synopsized in this section, showing the heterogeneity of the process, the stakeholders involved, and the condition of the property at the time each project was established. The location of the participating settlement projects is shown in Figure 1.5.

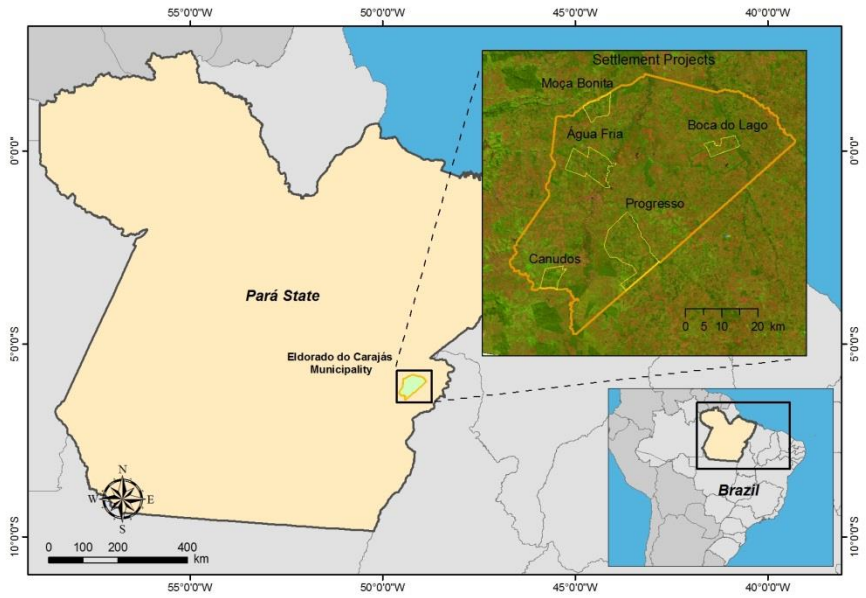


Figure 1.5 The selected settlement projects in Eldorado do Carajás, Pará, Brazil

1.6.1.4 PA Água Fria

PA Água Fria is located in a former Brazil nut collection area. The person granted government permission in the 1970s to exploit 4,200 hectares of Brazil nut trees sold the area to another person in the mid-1980s. This practice, although not legal, was common in these permissioned areas (Otsuki, 2007). The new owner exploited all the valuable timber in the area, such as cedar (*Cedrela odorata*) and mahogany (*Swietenia macrophylla*), creating

pasture land in the opened areas. Local landless people, former miners, and former rural workers, organized by the Workers' Union, invaded the farm in 1986, establishing the first agricultural areas. After several conflicts, including the murder of the Union's leadership, PA Água Fria aggregated other surrounding farms and was established officially in 1992, occupying 7,920 hectares today. Property area per household varies from 40 to 60 hectares.

1.6.1.5 PA Progresso

The historical process of PA Progresso was quite different. The area belonged to a commercial bank (Banco Bamerindus) from 1975, occupying 59,000 hectares spread over three municipalities (24,300 hectares of which were in Eldorado do Carajás). The bank's land use project planned to have 35,000 hectares as forest reserve, 24,000 hectares as pasture areas, 11 stables, 250 km of roads, and 90 houses for employees. According to local testimony, at the end of the 1980s, the bank attempted to expand the farm, expelling squatters from a small village close to the farm's border. Squatters and landless people were supported and organized by the CPT. However, in 1996 it was rumoured that the farm (and the entire Bamerindus group) was bankrupt. That year, several families who were not part of the social movement invaded the farm and started to live there. In 1997, the Brazilian Central Bank declared the Bamerindus bank bankrupt, and its farm was made available to INCRA for the ARP. Supported by the CPT and the Workers' Union, PA Progresso was officially established in 1998, accommodating 415 families on 15,140 hectares of forest and pasture areas. Average property size is about 20 hectares.

1.6.1.6 PA Moça Bonita

PA Moça Bonita was established in a former Brazil nut collection area in 1999. The exploitation of the area before the establishment of the settlement project was similar to the others, because when settlers arrived the most valuable wood had already been removed. The first occupation occurred in 1997, supported by the Workers' Union. Compared with others, the struggle for the land was rather peaceful in this case. INCRA established 86 farm plots in an area of 3,415 hectares, varying in size from 20 to roughly 70 hectares.

1.6.1.7 PA Boca do Lago

Occupying a former area of Brazil nut collection, PA Boca do Lago was officially established in 2001. This historical occupation was quarrelsome however. Five persons were murdered in

1989 during the struggle for land. Squatters definitely occupied the farm area in 1991, waiting for more than 10 years to be expropriated by INCRA. The farm comprises 10,600 hectares approximately, divided into three different settlement projects. PA Boca do Lago covers about 3,000 hectares, divided into 63 farm plots. Plot sizes are between 45 and 60 hectares.

1.6.1.8 PA Canudos

After the massacre of Eldorado do Carajás in 1996, the MST organized several farm invasions in the municipality. Inspired by the successful establishment of a settlement project called PA Cabanos, landless people, supported by the MST, invaded a neighbouring former Brazil nut collection farm in 1999. This invasion established the PA Canudos, which was officially recognized by INCRA in 2004. PA Canudos encompasses 62 farm plots, consisting of around 45 hectares each.

1.6.2 Data collection

Fieldwork was conducted in the study area over a period of five months in two phases. Both phases coincided with the Amazonian dry season because in the rainy season it would be very difficult to travel on the roads and reach some properties. The first phase of data collection was June to August 2010 and the second phase was July and August 2011.

The starting point to organize the first phase of the fieldwork was a contact with the local extension service, which has close contact with settlers and their leaderships. I had known the coordinator of the biggest local extension service (Coopserviços), Mr Deuzinho Alves, since 2007. He arranged a meeting with five technicians from different extension services and a state government program (Coopserviços, Servtec, and Pará Rural, respectively) to discuss the fieldwork planning and strategies. Two of these technicians were also settlers, and one of them was the local MST coordinator. The first step was to select a representative number of settlement projects to be part of the research. On the basis of location, access, and the different historical processes carried out by different groups (CPT, Union, and MST) involved in the struggle for their establishment, five settlement projects were chosen from the 21 located in Eldorado do Carajás in 2010 (see previous section). There was consensus on the representativeness of the selected projects as compared to the others.

The next step was to contact the leadership of each settlement project and explain to them what the research was about. To do so, I started, together with the leadership and the coordinator of the Coopserviços, to randomly select the participants for the research. Random sampling from a finite population gives each possible sample an equal probability of being

selected from the entire population (Kothari, 2009). Minor adjustments were made if warranted by the road conditions to access a property, or when the household was not available. Subsequently, in-depth recorded open-ended interviews were conducted with the household heads, although in most cases other members (husband/wife, sons and daughters) also participated. Before the interviews started, the leadership of the settlement project introduced me and the relevance of the research for the household. Interestingly, a few settlers suggested that I should schedule the visit in advance so they could 'better organize their thoughts and talks.' However, later on, they understood that the focus of the interview was just to obtain testimony that was free from any preconception of what should or should not be said. Each interview took about two hours.

The total survey sample included 42 households, distributed over the five settlement projects previously selected, as shown in Table 1.3. The sample size was defined by the social science *saturation point* technique. Data collection reaches this point when interviewing more participants does not add new or additional valuable information to the research (Guest et al., 2006). In addition to settlers, 12 key stakeholders from different governmental and non-governmental institutions, such as the Federal University of Pará, INCRA/Marabá and MST, were also interviewed, providing new insights for the research by expanding the diversity of sources of data and information. Further data on the households were obtained from the census questionnaires, administered by the local extension service.

The recorded open-ended interviews addressed the life history of each family, including their background before they were settled and the activities and practices developed after arrival at their properties. The quantitative and qualitative analysis of these interviews, together with the census questionnaires, formed the basis for identifying the settlers' livelihood strategies and livelihood trajectories.

Secondary data were collected from diverse sources. Data and information about the settlement projects, such as maps and historical processes of land occupation, were obtained from INCRA and the local extension service, respectively. Satellite imagery were collected from the INPE website. The ecological–economic zoning report was obtained from the Pará Rural program. Additional studies and unpublished reports were obtained from the local extension service.

After the interviews and still in the first phase of the fieldwork, a workshop was conducted in each settlement project, aimed at obtaining an individual participatory map

representing each settler's perceptions on forest and non-forest areas in 2010. The number of participants in these workshops is shown in Table 1.3.

Table 1.3 Participants in the recorded open-ended interviews and in the workshops

Settlement Projects	**Interviews (2010)**	**Workshop participatory mapping (2010)**	**Workshop settlers' perceptions (2011)**
Água Fria	10	6	7
Progresso	14	6	8
Moça Bonita	6	4	4
Boca do Lago	6	4	4
Canudos	6	4	3
Key stakeholders	12		

In the second phase of the fieldwork, I visited the properties of those who had participated in the participatory mapping workshop a year earlier, aiming to collect ground control points obtained from GPS coordinates for each property. After the visit, three workshops were organized aimed at capturing the settlers' perceptions about factors that affect their livelihood security and environmental sustainability.

1.6.3 Data analysis

Different methods of analysis were applied depending on data source, information collected, and the objective of the chapter (Table 1.4). The open-ended recorded interviews were processed in the qualitative data analysis software Atlas.ti (version 6.2), and the main messages from each interview were coded and transcribed. Fieldwork observations were aggregated in the transcriptions and crosschecked with local technicians and leaderships to clarify concepts and to ensure comprehension of the issues discussed with settlers. The outcomes from both workshops (participatory mapping and settlers' perceptions) were also discussed with local experts and leaders in order to increase the credibility and reliability of the data. Triangulation of multiple methods, such as interviews with observation, produces a more accurate, comprehensive, and valid representation of the object of study in qualitative analysis in social science research (Silverman, 2009).

Table 1.4 Data source and analysis used in this study according to the chapter

	Source of data	**Data analysis**
Chapter 2: Livelihood strategies in settlement projects in the Brazilian Amazon: determining drivers and factors within the Agrarian Reform Program	Interviews Census questionnaires Reports Scientific articles	Content analysis Factor analysis Cluster analysis ANOVA Pearson chi-square test
Chapter 3: From space and from the ground: determining forest dynamics in settlement projects in the Brazilian Amazon	Satellite imagery Workshops Participatory maps Reports Scientific articles	Band analysis Principal components analysis Maximum likelihood method Content analysis F-test T-test
Chapter 4: Analysing the influence of livelihood trajectories on forest dynamics at property level: Do livelihoods make a difference for forests?	Chapters 2 and 3 Interviews Census questionnaires Satellite imagery Reports Scientific articles	Content analysis Band analysis Principal components analysis Maximum likelihood method
Chapter 5: Mapping future changes in livelihood security and environmental sustainability based on perceptions of small farmers in the Brazilian Amazon	Chapters 2 and 3 Workshops Fuzzy cognitive maps Reports Scientific articles	Matrix Dynamic changes in the matrix

Content analysis was the main method used to investigate the secondary data, such as reports and articles. Other secondary data, such as satellite imagery, were analysed using a set of accurate procedures, such as geometric rectification and supervised classification.

Statistical analyses of the quantitative data, such as factor and cluster analysis, were executed in the software SPSS program (version 17.0.3).

1.7 THESIS OUTLINE

This thesis consists of six chapters, including a general introduction, four chapters designed as scientific papers, and a final chapter with synthesis and conclusions. This first chapter gives an overview of the livelihoods perspective and forest dynamics, addressing also the genesis of agrarian reform in Brazil and the land occupation process in the southeast of Pará. It also includes the research problem, research questions, research objectives, and the methodology adopted in subsequent chapters. Each chapter is related to the SLA framework, in line with its specific objective (Figure 1.6).

Chapter 2 identifies three clusters of livelihood strategies adopted by settlers in 2010 from the agrarian reform perspective. This chapter also identifies the underlying factors that have driven livelihood choices, the integration of settlers into commercial markets, and the agrarian reform process.

Chapter 3 analyses forest cover changes from 1985 to 2010 at two levels: the municipality and the areas where the settlement projects were established. It considers forest dynamics as deforestation and reforestation. This chapter also investigates settlers' perceptions about what forest means for them.

Chapter 4 combines Chapters 2 and 3, expanding the livelihood perspective into livelihood trajectories, attempting to identify their effects on forest dynamics at property level.

Chapter 5 describes settlers' perceptions about the factors influencing their livelihood security and environmental sustainability in 2011. On the basis of the livelihood strategy clusters identified in Chapter 2, settlers' perceptions were compared, aimed at finding similarities and differences among them. Future changes for the people and for the forest were also identified on the basis of existing optimistic and pessimistic scenarios.

Finally, Chapter 6 presents the main findings of this thesis as reported in the various chapters. In doing so, it reflects on the study objectives, theoretical concepts, and the literature on livelihoods and forest dynamics.

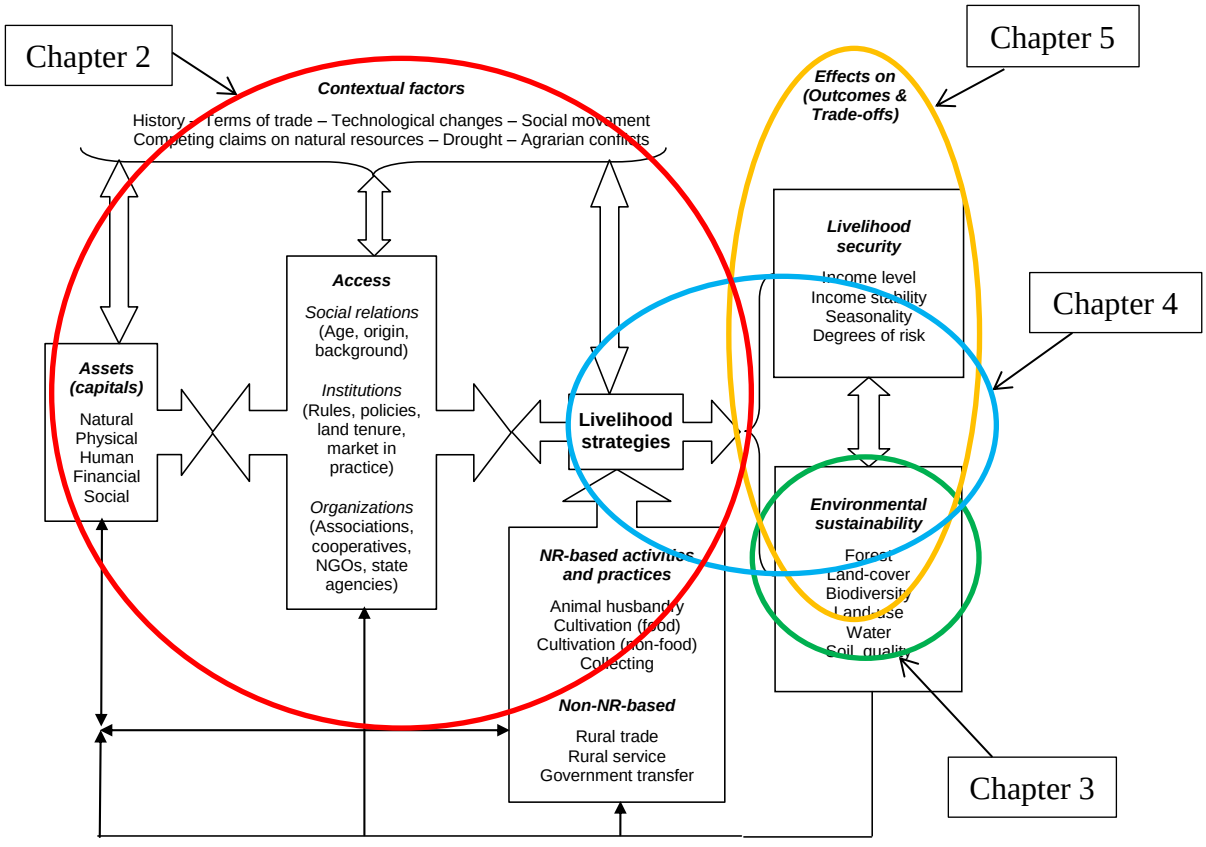


Figure 1.6 Structure of the thesis

Chapter 2

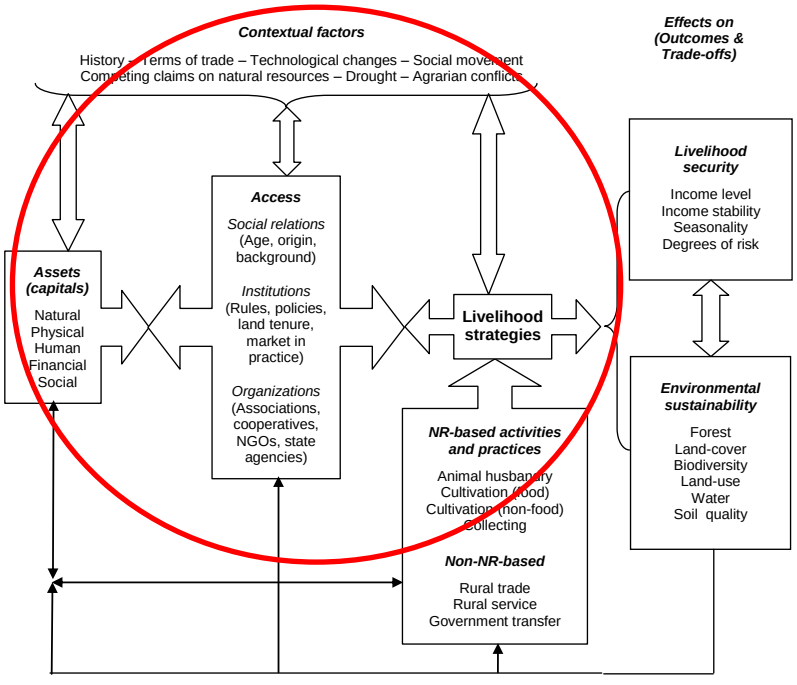
The happiest people do not have the best things.
They know how to make the best
from the opportunities that appear in their paths.

(lines from the poem *Há Momentos* by the Brazilian poetess Clarice Lispector)

2 Livelihood strategies in settlement projects in the Brazilian Amazon: determining drivers and factors within the Agrarian Reform Program

Fábio H. Diniz, Marjanke A. Hoogstra, Kasper Kok, Bas Arts

What to do to make a living in settlement projects under the framework of the Agrarian Reform Program is a constant challenge for the settlers. Household choices can be constrained by several factors, both internal and external, and at several scales and levels. Chapter 2 seeks to identify the livelihood strategies adopted by settlers in the agrarian reform settlement projects, aware of the factors that can be driving their household choices. Theoretically, this chapter addresses the combination of contextual factors, assets, access (mediating factors), natural and non-natural resources-based activities, and practices that have driven settlers into their chosen livelihood strategies.



This chapter is under review at the *Journal of Rural Studies*.

Abstract

Over the last decades, hundreds of thousands of families have settled in the Brazilian Amazon within the framework of the Agrarian Reform Program (ARP). The rationale behind the program is to enable settlers to earn their living by small-scale farming and producing an agricultural surplus for the market. This paper aims to analyse the settlers' livelihood strategies under the framework of the ARP and its objectives. The paper considers more than just land use shares. Income composition, capital (human, physical, natural, social, and financial), mediating process, and context are also included, and these reveal three groups of livelihood strategies. Most of the settlers have achieved the ARP goals, mainly by deploying livestock strategies, particularly milk production.

Keywords: settlers; livelihood security; milk production; southeast Pará; Brazil

2.1 INTRODUCTION

The Amazon biome is the largest continuous region of tropical forest in the world, containing parts of nine South American countries. Around 69% of the biome is within Brazil, a geopolitical area defined by the federal government as the Legal Amazon. This area comprises the entire Brazilian Amazon biome together with some transitional bordering areas of *Cerrado* (Brazilian savanna) and covers an area of about 5.1 million km^2. Being a separate unit facilitates planning and promotion of development of the Amazon region (INPE, 2011). The area is home to about 25 million people or 13% of the Brazilian population (IBGE, 2011a).

In the past, many indigenous groups occupied the area. After several cycles of spontaneous colonization throughout the centuries, the Brazilian government started colonizing the area massively after 1950 through several migration programs (Homma, 2000; Intini, 2004; LASAT/MDA, 2006; Girardi, 2008). The reasons behind these colonization processes are manifold, including reinforcing Brazilian sovereignty over the Amazon; alleviating the social problems in other regions, especially in the northeast where drought has been an intermittent problem; increasing domestic and export food crop production; and decreasing land conflicts in other places in the country (Fearnside, 1984; Browder, 1988). In the past decades, the Legal Amazon has also been the main region for the establishment of settlement projects within the Agrarian Reform Program (ARP). From 1964 to 2011, roughly 750,000 families, corresponding to around 60% of all families that participated in this program in the entire country, were settled in this region (Pacheco, 2009a; INCRA, 2012).

At first glance, agrarian reform can be regarded as 'a set of measures that aims at distributing land to achieve the principles of social justice and increasing productivity' (MDA/INCRA, 2004). This might be considered a solution to some of the country's problems because it embraces policies that provide increased access for landless people to natural resources (land, water, and forest), to credit, to technology, to goods and labour markets, while at the same time distributing political power (Leite and Avila, 2006). However, the mere availability of these sets of policies may not be sufficient for poverty alleviation and sustainable rural development, since other factors such as human capabilities and social conflicts can influence such outcomes. Moreover, the policies that support the ARP may be contradictory in nature or may restrict settlers in choosing their preferred livelihood strategies.

On the basis of the economic and socio-political imperatives of the first Agrarian Reform Plan, the government elaborated the second National Agrarian Reform Plan in 2004 (II PNRA), which projects an increased demand for food and agricultural products by Brazilian people to be supplied by family farming in settlement projects (MDA/INCRA, 2004; Borras et al., 2007). As a result, farms in the settlements projects are understood as units of production from which settlers are able to earn their living by small-scale commercial farming, producing an agricultural surplus for the market. Moreover, the plan aims to provide the settlers with the conditions to assure local sustainable development, paying unprecedented attention to the environment, agricultural prices, and marketing policy (Deere and Medeiros, 2007). Despite the importance of off-farm activities as a livelihood strategy in rural areas (Jacquelyn, 2010) and despite the fact that the II PNRA does not exclude the possibility of earning a living off-farm, the ultimate goal of Brazilian agrarian reform is to increase food production by on-farm activities. Consequently, in essence, it is a plan with a potentially high social impact, including the economic dimensions of generating employment, raising incomes through increasing food production, and integrating an ever larger portion of the population in the market (Gehlen, 2004; Deere and Medeiros, 2007). On the other hand, the failure of the ARP might have consequences at local (increasing conflicts), national (increasing social instability), and international (climate changes, increasing greenhouse effects, and reducing biodiversity by increasing Amazon deforestation) levels (Fearnside, 2005; Malhi et al., 2008; Shukla et al., 1990; Vieira et al., 2008).

The beneficiaries of the agrarian reform program (called settlers) are landless men and women rural workers (*sem-terra*) and small squatters/colonists (*posseiros*) (MDA/INCRA, 2004). In principle, land access is free for people who are recognized as potential settlers by the National Institute of Colonization and Agrarian Reform (INCRA), even though land allocation may take many years. Another way to access land in settlement projects is to buy a farm plot on the informal land market (Merry *et al.*, 2008). Although the agrarian reform rules do not allow a farm to be sold, this practice is widespread within almost every settlement project. However, the most important requirement for those who receive or buy a farm in a settlement project is to be recognized as a settler by INCRA by including his/her name on the official beneficiary roll (*relação de beneficiários – RB*) which guarantees access to all agrarian reform schemes (family allowances – *bolsa família* – other subsidies, credits, extension service, etc.). All the settlers who participated in this study belong to the *RB*, even those who bought their farm. INCRA recognizes a ‘new’ settler and includes him/her in the

RB on condition that he/she is a family farmer, according to the definition in Federal LAW 11.326/2006 (Brasil, 2006).

In principle, settlers may choose from a wide variety of different types of agricultural production and associated livelihood strategies. However, what people generally do to sustain their families is a function of individual preferences, opportunities available, and family as well as community needs, as interpreted in the light of local practices (Preston, 1994). Consequently, outcomes vary tremendously: there are cases of agricultural and livelihood security success, but there are cases of deep failure too. In this context, a number of crucial issues are shaped by and shape the settlement programs and their objective of agricultural modernization – issues like uneven rural development, inadequate food production, poor infrastructure, and large-scale deforestation (Batistella & Brondizio, 2001).

Although a number of studies have analysed the socio-economic dynamics and livelihood strategies in the Brazilian Amazon settlements (Walker & Homma, 1996; Carpentier et al., 2000; Fearnside, 2001; Heredia et al., 2005; Salisbury & Schmink, 2007; Pacheco, 2009a; Ludewigs et al., 2009; Oliveira & Almeida, 2010), almost all have related these dynamics to environmental issues, especially deforestation. However, the influence of the ARP objectives in terms of food production and inclusion of the settlers in the market have hardly been addressed. Therefore, the general aim of this paper is to analyse the development of the settlers' livelihood strategies from the perspective of the ARP and its aims. In doing so, the paper also assesses whether these strategies are achieving the ARP goal of food production to meet settlers' own needs and to have a surplus to send to market. Theoretically, this paper builds upon the sustainable livelihood approach (SLA). This leads us to formulate the following, more specific, research objectives:

(1) to determine the livelihood strategies of the settlers by assessing the factors of land use and income composition;

(2) to identify and analyse the influence of factors underlying livelihood strategies (the five different types of capital, mediating processes, and political and socio-economic contexts); and

(3) to analyse access to, and integration into, commercial markets.

These factors are assumed to influence small-scale farmers' livelihood strategy choices, in this case those made by Brazilian Amazon settlers.

2.2 CONCEPTUAL FRAMEWORK – LIVELIHOOD STRATEGIES

Robert Chambers (at IDS) and Gordon Conway (at IIED) are widely acknowledged for having put livelihoods centre stage in household research (Chambers & Conway, 1992). They first defined livelihoods simply as *'a means of gaining a living*,' but over the years the understanding of livelihood has developed into a dynamic and comprehensive concept in which all aspects of well-being (material as well as non-material) are incorporated (Scoones, 2009).

Recent studies show the enormous diversity in livelihood strategies that people deploy in order to achieve their livelihood goals; they differ between regions, between households, and in time (Ellis, 1998; Carpentier et al., 2000; Barrett et al., 2001; Jansen et al., 2006; Salisbury & Schmink, 2007; Tittonell et al., 2010). Several authors have developed classifications of livelihood strategies in order to structure this diversity (see e.g. Carney, 1998; Scoones, 1998; Devereux, 1999). This study aims to determine the livelihood strategies of the settlers in terms of two types of livelihood activities associated with income source: (1) on-farm activities: practices relating to agriculture such as animal husbandry and food cultivation and collection through processes of intensification or extensification on the household's own plot; (2) off-farm activities: practices relating to a range of off-farm income-earning activities, either temporary or permanent, such as animal training, small market activities, employment in other sectors, government transfers (pensions and subsidies).

The reason for choosing these two types of livelihood activities is that one of the underlying principles of the ARP (and the object of this research) is that households should be able to provide the majority of their livelihood security and a surplus of food production to the market from their own farm (MDA/INCRA, 2004). If households have to rely more on off-farm than on-farm activities and sources of income to provide their livelihood security, this may indicate misconceived assumptions underlying the ARP.

However, the livelihood strategies of the settlers are not the only object of this research; this study also wants to explore the factors that determine the settlers' livelihood strategies in order to be able to explain the settlers' choices. To do that, first of all a household's assets must be known as they are considered the main elements determining livelihood strategies (Scoones, 1998; Ellis, 2000; Carney, 2003). In addition to conventional assets like financial, natural, and physical capital (for example money, natural resources, and machines), household assets include various elements of human capital (e.g. skills, knowledge) and social capital (e.g. networks, associations).

Access to these assets is determined and mediated by a large number of structures and processes (factors that either prevent or support people in gaining access to the livelihood assets), such as rules, laws, organizations, state agencies, etc. (Ellis, 2000). Access is also influenced by contextual shocks (whether natural or manmade), trends (economic changes, technological developments, migration, etc.) and seasonality (of weather and agricultural production). These are so-called vulnerabilities (Carney, 2003), factors that are outside a person's control but influence access to an asset (Allison & Ellis, 2001). The available assets, the structures and processes, and the vulnerability context together form the basis on which people choose their livelihood strategies (Figure 2.1). In order to explain the livelihood strategies of the settler households, it is therefore important to factor in these elements, as in this study.

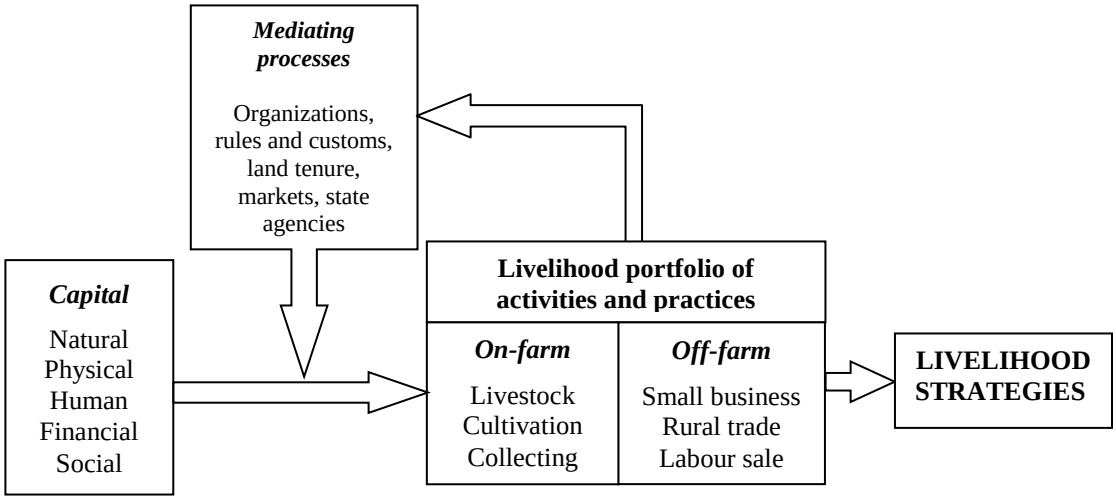


Figure 2.1 Livelihood strategies and determining factors
Note: Context of vulnerabilities, shocks, and trends: history – terms of trade – technological changes – social movements – competing claims on natural resources – droughts – agrarian conflicts
Source: based on Ellis, 2000; Carney, 2003; Scoones, 2009

2.3. METHODOLOGY

2.3.1 Case study

The southeast of Pará has been chosen as a case for this study as it is considered one of the most important areas of the ARP in the Legal Amazon. It encompasses the largest number of settlement projects in the country (over 500), involving over 66,000 families (MDA/SIT, 2011). There are several reasons for this large number of settlements. Historically, this area has attracted a high number of people, mostly small farmers from other poor regions who go there to look for work in the mines (Intini, 2004; Girardi, 2008). At the same time, this area

has been the origin of pressure from social movements – such as the Workers' Union, the Catholic Church's Pastoral Land Commission (Comissão Pastoral da Terra, or CPT) and the Landless Workers' Movement (Movimento dos Trabalhadores Sem-Terra, or MST) – against the government to accelerate the agrarian reform process through the establishment of new settlement projects. Their actions included invasions and camps along roads, and their pressure brought about an increase in the number of settlements in the region (Oliveira et al., 2005).

The case study is located in the municipality Eldorado do Carajás (Figure 2.2). This municipality is infamous as the place where 19 landless farmers were killed by the military police during a demonstration against the slow pace of implementation of the government's agrarian policies in 1996. Due to the severe conflicts in the area (Alston et al., 2000; Simmons et al., 2007), a number of studies planned to be conducted there were carried out in other areas in Pará State (Caldas et al., 2007). These conflicts have lessened in the last years however, and, although they have not ceased, it is safe to conduct surveys in this municipality.

The total area of Eldorado do Carajás is 2,957 km^2 with a total population of 31,745 people, of which 52% live in urban areas and 47% live in rural areas (IBGE, 2011a). Roughly 4,600 settler families in 21 settlement projects occupy about 67% of the municipal area (MDA/SIT, 2011). Moreover, around 800 families remain camped along the roads, waiting for a piece of land (Araújo, 2010). Land use in the municipality as a whole is mainly characterized by large areas of pasture (72%), followed by secondary vegetation (16%), primary forest (10%), and just 0.22% of the land is used for crops (ZEE, 2010). From 2004 to 2008, the GDP of the municipality increased by around 152%. In 2008, the agricultural sector accounted for, approximately, 27% of GDP, whereas the industry and services sectors represented 18% and 49%, respectively (IBGE, 2011a). Most industry and the services sector activities in the municipality are associated with agriculture (such as slaughterhouses, dairy plants, transport associations).

This case study was chosen for a variety of reasons. Besides being well-known and emblematic, reasons include the following: the area is located in the Amazon and encompasses a large number of settlement projects; contacts with settlers' leaderships, the local extension service, and local government since 2006 make it possible to access the households; and only a small number of studies have been conducted in this municipality.

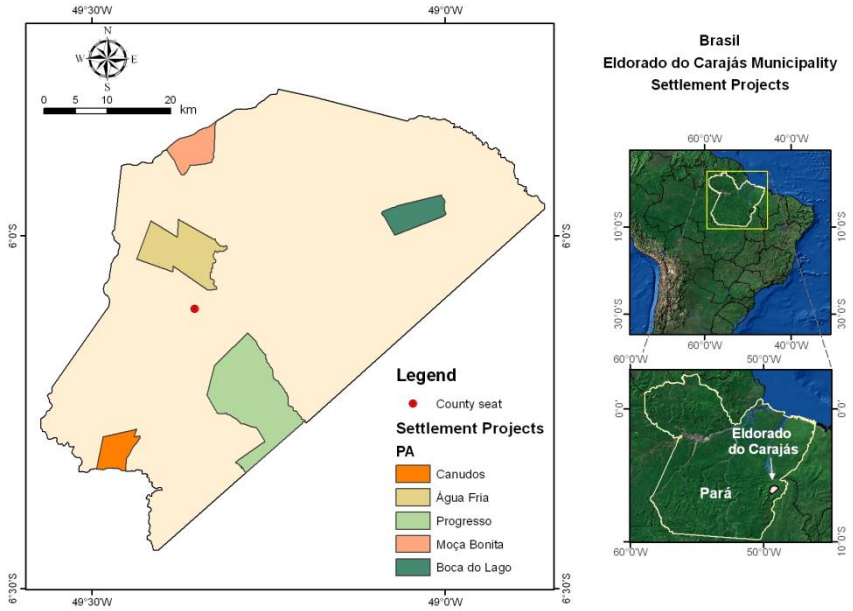


Figure 2.2 Case study area with selected settlement projects
Souce: INPE, 2011; INCRA, 2012.

Table 2.1 Sample data

Settlement Projects	Year of establishment	Total area (ha)	Total households	Household selected	Total area (ha) of households selected
Água Fria	1992	7,924	145	10	656
Progresso	1998	15,143	415	14	354
Moça Bonita	1999	3,411	92	6	356
Boca do Lago	2001	2,925	63	6	376
Canudos	2004	2,893	62	6	279
Total		32,296	777	42	2021

Source: Fieldwork notes and MDA/SIT, 2011

From the 21 settlement projects in the municipality, five projects were selected (see Figure 2.2): Canudos, Água Fria, Progresso, Moça Bonita, and Boca do Lago. The selection was based on (a) absence of conflict, (b) accessibility of the settlement projects, and (c) geographical distribution over the municipality. The household sample contained 42 households, randomly selected, with some minor adjustments when selected farms could not be reached (see Table 2.1 for more information on the sample).

2.3.2 Data collection

This study adopted a mixed method approach in which a quantitative component addressed the livelihood strategies and the related assets, and a qualitative component addressed the

structures, processes, and the vulnerability context, thereby operationalizing the conceptual model (see Figure 2.1). This mixture of qualitative and quantitative data research has gained importance in the literature on development and livelihood research (White, 2002; Ade Freeman et al., 2004). Silverman (2009) has even suggested that such a combined approach can actually provide a more convincing analysis than a single method.

Key household variables were collected through open-ended recorded interviews (carried out from June to August 2010) with each household head. Each interview took on average two hours. Further data on the households were obtained from census questionnaires. The local extension service conducted this census in every household in the municipality between August and December of 2009. INCRA and the Federal University of Pará/LASAT compiled the questionnaires. To collect data relating to structures, processes, and vulnerabilities, in every settlement one focus group meeting was organized. Lasting on average an hour and a half each, the meetings were useful to elicit collective experiences and opinions and to identify factors that might have been overlooked during the interviews. For instance, determinants of the context and some mediating processes – such as, respectively, technological changes (e.g. logistics of milk collection) and the role of the social organizations – were addressed in these meetings. On average, 65% of the households had at least one member participating in the meetings. General information about historical processes of land access, credit schemes, technological assistance, and market access was also collected through open-ended recorded interviews with 12 key stakeholders from several institutions, such as INCRA, Pará Federal University, extension services, dairy and beef companies, landless social movements, etc.

2.3.3 Data analysis

To group the individual households into distinct livelihood categories, we used a combination of factor and cluster analysis based on two important factors in livelihood strategies, i.e. land use and income composition. First, principal factor analysis was applied in SPSS (version 17.0.3) to analyse the correlation of the following variables: (1) size of total crop area, pasture area, forest area, and annual crop area; and (2) milk and cattle income, income from other livestock, and income from off-farm activities. The rotated factor loadings from the principal factor analysis served as input for a k-means cluster analysis.

Once the household sample was clustered into livelihood strategy groups, the household livelihood choices were linked with the asset-based variables of that household. Natural capital refers to the amount of land owned (more land stimulates on-farm activities)

and herd size (which is related to farm size and pasture area). Human capital variables include age of household head (determines labour capacity), household size (influences labour availability), level of education (important for off-farm employment opportunities), the number of years in the area (determines adaptation to the local production systems and livelihood opportunities), origin of birth (linked with previous agricultural practices and food traditions), and professional background (important for on- and off-farm employment opportunities). Financial assets refer to gross income per year (result of livelihood strategy and determines livelihood security), milk production, and herd size (both are sources of income and indicate market access). Social assets are represented by the presence of relatives in the same settlement project (facilitates collective support in times of need for intensive labour, e.g. harvest periods). Physical variables include the distance to the county seat (determines access to social support, e.g. hospital, high school, etc.) and the distance to the milk market (influences the opportunity to sell products). The ordinal variables, such as natural and financial capital, were analysed by comparing the frequencies in each strategy cluster, using one-way ANOVA (Tukey's test) in SPSS to determine the combination of significant variables in each cluster. In turn, categorical (or nominal) variables, such as origin and background in human capital, were analysed, also by comparing the frequencies in each cluster in SPSS, but using Pearson chi-square test.

The mediating structures and processes, and the vulnerability context, were determined by performing a systematic qualitative content analysis. This included reading and re-reading all available written information (such as the interview transcripts, transcripts of the focus group meetings, the census questionnaires, and the field notes). Data were coded in Atlas.ti.

2.4 RESULTS

2.4.1 Livelihood strategy clusters based on land use shares and income composition

The statistical analysis indicated three livelihood strategies among the settlers: (1) livestock-oriented strategy; (2) diversified-oriented strategy; and (3) off-farm-oriented strategy (Table 2.2). Cluster 1 was named livestock-oriented strategy, or just livestock, because it is based on extensive livestock farming. Most land use is pasture (75%). Cattle herd size (on average 36 animals) and milk production (on average 29,000 l/year) are significantly larger than in other clusters, reflected directly in income composition (see also Table 2.3). Consequently, most

income (93%) comes from livestock activities, roughly divided into milk production (69%) and cattle sales (19%), with a small amount (4.2%) from small livestock, i.e. chickens, pigs, and goats. Whereas milk production is the main income-generating activity, crop areas dedicated to cultivating cassava, rice, corn, beans, and perennials (coconut) are small, essentially meant for home consumption. Milk production, as a daily activity, needs more labour and time throughout the year than annual or perennial crops that depend on intense labour in certain seasons. Accordingly, off-farm income is low, representing just 6.4% of total income, mainly accounted for by off-farm activities (3.5%), pensions (1.3%), and government subsidies (1.6%).

Cluster 2, named diversified-oriented strategy, or just diversified, is characterized by a more diverse set of land uses and means to generate income. The main land use remains pasture (61%), despite lower milk production (average is 15,900 l/year) and smaller herd size (on average 20). The on-farm forested area (on average 14%) is significantly higher than in the first cluster. Nevertheless, crop areas (9.6%), especially those dedicated to annual crops (6.7%), are significantly higher than in other clusters. This is increasingly reflected in income composition, even though most income continues to come from livestock (68%). Within the latter income category and compared to the previous cluster, milk production decreases to 41% of total income, whereas cattle sale increase to 23% (although not significantly), and small livestock remains similar around 4%. In turn, the larger crop area contributes to 15% of total income, especially based on cassava (cassava flour) and rice sales, even though most rice, corn, and bean crops are for home consumption. Dependence on off-farm income also increases in this second cluster: around 17% of total income originates from off-farm activities. Most of these relate to the ownership of small shops, labour days on other farms, ownership of cassava flourmills, and horse training, all together corresponding to roughly 13% of total income, whereas government support such as pensions and subsidies correspond to 1.6% and 2.4%, respectively.

Cluster 3 was named off-farm-oriented strategy, or just off-farm, because it represents households with the highest off-farm income dependence. Land use is characterized by the largest share of forest area (22%), although this figure is not statistically significant compared with Cluster 2. Most land is dedicated to pasture (65%), but milk production (on average 8,100 l/year) as well as herd size (on average 13) are the lowest among the three clusters, whereas just 3.9% is dedicated to crops (cassava, rice, and corn), mostly for home consumption. Livestock activities provide around 41% of total income, divided into milk production (23%), cattle sales (13%), and small livestock (5%). In turn, roughly 55% of total

income originates from off-farm activities and/or government support. Most of the off-farm activities, corresponding to 33% of total income, relate to labour on other farms, ownership of small shops, and labour in external organizations, i.e. the municipality or the iron ore company. Dependence on government transfers is also higher in this cluster. Pensions provide 17% of total income, and subsidies correspond to 5%.

Table 2.2 Summary of the cluster analysis

Variable	**Cluster 1 Livestock (n=16)**		**Cluster 2 Diversified (n=13)**		**Cluster 3 Off-farm (n=13)**	
	Mean	SE	Mean	SE	Mean	SE
Land Use (%)						
Pasture	74.7	4.8	60.6	3.7	65.3	5.4
Forested	8.6$^{(3)}$	30	14.1	4.1	22.2$^{(1)}$	5.7
Crop (annual + perennial)	4.3$^{(2)}$	0.7	9.6$^{(1,3)}$	2.1	3.9$^{(2)}$	0.6
Income Composition (%)						
Milk production + cattle market	88.8$^{(2,3)}$	2.2	64.5$^{(1,3)}$	4.8	35.9$^{(1,2)}$	4.2
Gross income from off-farm activities	6.4$^{(3)}$	2.2	16.8$^{(3)}$	3.5	55.1$^{(1,2)}$	5.2

Note: Bracketed numbers indicate that differences are statistically significant among cluster number(s) 1, 2, 3 at the 5% level (ANOVA).

2.4.2 Underlying livelihood factors

Table 2.3 shows the results of the livelihood factor (capital and mediating processes) data gathered through qualitative and quantitative techniques. Some of the factors identified in the conceptual framework (see Figure 2.1) are statistically significant, such as human capital (origin and background), financial capital (milk production and herd size), and mediating process (milk market access). Others such as natural capital (farm size), physical capital (distance to the milk market), and some mediating processes (land access, credit scheme, technological assistance, and organizational capacities) are important according to the qualitative analysis.

Table 2.3 Capital, mediating processes, and factors among livelihood strategy clusters

Capital/ Process	Factors	Full sample (n=42)	Livestock (n=16)	Diversified (n=13)	Off-farm (n=13)
Human	[a]*Age of household head – years*				
	Mean	46.05	44.75	43.54	50.15
	Minimum	20	20	23	37
	Maximum	75	69	74	75
	SD	13.072	12.694	14.286	12.287
	[a]*Years on the farm*				
	Mean	12.45	13.56	10.77	12.77
	Minimum	2	5	2	5
	Maximum	28	28	25	23
	SD	6.259	6.703	7.132	4.693
	[a]*Household size*				
	Mean	4.19	3.56	4.77	4.38
	Minimum	1	2	1	3
	Maximum	8	8	8	7
	SD	1.671	1.750	1.878	1.121
	[a]*Years of education – head*				
	Mean	4.69	4.94	4.54	4.54
	Minimum	0	0	0	0
	Maximum	11	11	11	11
	SD	2.789	2.568	3.017	3.017
	[b]*Origin - %*				
	Northeast states	57	31$^{(2,3)}$	69$^{(1,3)}$	77$^{(1,2)}$
	Other states	43	69$^{(2,3)}$	31$^{(1,3)}$	23$^{(1,2)}$
	[b]*Background - %*				
	Crop-oriented	52	31$^{(2,3)}$	77$^{(1,3)}$	54$^{(1,2)}$
	Livestock-oriented	41	69$^{(2,3)}$	15$^{(1,3)}$	31$^{(1,2)}$
	Non-farm activities	7	0$^{(2,3)}$	8$^{(1,3)}$	15$^{(1,2)}$
Financial	[a]*Milk production - l/year*				
	Mean	18467.02	28949.38$^{(2,3)}$	15933.46$^{(1,3)}$	8099.23$^{(1,2)}$
	Minimum	0	10220.00	0	0
	Maximum	95040.00	95040.00	41400.00	19800.00
	SD	16545.51	20418.05	10170.29	6392.26
	[a]*Herd size - number of head*				
	Mean	24.19	36.13$^{(2,3)}$	20.54$^{(1,3)}$	13.15$^{(1,2)}$
	Minimum	0	12	10	0
	Maximum	100	100	42	43
	SD	19.58	24.4	10.73	10.68
	[a]*Gross income/year - US$**				
	Mean	11580.55	12382.87	11571.22	10602.42
	Minimum	4719.10	4994.38	4719.10	4770.79
	Maximum	36640.45	36640.45	19566.29	17751.81
	SD	6753.73	9334.45	4956.60	4524.00
Social	[a]*Farms with relatives in the same settlement project*				
	Mean	1.21	.81	1.38	1.54
	Minimum	0	0	0	0
	Maximum	6	5	4	6
	SD	1.718	1.424	1.325	2.332
Natural	[a]*Property size - Ha*				
	Mean	47.62	54.69	44.77	41.77
	Minimum	20	20	20	20
	Maximum	140	140	60	100
	SD	24.824	32.273	12.255	23.256

Physical	[a]*Distance from each plot to the county seat – Km*				
	Mean	30.95	31.13	28.38	33.31
	Minimum	13	17	13	15
	Maximum	63	63	44	59
	SD	14.204	16.116	11.544	14.773
	[a]*Distance to the milk market (dairy plant or cooler bulk tank) - Km*				
	Mean	5.02	4.37	5.31	5.54
	Minimum	0	0	0	0
	Maximum	18	18	17	16
	SD	4.683	4.319	4.498	5.517
Mediating processes	[b]*Land access – %*				
	Settled by INCRA	38	31	31	54
	Buyer	36	38	46	23
	Colonist/squatter	26	31	23	23
	[b]*Credit policy – %*				
	Access	83	88	69	92
	No access	17	12	31	8
	[b]*Technological assistance – %*				
	Regular	36	44	46	15
	Not regular	64	56	54	85
	[b]*Milk market access – %*				
	Regular	86	100	62	92
	Not regular	14	0	38	17
	[b]*Settler organizations*	All settlers are members of some organization (association or cooperative)			

Notes: *Calculated from the Brazilian Central Bank's official exchange rate on 20 July 2010 (US$ 1.00 = R 1.78), representing the mean gross incomes of each household. Bracketed numbers indicate that differences are statistically significant among clusters 1, 2, 3 at the 5% level. (a) ANOVA (Tukey's test); (b) Pearson chi-square test.

The results reveal a significant relationship between origin and background of settlers and their position within the clusters. The majority of the settlers interviewed (57%) came from northeastern states. However, they are not spread equally over the three clusters; rather, they are concentrated in the diversified and off-farm clusters (69% and 77%, respectively). In turn, most settlers in the livestock cluster (69%) came from other states (west-centre and southeast regions). In terms of background, 52% of the settlers were crop oriented, whereas 41% were livestock oriented, and 7% had non-farm activities as previous experience. Approximately 69% of the settlers in the livestock cluster were livestock oriented, whereas 31% were crop oriented, and no one had a background in non-farm activities. The diversified cluster represents 77% of crop-oriented settlers, whereas livestock-oriented and non-farm background settlers correspond to 15% and 8%, respectively. In terms of the settlers' background, the off-farm cluster is composed of 54% crop-oriented settlers, 31% livestock-oriented settlers, and 15% off-farm activities-oriented settlers. These results indicate that settlers tend to choose the type of livelihood with which they are most familiar.

In terms of financial capital, milk production and herd size are significantly different among clusters; on the other hand, mean gross income per year is the same among clusters, indicating differences in the sources of income.

The majority of indicators under human, social, natural, and physical capital are not significantly different across the three clusters, even though a qualitative analysis pointed out the importance of these variables for settlers' choices. For instance, despite the fact that farm size is similar in all three clusters, all of the settlers interviewed stated that this size is too small to provide their livelihood security and, at the same time, to obey the environmental law. This law determines that 80% of their property has to be covered by forest (although this might change in the near future; a new law is under discussion in the Brazilian Congress). In terms of physical capital, distance to the milk market is an important indicator; nevertheless, roads and bridges are in bad condition in some settlements, especially in the rainy season. This constrains a free choice of livelihood strategy as it becomes virtually impossible to travel on these roads.

Mediating processes identified in the interviews and focus groups relate to (1) land access, (2) credit scheme, (3) technological assistance, (4) milk market access, and (5) organizational capacity. A chi-square test of independence was performed to examine the relation between these categorical variables and the livelihood strategy clusters, except for organizational capacity because all settlers belong to one of the settlers' organizations. The relation was significant just for milk market access at the 5% level.

Regarding land access, the settlers can be identified as settled by INCRA, as buyers, or as colonists/squatters. In three cases, the farm is currently occupied by the sons of the original settler (settled by INCRA), indicating cases of land succession. In this study, the interviewees settled by INCRA (38%) are similar in number to those who bought their farm (36%), whereas the colonists/squatters account for 26%. The type of land access is similar in the livestock cluster, whereas most settlers in the diversified cluster are divided in buyers (46%) and settled by INCRA (31%). In turn, most settlers in the off-farm cluster are settled by INCRA (54%), whereas buyers and colonists/squatters have the same rate (23%). Land tenure was not identified as a vulnerability for 95% of the settlers (average of all three clusters); they are not afraid of losing their land rights because they are on INCRA's official beneficiary roll (*RB*).

The majority of settlers (83%) have had access to credit, reflecting a high rate of access in all clusters, ranging from 69% in the diversified cluster to 92% in the off-farm cluster, with 88% of the settlers in the livestock cluster having credit access. Most credits are

destined for house construction/renovation or for investment in any farming activity, in principle. However, the settlers clarified a negative point of credit policy in their cases, namely, bank pressure to apply the financial resources to farming activity only, especially cattle ranching, considering neither the human capital availability at household level, i.e. origin and background of the settler, nor the environmental aspects of their properties.

Technological assistance has been provided mainly by cooperatives of technicians contracted by INCRA according to the National Policy of Technological Assistance and Rural Extension to the Family Farmers and Agrarian Reform (Brasil, 2010). The Pará State agency of rural extension (EMATER-PA) also had a key role during the establishment of the settlement projects, especially in relation to the first credit line, but nowadays it plays a minor role for several reasons. Despite the state's policy of providing technological support to the settlers, most of them complained about the quality and quantity of this service. In general, 64% of settlers stated that they had not been assisted regularly (once every three months). The lack of regular technological assistance is similar in the livestock and diversified clusters (56% and 54%, respectively), whereas 85% of the settlers in the off-farm cluster remarked that they are not regularly assisted.

Milk market access can be constrained by problems associated with the condition of roads and bridges throughout the year. These problems could hinder or even prevent regular market access by the settlers. Although most of the settlers (86%) have accessed the milk market regularly, there is a statistical difference among the clusters. In the livestock and off-farm clusters, respectively, 100% and 92% of the settlers have regular access to the milk market, whereas 62% of the settlers in the diversified cluster do not have problems accessing the market. This high rate of market access usually leads to a high milk yield.

Formal settler organizations (associations or cooperatives) are present in all settlement projects, and all settlers in all clusters are linked to them because they can have access to alternative credit lines, e.g. for house renovation. However, these organizations mainly focus their attention on the implementation of the agrarian reform policies instead of supporting farming systems. The organizations' low involvement in, and lack of support for, farming systems were pointed out by 83% of the interviewees; they consider this a weakness. On the other hand, these organizations operate as 'the voice of the settlers,' demanding new policies to support them.

Concerning the livelihood context, the settlers perceive the vulnerability of their security as deriving from (1) the seasonality of production and (2) the uncertainty in market

prices. They are also vulnerable in terms of interaction with market parties, since their organizations undertake hardly any action to support their systems, even though they sell the milk together; this results in a high dependence on local and regional market parties, e.g. middlemen. In terms of shocks, floods and droughts have not been a problem for them, even though the general infrastructure (roads and bridges) and/or the household infrastructure of production (corrals, barns, and pasture areas) are often affected in the rain season. The settlers perceive long-term trends in, basically, two connected ways. It is necessary firstly to improve their farming systems, especially by adopting technological innovations to intensify land use and provide their livelihood security in a smaller area, and secondly to increase the forested area on their farm plots. The latter perception is linked to the prospect of some kind of environmental service as a future source of income for them.

2.5 DISCUSSION

This section discusses the three livelihood strategy clusters that resulted from the quantitative and qualitative analyses of land use shares and income composition. In addition, the impact of the underlying factors that have driven livelihood strategies is also considered.

2.5.1 Livelihood strategies, land use, and income composition

Several studies have classified livelihood strategies using either land use shares or income composition shares (Pichón, 1997; Browder *et al*., 2004; Jansen *et al*., 2006). However, using these two sets of variables in an isolated way to identify livelihood strategies can lead to misclassification when land use overlaps across clusters. For instance, the cluster analysis showed that more than 60% of land use shares in all clusters are predominantly pasture areas, suggesting that livelihood strategies automatically have an extensive cattle ranching system as the main activity (see Muchagata & Brown, 2003). Hence, all three clusters would fall under one category if only land use or main land use was considered. Therefore, analysing only land use shares, or even its combination (Pichón, 1997), is likely to produce a false typology, as suggested by Pacheco (2009b). Moreover, land use shares do not determine livelihood strategies, or even indicate them, since land use is generally only one element of choice making for household strategies (De Janvry and Sadoulet, 2002).

Income composition has also been used as a determinant of livelihood (Pacheco, 2009b), even though it could be understood as an outcome of livelihood strategies rather than

a determinant of them (Jansen *et al*., 2006). Nevertheless, income composition is considered a determinant of livelihood strategy in this study because land use can be influenced by off-farm income. For instance, whether household members have a pension or some other off-farm labour as their source of income, or are too old to farm, or have less time to work on their own farm, all these factors influence land use patterns. Therefore, this study combines both sets of variables – land use *and* income composition – to classify and name clusters. For example, although the largest area in the off-farm cluster is pasture, this cluster cannot be classified as livestock-based because most of the income originates from off-farm activities. Moreover, off-farm income also seems to induce a different land use share, as demonstrated in the off-farm cluster in which significant differences in forested area and total crop area were found, compared with the livestock and diversified clusters, respectively. In addition, both these latter clusters are agrarian systems providing most families with income from agricultural activities on their own farms, consistent with the ARP. On the other hand, the livelihood strategy of the off-farm cluster is based mainly on non-farm activities, implying higher government dependence in terms of pensions and subsidies, although the gross income/year does not significantly differ from that in the other clusters.

2.5.2 Underlying factors driving livelihood strategies

As already suggested in previous sections, livelihood strategies are not determined by land use share and income composition alone; some factors from livelihood capital, mediating processes, and the context also shape livelihood strategy choices. Even more so, all these factors together push settlers towards cattle breeding. Below, it is shown how these various factors do so. The background and origin of the settlers, interpreted as human capital, have played key roles in determining livelihood strategy choices, mainly in the livestock and diversified clusters. Other studies, even though at a higher level of administrative scale, such as Browder *et al*. (2004) and Jansen *et al*. (2006), have come to the same conclusion. In principle, people's livelihood choices are strongly linked to their region of origin, irrespective of the environmental conditions of the plot and the nature of the agrarian reform policies. To illustrate this, settlers who already had experience with cattle ranching (livestock oriented) tended to choose a similar livelihood strategy; on the other hand, settlers who had earlier experience with crop production (crop oriented) tended to keep doing so. These choices are clearly based on reducing the risk of venturing into a new activity to which they are not accustomed, especially in a situation where technical assistance is limited. Despite the

suggestion of a logic of free livelihood strategy choice, the results of this and other studies show that a logic of path dependency seems a more appropriate suggestion. Nevertheless, it is obvious that some mediating processes of agrarian reform, i.e. credit policy, technological assistance, social organization, land access, and land tenure, also play key roles.

PRONAF (National Program for Strengthening Family Farming) provides special subsidized credit for settlers (PRONAF A) at an annual interest rate of only 1.15%. The loan is split over seven years with three years' grace and a 40% discount of the total amount lent (MDA, 2011). However, in spite of the crop-oriented origin and background of some of the settlers, the bank's technicians pushed all credit to cattle breeding, especially in the first credit lines in early 2000. Given that the markets for milk and beef were already established, cattle breeding was believed to be more secure for the settlers, and, hence, for the bank, to be sure that the loan would be repaid. In other words, economic security, ultimately for the banks, was the major factor considered in the credit analysis; the banks did not hold social and environmental dimensions in high regard at that time. This entailed some difficulties for settlers who were not familiar with cattle ranching: some of them were afraid to milk cows or even to be in contact with cattle. Moreover, it also apparently induced more deforestation, since many settlers converted forest areas into pasture to enable cattle activity. For instance, a settler categorized in the diversified cluster who was interviewed in PA Progresso had been planning to crop black pepper and coconut when he was settled by INCRA 13 years previously, but 'the bank sent me cows,' in his own words, inducing him to increase the pasture area on his farm plot. However, some years later, he started cropping when money became available because he has remained strongly rooted in his original crop-oriented background.

Furthermore, land characteristics before the settlement projects were established have also strengthened the cattle orientation. Many settlers that were originally crop oriented became cattle oriented because many farm plots consisted mainly of pastures, leaving only small areas for cropping (Nogueira, 2010). Similar processes of settlement project formation, as discussed by Simmons et al., 2010, and so-called *direct action land reform* (DARL), were also found in the study area. The complexities involved in these formations can be an important constraint on settlers' livelihood choices. The processes of struggle for the land and to ensure people's rights have evolved step by step. The first goal is to obtain the land. Historically, this step has involved conflicts, as touched upon earlier. Usually, just after an invasion and/or the establishment of a camp on a large farm, the government, through INCRA, starts to assess the expropriation process. After the conclusion of this process (maybe

some years), INCRA splits up ('cuts,' according to the settlers) the property into as many farms as possible, depending on the environmental characteristics of the area (soil quality, slope steepness, water, land cover, etc.), even though the pressure from social movements to settle as many families as possible leads the process as well. Sometimes, either there are more families camped than the capacity of the land allows or there are many colonists/squatters already established in the area, and this results in a smaller farm plot to accommodate everyone. This happened, for instance, in PA Progresso. After all the steps for expropriation and division of the land had been taken, the settlers accessed the farms by lottery. Hence, there has never been a background analysis of settlers' skills, causing some difficult situations. For instance, several crop-oriented settlers were established in pasture areas, whereas livestock-oriented settlers were settled on forested farms. In a few cases however, settlers exchanged their plots among themselves. Consequently, settlers had to shift their activities from crop oriented to livestock oriented or convert forest areas into pasture on their farm plot, depending on their preferred orientation.

The formal organizations (associations and cooperatives) are an effective interlocutor between the settlers and the government since they are able to pressure INCRA at the national level to consider their demands, implying a certain level of political empowerment on the part of the communities. On the other hand, the social and economic repercussions of these organizations' lack of support are reflected in the dependence of the settlers on the market to resolve questions that they could resolve themselves, i.e. the logistics of the bulk tanks used by the industry to collect milk; this dependence leads to lower prices. Moreover, the settlers are not well organized to discuss the level of prices and their integration in the market; all these processes are dominated by the milk industry. This situation is surprising because of the settler organizations' ability to successfully struggle for the land, as the past has shown.

The technical assistance provider, perhaps implicitly or indirectly, also drives cattle breeding as it is responsible for preparing and monitoring the projects approved by the banks. Moreover, the lack of support in the social organization of production, in terms of management process, production, and marketing, has also induced settler dependence on the market. On the other hand, the number of available technicians is small in relation to the large number of settlers that need assistance, and this has been a challenge to the extension service.

In terms of scale, it is essential to highlight that settlers are subject to federal policies, resulting in a direct link between the settlers and the national government. Local and state governments do not have any influence on the settlement projects in terms of responsibility to

maintain or improve the infrastructure (roads and bridges, electricity, etc.), credit lines, and technological assistance, at least until the settlement projects achieve autonomy.

To sum up, just like other key literature (Vosti et al., 2003; Marquette, 2006; Siegmund-Schultze et al., 2007; Salisbury & Schmink, 2007), this study reveals the importance for livelihood choices of the multi-functionality of cattle breeding – especially dairy cattle – such as herd mobility, non-labour intensive investment, providing cash, savings, liquid assets, and food security. Additionally however, this study shows that the ARP itself, in terms of previous nature of the farm plot, land access conditions, credit policies, and technical assistance, has played an enormous role in driving livelihood strategy choice.

2.5.3 Interaction with the market

The sum of the factors and processes previously discussed has driven settlers' livelihood choices mainly towards milk production as the main strategy (at least in the settlement projects investigated in this study). Moreover, environmental conditions and expansion of markets (both beef and milk) can also explain why the majority of farming activities across the clusters are based on livestock, mainly milk production, even in the off-farm cluster.

Environmental conditions such as precipitation level, temperature, air humidity, and types of pasture produce extremely favourable conditions to raise cattle in the Amazon region (Margulis, 2004). In addition, the option of a dual-purpose system oriented to dairy, as pointed out by Vosti et al. (2003), can contribute to settlers' livelihood security in several ways – for example, the sale of continuous milk yields ensures a safe money income throughout the year. In general, there is no difficulty in accessing the market, either milk or beef, even though flowing milk production has been a problem in the rainy season in the study area. Local and regional markets still demand cattle products, and key business assets (animals) are marketable (FAO, 2009). Furthermore, herd mobility favours this activity as a livelihood strategy, reducing risks from flooding in the rainy season.

The improvement of infrastructure, such as electricity and roads, and a certain stabilization in agrarian conflicts, allowed the flow of milk production from the settlement projects to increase, attracting dairy industries into the region from the early 2000s (Alves et al., 2006), thus providing secure market access for the settlers. Milk market access has also been facilitated by the expansion of bulk processing whereby the milk is stored at low temperature ($4^{o}C$) in a cooler tank and collected by truck every 48 hours. This process has been adopted very fast in the municipality: in 2006, there were six cooler bulk tanks; in 2010, there were 187 tanks spread over the municipality (SEBRAE, 2010). Despite the enabling

forces that have driven this process, it seems to be a *slow* process towards *on-farm* intensification of milk production, especially in settlement projects within the livestock cluster. This becomes clear when some settlers or a group of them begin to incorporate some technological improvements in their farming system, such as pasture rotation, sugar cane to feed the animals in the dry season, and livestock controls. On the other hand, this process seems to be constrained by the lack of regular technological assistance and lack of production infrastructure, such as tractors, attachments, and spare parts.

Diversification has been relatively modest in Amazon settlements (Perz, 2005). The majority of income even in the diversified cluster comes from livestock activities (Alves & Homma, 2004), determined more by the agrarian reform conditions than by the settlers' free will. Although diversification seems to be small in general terms, it is important for reducing risks to families' livelihood security as the seasonal decrease in milk production coincides with the harvesting, processing, and storing of cassava (cassava flour) and rice (May/June). However, market integration of crop production has been problematic because of the small-scale and scattered production of crops in the settlement projects and the lack of organizational support.

In turn, as a non-agricultural system, the off-farm cluster does not follow the production logic as it encompasses people who are more dependent on off-farm activities and government transfers (pensions and subsidies). Moreover, some of these off-farm activities are nature based, for instance, when settlers work on other farms as daily workers, fixing fences, cropping, or doing other agricultural work. For reasons linked to household characteristics and composition, physical characteristics of the farm and/or personal character and behaviour, some settlers are not able to provide their livelihood from their own farm. However, most off-farm activities in this cluster are linked to settlers' own small businesses and regular waged work. As far as the objectives of the ARP are concerned, settlers from the off-farm group seem not to be responding to these objectives, as gross on-farm production – either crop or livestock – comprises less than 50% of income composition. However, this cluster has the highest share of forested area on its plots. This suggests that households have sources of income off-farm, and the remaining forested area is larger than on other farms with intensive crop and/or livestock dependence. On the other hand, the gross income among clusters is similar to the national average income of around US$ 10,000.00 (IBGE, 2011a).

2.6 CONCLUSIONS

This study has distinguished three clusters of livelihood strategies. These clusters were identified by the combination of sets of drivers and factors because the isolated analysis of either land use shares (especially when there is overlap in types of land use) or income composition was not sufficient to define livelihood strategies in the case study. Moreover, a large number of additional factors and processes laid down in the ARP have shaped the clusters.

Most of the settlers in these clusters are achieving the ARP goals of food production and market integration, with more or less similar levels of average annual income. The main on-farm activity in all clusters is cattle breeding, where dairy cattle dominate, even though other activities such as crops (bean, rice, cassava, and corn) and small livestock (pig, chicken, and goat) also contribute to livelihoods. However, milk production has not been a free choice for the settlers: the agrarian reform process itself has shaped this livelihood strategy choice.

Although it is not often acknowledged in the literature, the settlers are well integrated in the market because of the dairy and beef chains already established in the region. This is all the more remarkable as the settler organizations do not give priority to supporting the production systems technically or to establishing a better market position for their members.

This study debunks some of the myths about smallholders in settlement projects in the Amazon. The settlers have an annual income close to the national average, being less poor than often thought. They are beyond subsistence level; most of them do not rely on subsidies such as the *bolsa família*, and they are proud not to receive it. Some of them are integrated into a (dairy) market chain. Beef marketing is important for income composition, although not the primary activity. Finally, incidences of land conflicts and violence are rare nowadays and, insofar as these emerge, they are not evenly spread over all settlement projects.

However, at the end of the day, the settlers face numerous difficulties at local level to provide for their livelihood security, even though most of them acknowledge that they are better off today than before.

Chapter 3

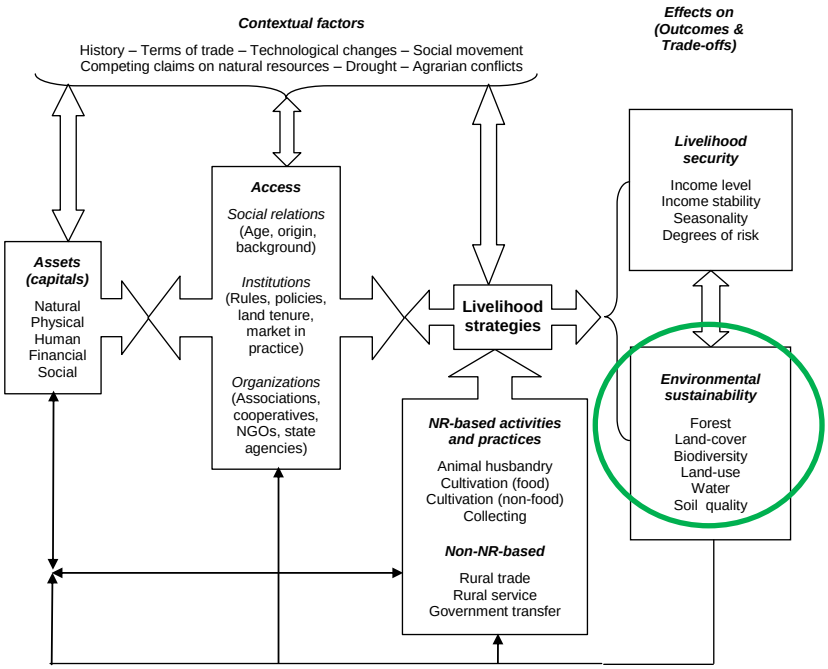
Nature goes her own way,
and all that to us seems an exception is really according to order.

(quotation from the writer and philosopher Johann Wolfgang von Goethe cited in the book *Conversation of Goethe with Johann Peter Eckermann* by Johann Peter Eckermann)

3 From space and from the ground: determining forest dynamics in settlement projects in the Brazilian Amazon

Fábio H. Diniz, Kasper Kok, Marcos C. Hott, Marjanke A. Hoogstra-Klein and Bas J. M. Arts

Forest cover changes within settlement projects have been addressed as a unidirectional and linear process towards deforestation. This chapter addressed forest cover changes as a dynamic process in settlement projects, involving deforestation and reforestation. In a multi-scale perspective, this chapter analyses forest dynamics within the areas where settlement projects were established, taking into account settlers' perceptions about what forest means for them. Theoretically, this chapter addresses environmental sustainability, understood as forest dynamics (deforestation and reforestation). Forest transition theory is proposed as the framework to analyse forest dynamics in the study area.



This chapter is under review by the journal *International Forestry Review*.

Abstract

Deforestation in the Brazilian Amazon has been partially attributed to the establishment of settlement projects. Acknowledging the difficulties in quantifying the rate and patterns of deforestation, the objective of this paper is to determine forest dynamics (deforestation *and* reforestation) in areas where settlement projects have been established, at multiple levels and using different methods. Using satellite imagery from 1985 to 2010, a study was conducted in five settlement projects in Pará State, aiming to determine forest dynamics at municipal and settlement levels. At property level, participatory maps were constructed to understand settlers' perception of forest/non-forest areas. The results show that reforestation is the current process in the municipality and in some settlements. Settlers, however, perceive areas with secondary regrowth as potentially fertile cropland and might deforest again in the future. More research is needed to elucidate whether the observed reforestation will lead to a forest transition or is merely a temporary trend.

Keywords: deforestation; remote sensing; stakeholders' perceptions; agrarian reform; Brazil

3.1 INTRODUCTION

The disappearance of primary forest in the Brazilian Amazon region is a widely recognized problem, with multiple local, regional, and global consequences, e.g. on biodiversity, soil, and climate (Demiranda & Mattos, 1992; Faminow, 1997; Fearnside, 2005; Hecht, 1993; Scouvart et al., 2008; Shukla et al., 1990). Most of the deforestation has been linked to actions taken by large and medium landholders (Aguiar et al., 2007; Caldas et al., 2007; Ludewigs et al., 2009; Margulis, 2004), but the large number of settlement projects (PAs) established under the Agrarian Reform Program (ARP) have also been highlighted as a noteworthy underlying cause (Brandão Jr. & Souza Jr., 2006; Fearnside, 1984; Pasquis et al., 2005; Santos, 2010; Soler et al., 2009). From 1964 to 2011, roughly 750,000 families, corresponding to about 60% of all families in this program in the entire country, were settled in the Brazilian Amazon (MDA/SIT, 2011; Pacheco, 2009a).

The primary goal of the ARP is the establishment of settlement projects, mainly by redistributing large areas from private landholders to landless rural workers and small squatters/colonists (denoted *settlers*) through the Instituto Nacional de Colonização e Reforma Agrária – INCRA (National Institute for Colonization and Agrarian Reform) (Fearnside, 2001; MDA/INCRA, 2004). After establishment, farms in the settlement projects are understood as units of production from which settlers are able to earn their living by small-scale commercial farming, producing an agricultural surplus for the market. Furthermore, settlers have to fulfil environmental requirements to establish production fields on their plots (MDA/INCRA, 2004). Although a settlement project helps poverty alleviation and promotes social development (Leite & Ávila, 2007), its establishment is a process associated with many of the direct and indirect drivers of deforestation mentioned above (van De Steeg et al., 2006).

As is clear from the above, the causes and consequences of deforestation have been studied in much detail and over a range of scales and levels. However important, this impressive body of literature somewhat blurs the fact that there are unanswered scientific questions regarding more fundamental issues. In particular, questions about the location, rate, and magnitude of deforestation in general and as caused by settlement projects have not been addressed satisfactorily (Brandão Jr. & Souza Jr., 2006; Godar et al., 2012b; Pacheco, 2009b).

This issue is further complicated by the fact that deforestation is a far from unidirectional process, with secondary forest regrowth being recorded (Hecht, 2012; Nepstad

et al., 1991; Perz & Skole, 2003; Perz & Walker, 2002; Steininger, 1996). Despite the unquestionable environmental and ecological value of the primary forest, the secondary forests provide complementary conservation services as well, and biomass build-up is important for carbon sequestration (Barlow et al., 2007; van Breugel et al., 2011). When deforestation decreases and reforestation becomes the dominant process, it can be labelled as forest transition (Mather, 1992; Perz, 2007; Rudel, 1998; Rudel et al., 2005; Rudel et al., 2010; Walker, 1993).

Forest transition theory (FTT) provides a broad framework to analyse forest dynamics, i.e. deforestation and reforestation (Hecht, 2012). Defined as the spatial forest recovery of agricultural lands, FTT was designed to explain the dynamics of temperate forests at national level (Mather, 1992, 2001; Walker, 2012). However, several studies have also addressed the drivers and pathways involved in the dynamics of tropical forests at regional and municipal levels (Aguilar-Stoen et al., 2011; Perz & Skole, 2003; Rudel et al., 2002; Sloan, 2008; Walker, 2012). Reflecting some place-specific circumstances, the abandonment of agricultural lands, creating forest plantations, and the establishment of agro-forestry systems have been described as generic tropical forest expansion pathways (Meyfroidt & Lambin, 2011; Rudel, 2010; Rudel et al., 2002). In this context, it is important to realize that Brazil has a powerful, data-rich, and therefore very influential spatial monitoring system, which determines the main source of data on deforestation. This monitoring system uses a particular method based on satellite imagery which focuses on the disappearance of primary forest (INPE/PRODES, 2008). Consequently, relatively little attention has been paid to processes of forest regrowth and forest transitions in Brazil.

The multi-level approach taken in this paper (municipality, settlement, individual properties) enables a spatially and temporally detailed analysis of forest dynamics, using different sources of data and temporal information from space (satellite imagery). Data from interviews, workshops, participatory mapping, and census questionnaires are included to refine the understanding of forest dynamics at property level.

Some studies have noted a considerable discrepancy between what small farmers perceive as forest/non-forest areas and what satellite image classifications indicate (Wynne et al., 2007). As described by Homma et al. (1993), settlers have a detailed knowledge on types of secondary forest. With the aim of determining how local agents perceive forest dynamics at property level, this study has used a participatory mapping technique. The hypothesis is that the combination of both these perspectives (from space and from the ground) will provide a

more complete picture of forest dynamics and the historical role of agrarian settlements on this process (Brondízio, 2005; Perz & Skole, 2003; Rudel, 2005).

Summarizing, in order fully to understand forest dynamics, an analysis of direct and indirect drivers is needed, but needs to be preceded by a more elemental study that analyses rates and patterns of deforestation as perceived by different means. In other words, land cover change needs to be fundamentally understood before land use and land-use change can be addressed. This paper, therefore, has to be seen as part of a larger on-going study on the socio-economic and environmental consequences of the establishment of settlement projects in the Brazilian Amazon. Although the role of settlement projects in deforestation is part of the discussion, this paper does not attempt to detail land-use trajectories adopted by settlers after deforestation or even to identify direct or indirect drivers of deforestation; rather, the prime objective of this paper is to determine forest dynamics in areas where settlement projects were established under the ARP. The specific objectives include: (1) to determine the relation between the establishment of settlement projects and forest dynamics at municipal and settlement level over time from 1985 to 2010 at five-year intervals; and (2) to identify possible differences between local settlers' perceptions and classified satellite imagery.

3.2 MATERIALS AND METHODS

3.2.1 Study area

The Amazon biome is the largest continuous region of tropical forest in the world. Sixty-nine percent of this biome is within Brazil, whose government has defined it as the Legal Amazon[10] (Figure 3.1). The area covers approximately 5.1 million km^2 or 61% of Brazil's territory (INPE/PRODES, 2008) and is home to 24 million people or approximately 13% of the country's population (IBGE, 2011a). In 2011, the cumulative deforested area in the Legal Amazon amounted to approximately 750,000 km^2, or 18.7% of the forested area (INPE/PRODES, 2012). However, the annual deforestation rate has been decreasing over the past ten years from about 27,000 km^2 to less than 5,000 km^2, in 2012 with an average of about 12,000 km^2. Secondary regrowth corresponded to around 21% land cover of previously deforested areas in 2008 (EMBRAPA & INPE, 2011).

[10] Created by Law 1.806 of 06.01.1953, the Legal Amazon is a geopolitical concept used to plan and to promote the development of the region. It comprises the entire Brazilian Amazon biome and some transition areas bordering *Cerrado* (Brazilian savanna) (INPE, 2008).

Most deforestation in the Legal Amazon is concentrated along the so-called Arc of Deforestation (see Figure 3.1). This arc represents the areas with the highest rates of agricultural expansion and thus with the greatest pressure on the remaining forested areas (INPE/PRODES, 2008).

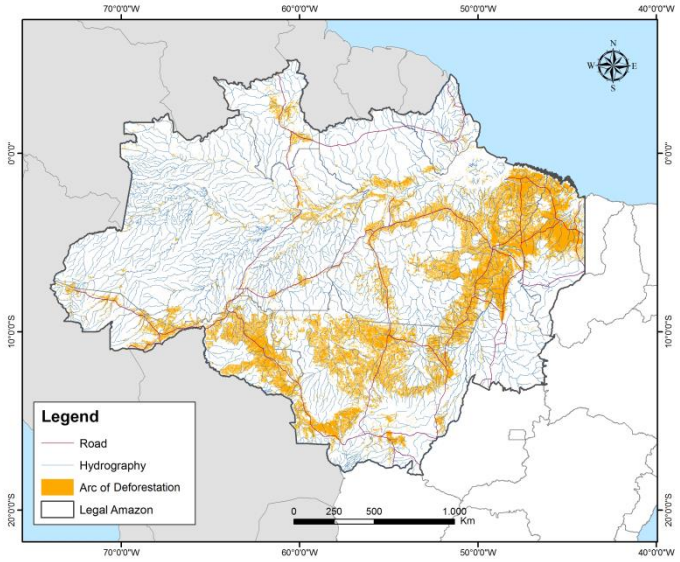


Figure 3.1 The limits of the Legal Amazon and the Arc of Deforestation – accumulated deforestation to 2010. Source: IMAZON, 2010; adapted by the authors

The study area was selected on the basis of two main criteria: the area should be within the Arc of Deforestation to contribute to understanding forest dynamics in general, and the area should encompass several settlement projects to contribute to specific understanding of forest dynamics in settlement projects. The municipality of Eldorado do Carajás presents all attributes of selection. It is located in the southeast of Pará State, covering about 3,000 km^2, where 21 settlement projects had been established by 2010. These settlement projects cover close to 2,000 km^2 or approximately 67% of the municipality. The first settlement project was established in 1988, three years before the start of the municipality, but Eldorado do Carajás is widely known in the context of social movements' struggle for land rights. It was the scene of conflict between military police and landless farmers, resulting of 19 landless people being killed in 1996. The immediate result was that the federal government settled a large number of families in Eldorado do Carajás. After the conflict, between 1997 and 2004, 16 new settlement projects were established in the municipality where 2,738 families were settled on about 100,000 hectares. The consequence of this massive and unplanned process has been the shrinking of the primary forest to less than 10% of the total

area of the municipality in 2011 (INPE/PRODES, 2012), with this being the major environmental problem in the past decade.

From the 21 PAs established in Eldorado do Carajás, five were selected for this paper: PA Canudos, PA Água Fria, PA Progresso, PA Moça Bonita, and PA Boca do Lago (Table 3.1). The selection of these settlement projects was based on (a) accessibility of the settlement projects and (b) geographical distribution over the municipality (Figure 3.2). All selected settlement projects had similar processes of formation, based on *direct action land reform* (DALR) (Simmons et al. 2010).

Table 3.1 General characteristics of the selected settlement projects

Settlement projects (PAs)	**Year of establishment**	**Total area (ha)**	**Total households**
Água Fria	1992	7,924	145
Progresso	1998	15,143	415
Moça Bonita	1999	3,411	92
Boca do Lago	2001	2,925	63
Canudos	2004	2,893	62
Total		32,296	777

Source: Fieldwork notes, classified images and INCRA

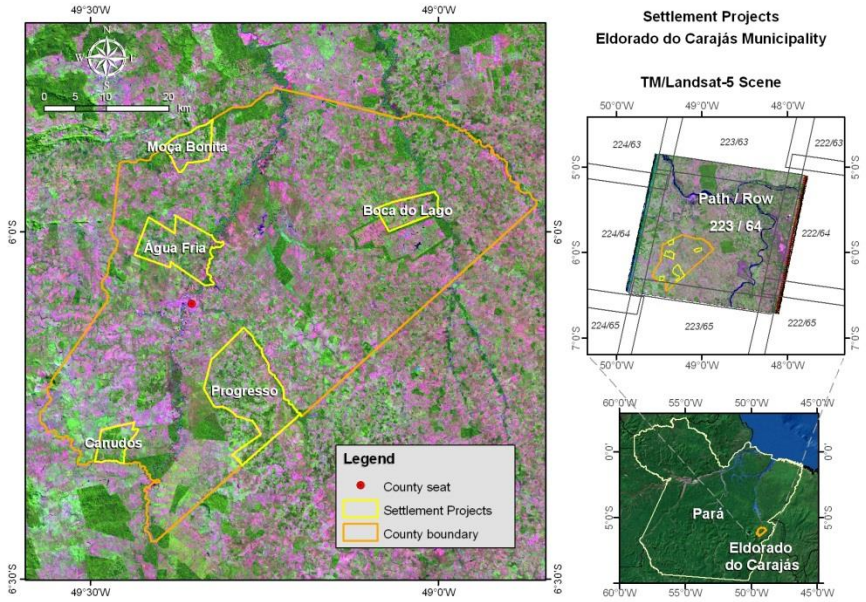


Figure 3.2 Study area location indicating municipality limits and the delineation of the settlement projects.

3.2.2 Data collection

3.2.2.1 *Image data processing*

The image data consisted of six multi-temporal series of TM images: scene 223/64 (path/row) Landsat-5/TM images, bands 3, 4, and 5, from 1985 to 2010, with one image for every period of five years. This scene covers the entire municipality of Eldorado do Carajás. The images were collected from INPE (National Institute of Space Research).

The geometric rectification was done by using control points from a 2006 USGS orthorectified image as georeference. The control points were distributed as equidistantly as possible in relation to unregistered imagery, facilitating the finding of reference points, and rectifying the images of the other years. The minimum root-mean-square error (RMSE) from the control point set was met for all images, using 2^{nd} order polynomial transformation which presented better results. Subsequently, a nearest neighbour resampling was done, using Universal Transverse Mercator (UTM) projection, zone 22 South, and South American Datum of 1969 (SAD 69). A statistical band analysis was used to select the bands containing the largest amount of spectral information through the correlation matrix. Based on the points collected in the field and additional fieldwork information, training data sets were created. A principal component analysis was performed to improve the classification process using a maximum likelihood supervised classification method. Both the initially generated classes and the resulting reclassification were based on the use of a false-colour composition of bands 3, 4, and 5. The accuracy of images classification was checked by using ground control points obtained from 75 ground GPS coordinates. The ground control points were randomly collected within pasture and forested areas (primary and secondary) in each sampled property. Global exactness, representing the simple percentage of exactness between the ground control points and the attributed class and the Kappa index that weights the exactness by the total number of observations, was used to measure the accuracy of the classifications. The results of the classifications and reclassified images resulted in two land cover classes (Figure 3.3).

Given the focus on forest and deforestation, a binary classification was adopted to estimate the forest cover area at municipal and settlement project levels as well as to compare settlers' perception of forest cover at property level:

Forest: primary or secondary dense tropical rainforest, and regeneration with dense shrub sub-thicket, developed canopy, represented in the same way as forest (*capoeira*);

Non-forest: set of herbaceous crops, arboreal-shrub dispersed (*juquira*), pixels that represent exposed soil, pasture, water, and urban spot.

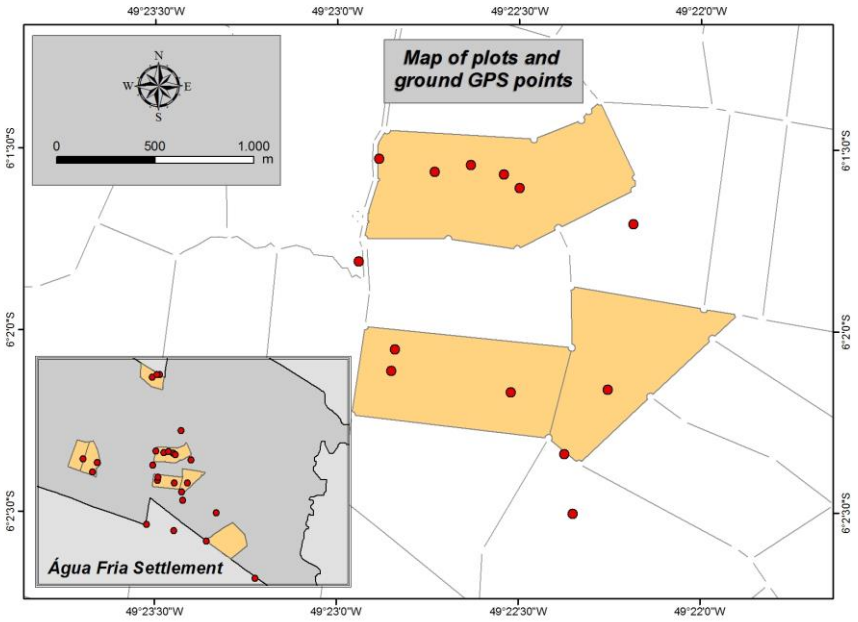


Figure 3.3 Example of cartographic base of a settlement project from INCRA and ground points collected in the field**.**

Settlement projects grids were obtained from INCRA. Pixel-to-pixel transition in cover classes (forest/non-forest) were compared for the temporal series of the classified images (McCracken et al., 1999).

3.2.2.2 *Settlers' perceptions: qualitative and quantitative survey*

In order to determine settlers' perceptions about forest/non-forest areas at property level, 24 households were randomly selected in the settlement projects, with some minor adjustments when selected farms could not be reached. Fieldwork survey was conducted in these households from June to August 2010. During this period, coordinates of current land-use areas (forest and non-forest) from each property were collected using GPS. The visit to each household took on average one day.

After the visits, one workshop in each selected settlement project was conducted with, at least, one participant from each selected household. Using participatory mapping techniques (IFAD 2009), the workshop aimed to obtain participatory maps depicting the spatial patterns of land use and land cover at property level (Wynne et al., 2007), representing the perception (2010) of the settlers on current forest and non-forest areas (Figure 3.4). Participatory maps provide a visual representation of people's perception of the land,

including depictions of natural–physical features and resources and socio-cultural features as known and perceived by local people (IFAD, 2009).

The extent of forested and non-forested areas within each property represented and quantified in the participatory maps was compared with the estimated forest cover in the classified images of July 2010. These comparisons allow for an analysis of the perception of the settlers and their families in terms of forest/non-forest areas and what satellite imagery indicate. Both statistical analyses F-test and t-test were performed.

Figure 3.4 Examples of participatory maps drawn by the settlers.

3.3 RESULTS

The images classification from Landsat-5/TM scene 223/64 in 2010 had an accuracy of 96% of global exactness and 95% in terms of Kappa index. This indicates that the resulting classification for 2010 had a very high quality. The accuracy of the other images was assumed similarly high.

3.3.1 Forest dynamics at municipal level

The forest dynamics throughout the period of analysis are visualized in Figures 3.5 and 3.6. Figure 3.5 shows the forest and non-forest areas, including deforestation and reforestation, in Eldorado do Carajás in 1985, 2000, and 2010. Figure 3.6 combines this information by showing the forest dynamics in the municipality from 1985 to 2010.

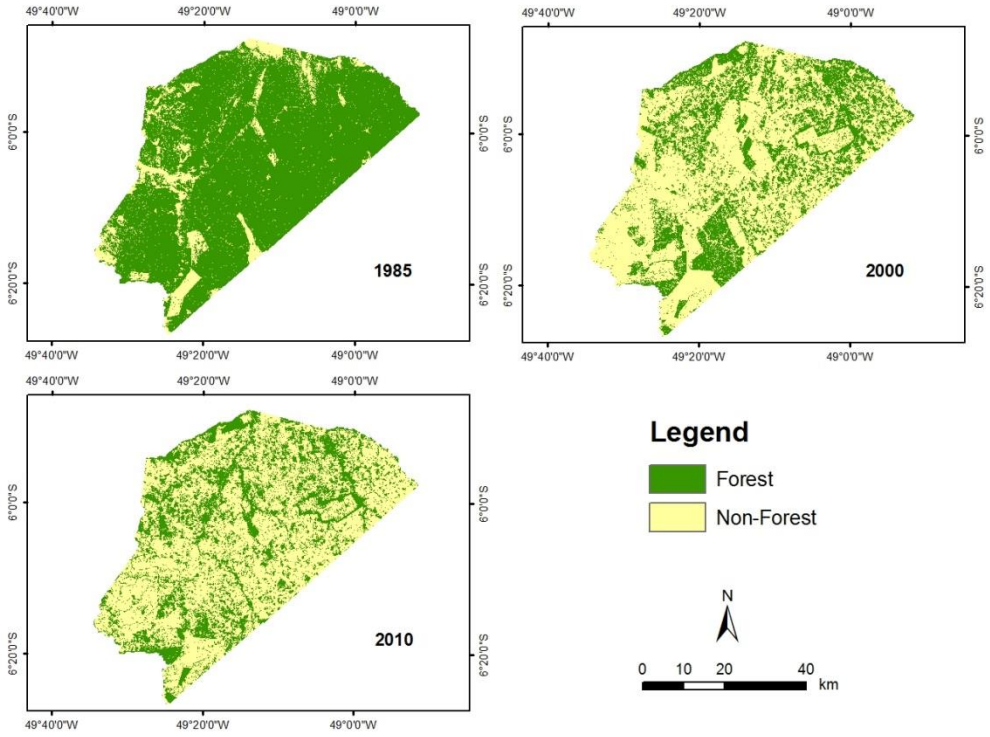


Figure 3.5 Binary classification of land cover changes in 1985, 2000, and 2010 in Eldorado do Carajás.

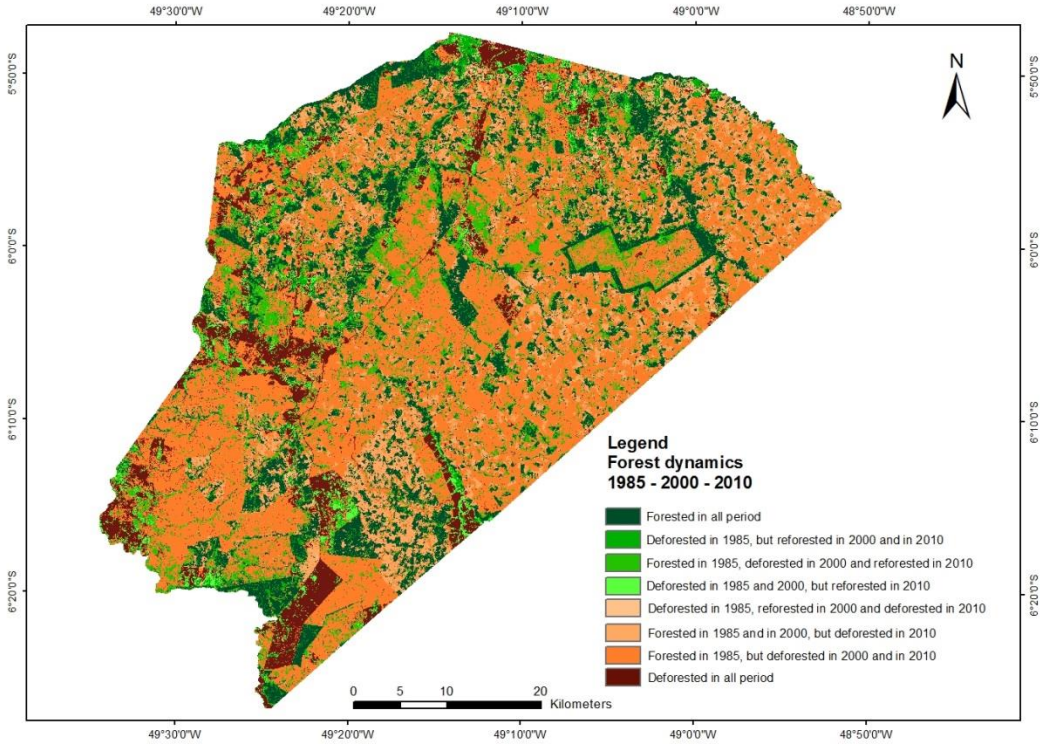


Figure 3.6 Information of three satellite imagery combined at municipal level.
Note: Colours indicate current state, with greenish colours indicating forest and brownish indicating non-forest. Lighter tones indicate an early change, darker tones a more recent change.

From 1985 to 2010, forest dynamics in Eldorado do Carajás were very high (Table 3.2). In 1985, before the establishment of any of the settlement projects, 14% of the area was deforested. In 1990, a year before the municipality of Eldorado do Carajás was formed, the deforested area was 25% of the total area, with two settlement projects established. The results show that deforestation peaked in 1995 (123,614 hectares or 42% of the total municipal area), when just five settlement projects were established in the municipality. From 1995 to 2000, the influx of people and new settlement projects virtually tripled following the conflict between the military police and landless farmers in 1996. Although the deforestation rate in this period (59%) was lower than in the previous periods, the absolute area of deforestation was the highest: 72,373 hectares of forest disappeared. In turn, between 2000 and 2005, the influx of people and new settlement projects peaked, but the deforestation rate in this period decreased dramatically to 5% or 9,180 hectares. In the last period of analysis (2005–2010), when the influx of people and number of settlement projects had stabilized, a slight secondary regrowth was observed, reaching a rate of 3% or 6,058 hectares of recovery.

Table 3.2 The evolution of forest dynamics and the establishment of settlement projects at municipal level

Year	Total Def. (ha)	Municipal area (%)	Def. rate (%)/ period	Def. /period (ha)	Settlement projects (N°)	Area of settlement projects (ha)	Families settled (N°)
1985	41,519	14	0	41,519	0	0	0
1990	74,152	25	79	32,633	2	52,315	996
1995	123,614	42	67	49,462	5	95,798	1,876
2000	195,987	66	59	72,373	14	165,983	4,026
2005	205,166	69	5	9,180	21	197,578	4,614
2010	199,108	67	-3	-6,058	21	197,578	4,614

Sources: Estimates based on classified images and data from INCRA

3.3.2 Forest dynamics at settlement project level

Forest dynamics between 1985 and 2010 for the five settlement projects studied in detail are presented in Figure 3.7. In general, almost all show similar dynamics, with an initial period of strong deforestation followed by a period of stabilization or slight recovery. The percentage of forest in all five projects in 2010 is slightly higher than the percentage of forest at municipal level. A more detailed analysis, however, reveals considerable differences between the settlement projects.

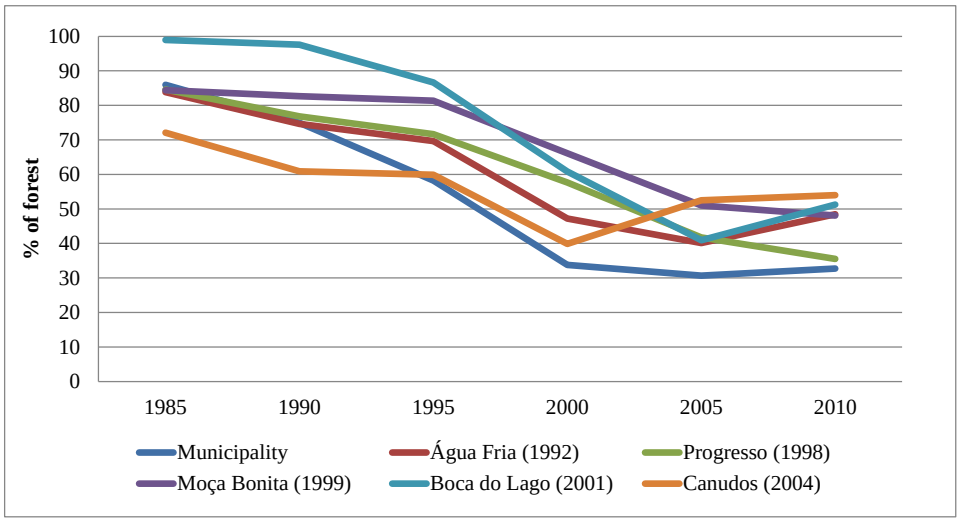


Figure 3.7 Forest dynamics at settlement projects relating to forested area and the year of establishment of the settlement projects.

In Table 3.3, forest dynamics are presented, given as the deforestation or reforestation (negative deforestation) rate relating to the previous period, taking 1985 as base year. Deforestation rates varied strongly over time and within PAs. The years 2000 and 2005 were particularly negative for the forest in most PAs, except Canudos in 2005. Whereas Canudos presented negative deforestation rates in two consecutives periods (2005 and 2010), Progresso and Moça Bonita presented positive deforestation rates throughout the study period. In turn, Boca do Lago presented high forest dynamics, starting with a 1% deforestation rate in 1985, peaking at 33% in 2005 and presenting a negative deforestation rate of -25% in 2010.

Table 3.3 Forest dynamics at settlement project level throughout the study period

Settlement projects (PAs)	**Year established**	**Total area (ha)**	**Forest (ha) 1985**	**Deforestation rate (%) between periods**					**Forest (ha) 2010**
				1990	1995	2000	2005	2010	
Água Fria	1992	7,924	6,642	11	7	32	15	-21	3,838
Progresso	1998	15,143	12,806	9	7	20	28	15	5,376
Moça Bonita	1999	3,411	2,879	2	2	19	23	6	1,640
Boca do Lago	2001	2,925	2,894	1	11	30	33	-25	1,499
Canudos	2004	2,893	2,085	16	2	33	-32	-3	1,561

Source: Classified images

Comparison of forest cover area in the year of the establishment of each PA with the forest cover area in 2010 (Table 3.4) reveals that only Canudos presented forest recovery (negative deforestation rate). On the other hand, Água Fria and Progresso presented the highest deforestation rate (33% and 44%, respectively), and Moça Bonita had 30%. Boca do

Lago had 10% deforestation throughout the period. Interestingly, both Boca do Lago with a small deforestation rate and Canudos with a negative deforestation rate were the last PAs established. This suggests a low correlation between the year of establishment and deforestation rate. This observed low correlation between establishment of PA and deforestation rate suggests the presence of other important agents of deforestation besides settlers.

Table 3.4 Comparison of forest dynamics in the year of settlement project establishment and forest cover in 2010

Settlement projects (PAs)	Forest (ha) in the year of establishment	Forest (ha) 2010	Rate of deforestation %
Água Fria	5,705	3,838	33
Progresso	9,540	5,376	44
Moça Bonita	2,354	1,640	30
Boca do Lago	1,667	1,499	10
Canudos	1,418	1,561	-10

Source: Classified images

3.3.3 Settlers' perceptions and the classified satellite imagery

Figure 3.8 shows some of the 24 maps produced by the settlers during the participatory mapping workshops and their respective binary maps of land cover classification.

Figure 3.8 Some participatory maps from the workshops and their respective classification from satellite imagery.

The overall appearance of the participatory maps indicates a similarity with the classified images in terms of the shape of the properties. Areas of forest are also well positioned in the participatory maps, considering what participants understand as a forest. During the presentation of the participatory maps in the workshops, the participants commented on what they consider more important in their properties and their feelings on forest. Most settlers pointed to the house, surrounding garden, pasture areas, and the cattle as their major achievements. Forest areas were mostly connected with the source of water and biodiversity.

The participatory maps were also used to derive estimates of the amount of forest and non-forest present in 2010. These were compared with the estimates of forest/non-forest areas from the classified images of the same year (Table 3.5).

Table 3.5 Settlers' perception and classified images areas

Settlers' reference	PA	Property size (ha)	Perception estimative (ha)	Classified images estimative (ha)
1	Água Fria	140	.0	59.9
2	Água Fria	50	.0	7.4
3	Água Fria	50	.0	17.0
4	Água Fria	65	.0	32.3
5	Boca do Lago	65	25.0	30.7
6	Boca do Lago	80	15.0	29.8
7	Boca do Lago	65	5.0	31.3
8	Boca do Lago	100	15.0	19.1
9	Progresso	20	.0	10.1
10	Moça Bonita	50	15.0	10.9
11	Agua Fria	45	15.0	36.6
12	Agua Fria	60	15.0	24.6
13	Moça Bonita	42	2.0	13.7
14	Moça Bonita	60	20.0	27.0
15	Canudos	47	.0	18.4
16	Canudos	45	.5	4.5
17	Agua Fria	100	35.0	19.9
18	Boca do Lago	35	2.0	32.1
19	Boca do Lago	55	30.0	40.1
20	Progresso	40	5.0	8.5
21	Progresso	20	1.0	9.0
22	Moça Bonita	35	20.0	16.6
23	Moça Bonita	50	22.5	14.3
24	Moça Bonita	71	20.0	12.6

Source: Classified images and participatory mapping workshops

The mean total area of the selected properties was 58 hectares (SE=5.44 ha). Results estimated the mean forested area from participatory mapping to be 11 hectares (SE=2.24 ha) or 18.9% of the total area, whereas the estimate of the mean forested area from the classified

images was 22 hectares (SE=2.65 ha) or 37.9% of the total area. If these results are compared, the average percentage of forested area in the satellite imagery is almost twice as high (92.2% higher) as the average based on the participatory maps. The methods i.e. participatory mapping and satellite imagery, were compared by *F*-test, resulting in no statistical difference between their variances ($p (F \leq f) = 0.4227$). Further, a *t*-test was performed to know whether the means from both methods were significantly different or not. The result shows that the mean forested area in the settlers' perceptions and from classified images was statistically different ($t (23) = -3.424$ $p < 0.05$).

3.4 DISCUSSION

3.4.1 Settlers' perceptions versus classified satellite imagery

The difference between the results from the image classification and settlers' perception of land cover can be explained as follows. In the early stage of land occupation, settlers cannot infer the quality of the soil under the forest, clearing the forest in a random way (Mather and Needle, 1998). With an increasing knowledge on the edaphic characteristics of the plot, the settlers tend to reserve some better areas to crop mainly beans, cassava, rice, or corn, establishing pasture in poorer areas. However, because they lack access to crucial inputs such as limestone and fertilizer (either because of high prices or the simple absence of suppliers) and other household limitations (labour and capital availability), the settlers tend to leave the better areas 'resting' for some years, forming diverse types of *capoeira*, aiming at natural soil recovery through organic matter and nutrient accumulation from the secondary regrowth (Brown and Lugo, 1990; Feldpausch et al., 2004; Homma et al., 1993). In other words, the settlers do not consider these 'resting' areas or *capoeira* as forest, but rather as potential areas to be cropped in the future, even areas with 10 years of forest regrowth. This finding corroborates the differences in forest transition in temperate and tropical forests, as suggested by Rudel et al. (2002).

Curiously, the amount of area perceived by the settlers as forest on their properties is very similar to the official rate of deforestation as calculated by INPE for the municipality, strengthening the suggestion that settlers do not regard regrowth as forest. The data in Table 3.5 provide further evidence for this statement. For instance, when asked how many hectares of forest he had on his property, settler number 1 answered zero, despite the classified images indicated roughly 60 hectares. For him, formations four, five, even 10 years' old are 'resting' areas. Moreover, settlers usually associate forest with the forest that existed on their arrival.

During the participatory mapping workshops, it was very common to hear statements such as 'since I arrived at the plot, I have never cultivated this forest area' or 'everything was forest when I arrived here, but now I have nothing of forest on my plot.'

3.4.2 Forest dynamics at municipal and settlement level

The establishment of settlement projects in the Brazilian Amazon has often been linked with deforestation (Brandão Jr. & Souza Jr. 2006; Fearnside 2008). There is evidence that, indeed, deforestation increases when a farm is established as a productive unit (de Espindola et al. 2012; Machado 2002; Moran et al. 2002). Agrarian reform usually aims at more intensive and productive use of land to provide local residents with food and a cash income (Futemma & Brondízio 2003). However, current deforested areas in the settlement projects cannot be attributed just to the settlers' activities over time, for a variety of reasons. First and foremost, a portion of the land occupied by INCRA settlements was deforested before these lands were expropriated, corroborating inferences from Pacheco (2009a) and Godar et al. (2012b). From Table 3.2, it is clear that deforestation in Eldorado do Carajás occurred mainly in the period 1985–1995, independent of whether the area was an official settlement project or not. In fact, just five settlement projects were established in Eldorado do Carajás during that time. Although deforestation was also intensive immediately after the establishment of the settlement projects in most cases (Figure 3.7), the settlers cannot be blamed as the sole, or even the most important, agent responsible for clearing forest areas in settlement projects.

A second, underlying factor that can contribute to explaining why deforestation in most of the settlement projects peaked in 2000 and 2005 (Table 3.3) is credit availability. The credit lines released in Eldorado do Carajás at that time were, mostly, intended for cattle purchase, inducing, initially, more deforestation for pasture formation. Since the goal of the ARP is to establish units of production in the settlement projects, stimulating agricultural intensification under the agro-ecological approach adopted in the areas already deforested might also alleviate the pressure on secondary forest (Altieri, 2002; Line Carpentier et al., 2000; Vosti et al., 2003).

3.4.3 Forest dynamics at municipal level – forest transition?

The results for forest dynamics at municipal level and at some settlement projects (Figure 3.7) show some similarity with the U-curve of forest transition theory (Rudel et al. 2005).

Independent of the agents at work, forest cover first decreases and then increases in the municipality and in the majority of settlement projects. This robust finding suggests that a forest transition is on-going in the last period of analysis. However, FTT was designed to be applied at national and regional levels (Mather 1992; Meyfroidt & Lambin 2011; Walker 2008, 2012), primarily because FTT concerns long-term changes in the extent of forests, not the short-term, cyclical changes in forest cover that occur when, for example, shifting cultivators clear land and then abandon it several years later (Rudel 2005).

Reforestation is part of a complex process, starting with deforestation, in a system that is still in development and that may be affected by several factors (Mello & Alves, 2011). In this paper, reforestation is a noteworthy process in the entire municipality, despite its fragmentation (Figure 3.5), with locally a very strong increase in forest cover. It is particularly strong after 2005, and thus a recent phenomenon in the municipality. Curiously, it happened after the stabilization of the number of settlement projects established and families settled in the municipality.

Although remarkable in the study area, reforestation at municipal level in the Brazilian Amazon depends on a complex interplay of institutional framings, political arrangements, and socio-economic contexts from international to local level (Hecht, 2012). For this reason, it is premature to confirm that forest transition is taking place in Eldorado do Carajás; reforestation has to be observed in future periods to assure the occurrence of forest reversal at municipal level. However, the fact that it has taken place independent of location and main agent of deforestation does point towards the existence of a forest transition at municipal level.

3.5 CONCLUSIONS

This paper has demonstrated the importance of studying forest dynamics rather than deforestation, especially to observe and better understand possible forest transitions at municipal level.

The forest dynamics analysis at municipal level showed a clear increase of forest in the last period (2005–2010), suggesting that a forest transition is taking place in Eldorado do Carajás. In this sense, FTT was helpful for analysing forest dynamics at municipal level. However, future studies in this municipality and in others with a high density of settlement projects are needed to confirm or refute this trend.

Independently, when the settlement projects were established, there were rather strong similarities in forest dynamics. Most of the settlement project areas display forest recovery in the last period of analysis (2005–2010), remarkably including the settlement project that was established last (Canudos/2004). Evidently, forest dynamics depend on conditions (that might be operating at other levels) other than settlement establishment alone. Further studies might combine forest dynamics with factors such as history of land occupation, infrastructure, settlers' background, credit access, technological assistance, and forest dynamics at settlement project and property levels. Although the diversity of drivers is not remarkable, the lack of correlation with date of establishment is.

Settlers do not perceive secondary regrowth as forests, even in areas that have been recovering for 10 years or more. These 'resting' areas can be understood in two ways. On the one hand, they will be the first areas to be cultivated again either when inputs are available or when there is need to increase production. Therefore, they can be regarded as areas under high risk. On the other hand, they can be seen as having a high potential of remaining forested. Agricultural intensification in areas that are already deforested might also foster conservation of the current secondary forest and stimulate new regrowth areas, and therefore strengthen forest transition in the municipality.

All in all, particularly the tension between an apparent forest transition (shown by satellite data) and a large 'resting' area that could be a ticking time bomb for forest recovery (shown best by combining satellite and settlers' perceptions) should be the topic of further studies on forest dynamics, combined with factors that determine forest cover change specifically in Eldorado do Carajás, but also more generally in other areas with high densities of settlement projects in the Brazilian Amazon.

Chapter 4

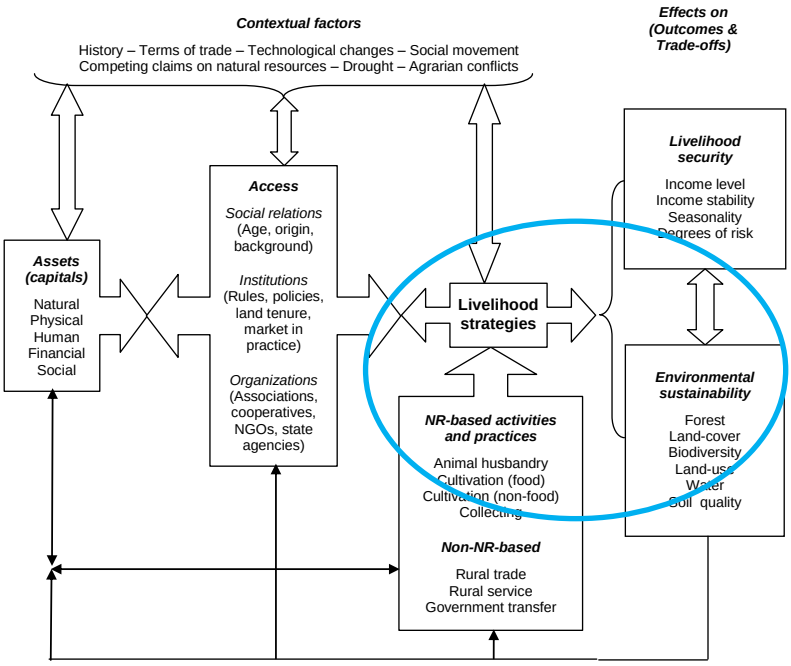
Wayfarer, there is no way,
you make the way by walking.
As you go, you make the way…

(lines from the poem *Proverbios y Cantares XXIX* by the Spanish poet Antonio Machado)

4 Analysing the influence of livelihood trajectories on forest dynamics at property level: Do livelihoods make a difference for forests?

Fábio Homero Diniz, Marjanke A. Hoogstra-Klein, Kasper Kok, Bas Arts

Following from Chapters 2 and 3, Chapter 4 investigates the effects of livelihoods on forest dynamics at property level. The main research question addressed in this chapter is: do settlers with different livelihoods produce different forest dynamics? To answer this question it was necessary to identify and describe livelihood trajectories and forest dynamics at property level, building upon the livelihood strategy clusters identified in Chapter 2. Theoretically, this chapter addresses the link between livelihood strategies and environmental sustainability over time, as indicated in the SLA framework, here interpreted in a dynamic way as livelihood trajectories and forest dynamics, respectively.



This chapter is in process for submission to a peer-reviewed journal.

Abstract

The objective of this paper is to analyse the influence of settlers' livelihoods on forest dynamics at property level. The assumption is that different livelihoods adopted by settlers in the Brazilian Amazon settlements might make a difference to forest dynamics. Several analytical steps were taken in the attempt to find patterns of livelihoods affecting forest dynamics over time in the study area. Content analysis of in-depth open-ended recorded interviews, fieldwork notes, and data from census questionnaires were used to cluster livelihood strategies in 2010 and to identify livelihood trajectories from the year of arrival onwards of each family at its property. Satellite imagery associated with household data were used to estimate land cover change at property level from 1985 to 2010, including the year of arrival. Various livelihood trajectories and forest dynamics driven by many factors were identified, but it was not possible to determine general patterns of effects. Although it was not possible to discern general patterns for several reasons, individual analysis provided insights about factors that have driven livelihood trajectories and their effects on forest dynamics.

Keywords: deforestation, reforestation, livelihood strategies, agrarian reform, southeastern Pará, Brazil

4.1 INTRODUCTION

Conversion of forest into agricultural land has been the most common land cover change in the Brazilian Amazon region in the past decades (Alves et al., 2009; de Espindola et al., 2012). Among several agents responsible for Amazonian forest conversion, such as colonists, big ranchers, and land-grabbers (Fearnside, 2008), the increasing number of settled families in official agrarian reform settlement projects has played a considerable role in the agricultural land expansion in the region (Caldas et al., 2010; de Espindola, et al., 2012; Diegues, et al., 1992; Marquette, 1998; Pacheco, 2009a; Van De Steeg et al., 2006). From 1964 to 2011, roughly 750,000 families were settled in the Brazilian Amazon in official agrarian projects established in different periods, occupying approximately 70 million hectares (INCRA, 2012).

Agricultural land availability is fundamental to settlers to provide their livelihoods by cultivating crops (annuals, perennials) and/or by establishing pasture to raise cattle (beef, milk) (Alves, et al., 2009; Fujisaka, et al., 1996; Marquette, 1998; Tourrand et al., 2004; Vosti, et al., 2003; Walker & Homma, 1996). In turn, the need for agricultural lands may imply negative effects on forest cover. As a result, settlers have been blamed as important agents of deforestation (Brandão Jr. & Souza Jr., 2006), even though some studies have indicated their minor responsibility for clearing the forest (Godar, et al, 2012b; Pacheco, 2009b). Moreover, secondary forest regrowth has been recorded in the Brazilian Amazon, making deforestation a far from unidirectional or linear process (Hecht, 2012; Nepstad et al, 1991; Perz & Skole, 2003; Perz & Walker, 2002; Steininger, 1996). Therefore, this paper broadens the analysis of forest cover change from a unidirectional deforestation perspective to forest dynamics, taking account of deforestation and reforestation.

Some studies have indicated that forest dynamics at settlement project level can vary tremendously, presenting a deforestation rate ranging between 30 and -30% from the year of establishment of the settlement projects to 2010 (Chapter 3). A possible explanation for these differences in forest cover might be associated with differences in livelihood strategies adopted by settlers at property level. Thus, the question here is whether livelihoods maintain and enhance, or deplete and degrade, the local natural resource base, interpreted as forest dynamics in this paper (Chambers & Conway, 1992).

Previous research has revealed that settlers with different livelihood strategies perceive different amounts of forest within their properties (Chapter 2). However, other studies demonstrate that there is a discrepancy between what local farmers perceive as forest and what satellite images indicate (Wynne, et al., 2007) (Chapter 3). Furthermore, the

perception of forest varies among settlers (Chapter 3), making it a problematic variable to be used in forest dynamics or even in deforestation analysis. Therefore, this paper associates household information on land cover change over time with satellite imagery to estimate forest dynamics at property level (McCracken et al., 1999; Wynne, et al., 2007). The possibility that reforestation is taking place on properties within settlement projects of the Agrarian Reform Program (ARP) opens up prospects of forest recovery in a large area in the Brazilian Amazon.

Livelihood strategies adopted by settlers can be identified and understood as snapshot events, where they are considered as a single moment rather than a phase (Zoomers, 1999); they are typically used in studies that identify typologies of smallholders and their relation to deforestation. For instance, Pacheco (2009b) identified seven typologies of settlers in two different areas in Pará State (Uruará and Redenção) in 2001 and 2002, respectively, based on farming systems and a wealth index. The author compared these typologies with the pace and magnitude of forest conversion from 1986 to 2001 in one area, and from 1986 to 2002 in another area, assuming that the colonists had not changed their livelihood strategies within households throughout the study period. Livelihood strategies, however, might also be dynamic and a moving target, changing according to opportunities and constraints faced by settlers over time (Zoomers, 1999). Thus, the concept of livelihood trajectories needs to be taken into account, referring to the changing ways in which individuals construct a livelihood over time (Bagchi et al., 1998). Therefore, livelihood strategies are interpreted as stable, whereas livelihood trajectories are understood as dynamic. Using the livelihood trajectory approach permits one to describe and explain the direction and pattern of livelihoods by examining household strategic behaviour (Bagchi, et al., 1998; de Haan, 2006). Moreover, understanding the processes and structures involved in livelihood trajectories opens up the opportunity to identify positive and negative factors and elements that can affect future livelihood development and forest dynamics.

Acknowledging the dynamics and complexities involved in both systems, i.e. livelihoods and forest dynamics, and building upon the sustainable livelihood approach (SLA), the objective of this paper is to provide a better picture of the influence of livelihoods on forest dynamics on properties within official agrarian settlement projects in the Brazilian Amazon. The fundamental question that emerges from this objective is: do settlers with different livelihoods produce different forest dynamics? In turn, the hypothesis suggested from this research question is that different livelihoods lead to different forest dynamics. Theoretically, this paper sheds light on a weak element of livelihood analysis as highlighted

by Scoones (2009): the necessity of analysing livelihoods as a dynamic phenomenon, reverberating across long-term change. Moreover, identifying the influence of livelihoods on forest dynamics would hopefully contribute to improving the processes and approaches used by policymakers and extension service agencies in order to achieve environmental sustainability in the region.

4.2 CONCEPTUAL APPROACH

People deploy livelihood strategies in order to achieve their livelihood goals, which are diverse and differ between regions, between households, and in time (Ellis, 1998; Scoones, 1998). Despite the usefulness of identifying and understanding the factors that have driven livelihood strategies adopted by settlers at a certain juncture, for Zoomers (1999), livelihood strategies can be studied only as an element of long-term development. The present author argues that households with similar combinations of practices, e.g. families that combine livestock and crop cultivation, can go in very different directions, and these livelihood trajectories just become clear over time. Thus, the livelihood strategies concept is supplemented in this study by the livelihood trajectories concept. The latter is considered an analytical concept, embedded in historical repertoires and in social differentiation, penetrating into the beliefs, needs, aspirations, and limitations of people's livelihoods (de Haan & Zoomers, 2005). The individual life history, understood as an individual's own story of changing livelihoods, constructed by himself – irrespective of whether the livelihood strategy choice is intentional or not – becomes the principal research unit in livelihood trajectory studies (Bagchi, et al., 1998; de Haan & Zoomers, 2005).

Rural livelihood trajectories in the Amazonian agrarian settlements shape and are shaped by the land use changes in the cycle of property formation, initially characterized by pulses of deforestation to establish crop and pasture areas (Brondízio, 2005). These pulses of deforestation include the direct conversion of forest to pasture or, more commonly, a longer trajectory beginning with an initial phase of establishing cropping systems and then pasture systems after a number of years (Alves, et al., 2009; Fujisaka, et al., 1996; McCracken, et al., 1999; Millikan, 1992). These developmental processes are associated with periods of establishment, expansion, and consolidation of land use activities (Brondízio, 2005). However, forest conversion is not a unidirectional activity towards deforestation as secondary forest regrowth has also been observed in the region (EMBRAPA & INPE, 2011) and within the Amazonian agrarian settlements (Chapter 3), characterizing forest dynamics.

Although rural livelihoods are associated with variation in the rate, extension, and direction of land use change (Brondízio, 2005), agricultural land availability is not the sole factor influencing livelihoods; rather, what people do for a living depends on their capabilities, their available assets, the activities necessary to make a living, and contextual factors, as identified by the SLA (Chambers & Conway, 1992). All of these factors are assumed to come together in the agrarian settlements to determine livelihood strategies and trajectories, influencing forest dynamics. For instance, credit availability can induce a farmer to allocate an area to a particular crop and, later, decide to abandon the area when the credit expires, resulting in an increase in secondary forest area (Brondízio, 2005). Therefore, the corollary of factors that drive livelihoods can induce deforestation or forest recovery.

4.3. DATA AND METHODS

4.3.1 Study area

The study area is located in southeastern Pará State, in the municipality of Eldorado do Carajás. This municipality presents all the necessary attributes for this study because it encompasses a large number of families settled under the ARP in the past years and environmental sustainability threats in terms of removal of forest cover (Chapter 3). Eldorado do Carajás covers about 3,000 km^2 and has 21 settlement projects. These settlement projects cover close to 2,000 km^2 or approximately 67% of the municipality. Several social movements were active in Eldorado do Carajás in the struggle for land rights, and it was the scene of a conflict between military police and landless farmers that resulted in 19 landless people being killed in 1996 (Chapter 2, section 2.3.1). The conflict created huge national and international pressure on federal government in relation to human rights and land rights. The immediate result was that the federal government settled a large number of families in Eldorado do Carajás. After the conflict, between 1997 and 2004, 16 new settlement projects were established in the municipality, where 2,738 families were settled on about 100,000 hectares. The majority of these settlement projects were established without planning. This unplanned process was said to be caused by a lack of appropriate policies, such as credit (first credit line was available in early 2000, when 4,026 families had already been settled for several years); technological assistance (this problem still existed at the end of the research period in 2010); infrastructure (roads, electricity, water); and market access (lack of roads), among others. The consequence of this massive process has been a struggle to achieve

livelihood security, with the concomitant threat to the area's environmental sustainability because the primary forest is shrinking.

From about 4,600 families settled in 21 settlement projects in 2010, 42 households were randomly selected in five settlement projects (PAs) in Eldorado do Carajás. The selection of these projects was based on (a) accessibility and (b) geographical distribution over the municipality (Figure 4.1).

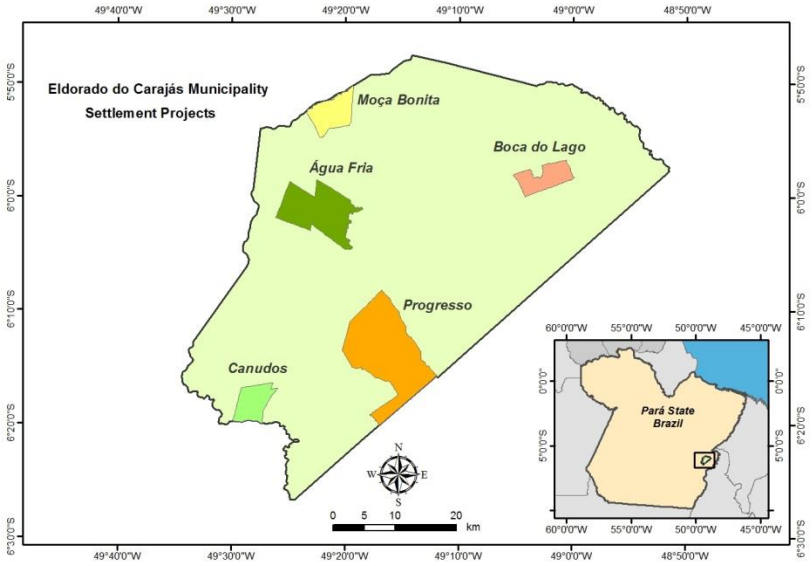


Figure 4.1 Case study municipality and selected settlement projects
Souce: INPE, 2011; INCRA, 2012

4.3.2 Determining livelihood strategies

A combination of quantitative (factor and cluster analysis) and qualitative methods (content analysis) was used to cluster the 42 households analysed in this paper according to the livelihood strategy adopted by settlers in 2010 (see Chapter 2). Among several parameters associated with land use shares, income composition, types of capital, mediating processes, and context, the resulting clusters were aggregated by the percentage of pasture, forest, and crop areas, source of income (gross income from cattle and off-farm activities), human capital (origin and background), and financial capital (milk production and herd size) in each property. The results indicated three different livelihood strategy clusters: 16 livestock-oriented settlers, 13 diversified-oriented settlers, and 13 off-farm-oriented settlers.

Livestock-oriented settlers base their livelihood on extensive livestock farming. The main source of income is milk production, whereas crop areas (cassava, rice, corn, and beans) are cultivated for home consumption. Their livestock background has driven most of them

into this cluster, reinforced by the available markets (milk and beef) and available credit for cattle breeding. Livestock-oriented settlers do not tend to depend on off-farm income.

Diversified-oriented settlers are characterized by a more diverse set of land uses and means to generate income. Although most income continues to come from livestock, settlers in this cluster have a significantly larger crop area than the other two clusters. Crop income derives mainly from the cassava flour and rice markets. Off-farm income such as pensions and the *bolsa familía* (family allowance) is also significant for this group. The majority of settlers in this cluster tend to come from a crop background, but accessible markets (milk and beef) and available credit for cattle breeding have driven the diversification observed in this cluster.

Off-farm-oriented settlers have the most off-farm sources of income. Although livestock (mostly milk production) still represents the main farming activity, the majority of income comes from labour on other farms, ownership of small shops, and labour in external organizations, i.e. the municipality or the iron ore company. Government transfers such as pensions and family allowances also play an essential role in their livelihood portfolios. Most settlers in this group have a crop background.

These three clusters are now used as endpoints to identify livelihood trajectories and forest dynamics in the period before 2010.

4.3.3 Determining livelihood trajectories

Individuals' life histories were compiled using in-depth open-ended recorded interviews. The activities and practices incorporated in the livelihood portfolio over time by each settler were coded using Atlas.ti software. A limited code scheme was used initially to code the main words used to identify a livelihood, and new codes were added to the list when necessary. This coding was refined, identifying details such as the main crops cultivated over time and the juncture at which settlers incorporated different breeds of cattle in their livelihood portfolio. Such detailing was crucial to identify later on the factors driving livelihood strategy choices over time. This coding was used to reconstruct livelihood trajectories from the year of arrival at the property until 2010 in a timeline table (Appendix). This timeline table describes the main livelihood activities and practices adopted by each settler throughout the study period, also indicating the percentage of forest cover at property level in the year of arrival and in the subsequent five-year periods after arrival.

Given the difficulty of retrieving information from human memory, the accuracy of responses in the interviews was improved by associating specific events with temporal and

thematic information, reconstructing the remembering process from higher-order events (Belli, 1998). For instance, questions in the semi-structured questionnaire, addressing what settlers did before and after they were settled, took the year of arrival at the property as the temporal and thematic event used for recalling their memories.

Further data and information about the households were obtained from official reports, fieldwork notes, and census questionnaires. Official reports describing the historical process of land occupation in the municipality as well as in each settlement project were collected from the National Institute of Colonization and Agrarian Reform (INCRA), the Pará Rural program, and the local extension service. Fieldwork notes detailing the land occupation process at property level were made during the visits to each property. The local extension service conducted the census in every household in the municipality between August and December of 2009. INCRA and the Federal University of Pará/LASAT compiled the questionnaires. Apart from these sources, other data and information about the historical process of land occupation, context, assets, and access, according to the sustainable livelihood framework, were obtained from open-ended recorded interviews with 12 key stakeholders from several local institutions, such as INCRA, Pará Federal University, extension services, dairy and beef companies, landless social movements, among others.

4.3.4 Determining forest dynamics at property level

The 42 participating properties were identified using INCRA's cartographic base for each settlement project (Figure 4.2). However, due to a lack of defined boundaries for some of the properties, a set of ground GPS coordinates collected at each property and descriptive information from INCRA and from settlers were used to vectorize these boundaries. From the set of GPS coordinates and a geo-referenced database CAD (Computer-Aided Design format) relating to the registered properties, procedures were adopted to import the boundaries into GIS as well as to implement necessary adjustments.

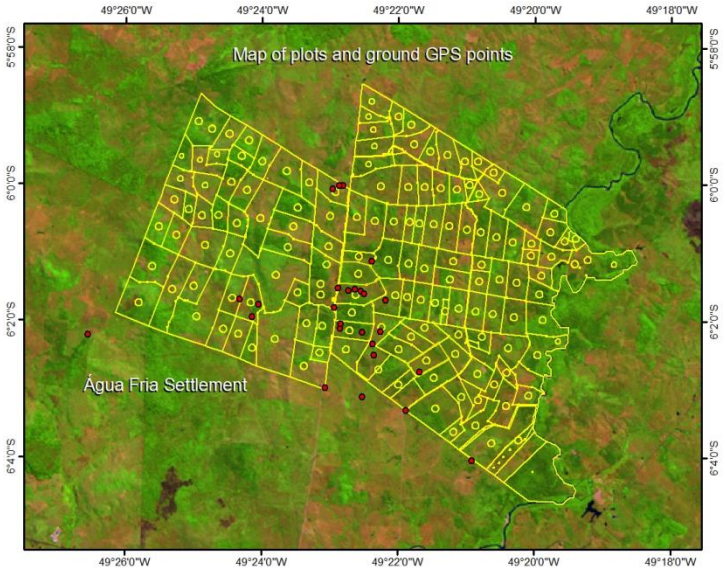


Figure 4.2 Example of INCRA's cartographic base for a settlement project and ground points collected in the field

Forest dynamics at property level were estimated from remote sensing and GIS associated with data collected from each household. We used the image data of multi-temporal series of six satellite imagery: scene 223/64 (path/row) Landsat/TM images, bands 3, 4, and 5, from 1985 to 2010, with one image for every period of five years. This scene covers the entire municipality of Eldorado do Carajás. The satellite imagery were downloaded from the National Institute for Space Research (INPE) website. Using a set of accuracy procedures, such as geometric rectification and supervised classification, images were classified and reclassified, resulting in the following two land cover classes:

- Forest: primary or secondary dense tropical rainforest, and regeneration with dense shrub sub-thicket, developed canopy, represented in the same texture as forest (*capoeira*);
- Non-forest: set of herbaceous crops, arboreal-shrub dispersed (*juquira*), pixels that represent exposed soil, pasture, water, and urban spot.

Data and information about land cover changes at property level over time were obtained from extensive open-ended interviews, describing the past land use at each point collected on the property, carried out between June and August 2010 with the head of the household. Each interview took on average three hours. In the cases where the year of arrival did not coincide with the five-year period of satellite imagery analysis, the exact amount of forest in the year of arrival was obtained by the interpolation method. The forest dynamics analysis examined the 42 settlers' properties following the year of arrival.

4.3.5 Determining the influence of livelihoods on forest dynamics

Three subsequent steps were taken to analyse the influence of livelihoods on forest dynamics in the study area. Each next step was necessary because no robust results had been found in the previous one, and a more complex type of analysis was subsequently followed (from simple relationships, to general patterns, to in-depth case studies).

In the first step, the aim was to identify a possible *relationship* between the three livelihood strategies identified in 2010 and forest dynamics. We assumed that the three livelihood strategy clusters identified in 2010 were stable, i.e. livestock-oriented settlers would execute the same set of activities and practices from the time of arrival until 2010, following other studies as already mentioned. In this approach, we also considered the individual forest dynamics in each cluster obtained from the satellite imagery from 1985 to 2010, at five-year intervals. The percentage of forest area in the exact year of arrival for each property was obtained by interpolation. For the year of arrival and 2010 (because at both times all settlers were already settled), we performed the Kruskal-Wallis test in the statistical software SPSS® version 19.0.0.1, seeking to evaluate the differences in forest cover area among livelihood strategy clusters at the time of households' arrival and the current situation. However, acknowledging that neither the livelihood strategy clusters nor forest cover were stable over time, we proceeded to the second step of analysis.

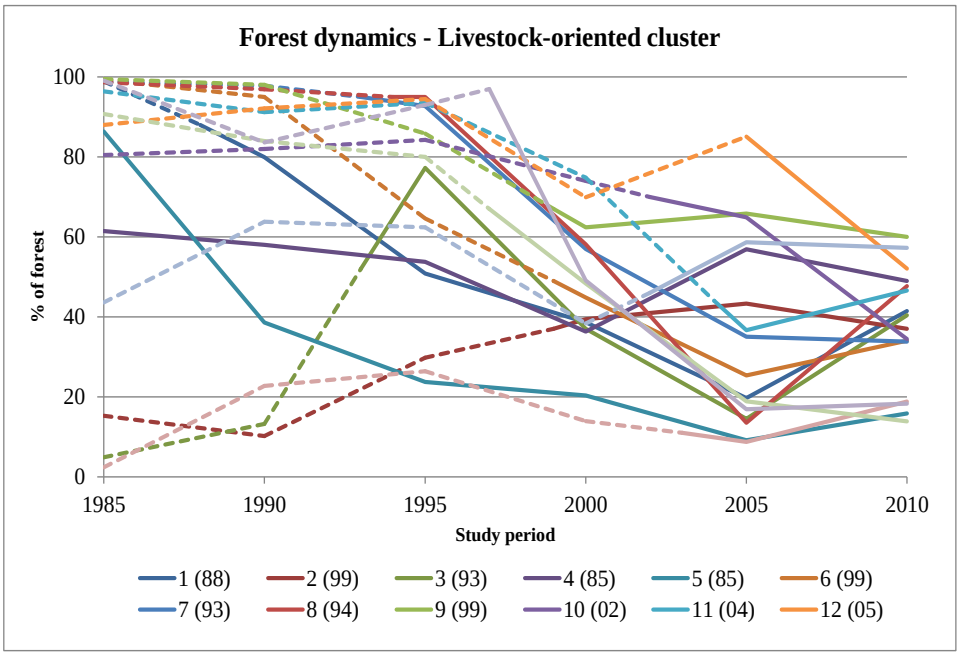
The second step aimed to identify *patterns* of effects of livelihood trajectories on forest dynamics. From the information in the timeline table (Appendix), livelihood trajectories were qualitatively grouped according to the main practices adopted by each settler, taking the year of arrival as the starting point. In turn, forest dynamics were obtained from the percentage of forest cover area at property level throughout the study period, represented by graphs and the information in Appendix. Thus, livelihood trajectory groups were compared with forest dynamics in an attempt to reach the objective of the paper.

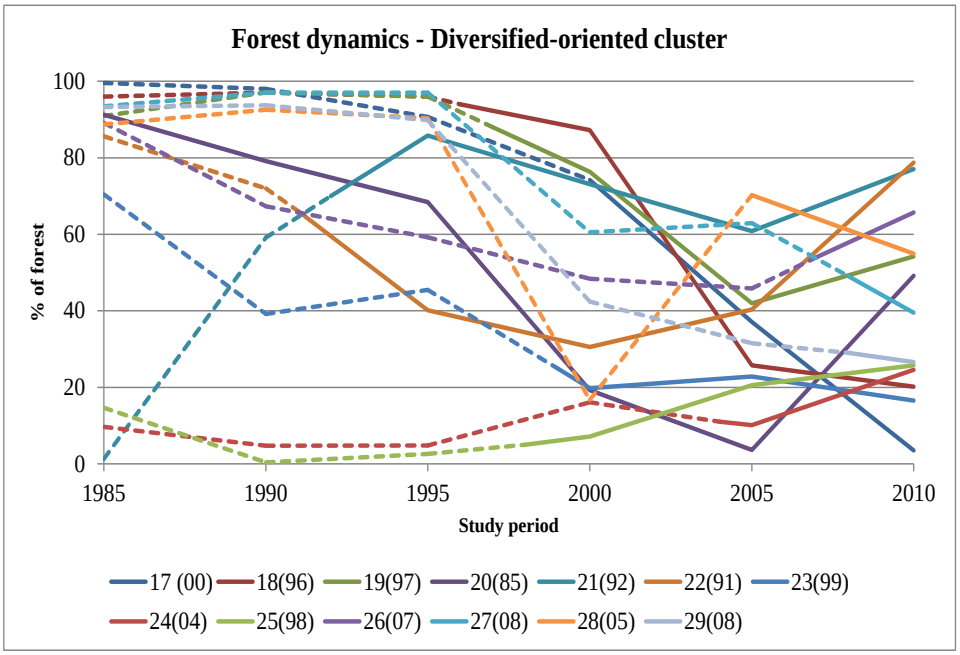
As no clear patterns appeared, the third step considered *individual* cases of livelihood trajectories and their influence on forest dynamics. The materials used in this analysis were the same as those used in the previous approach, i.e. the timeline table and the forest dynamics represented by forest cover area over time, obtained by satellite imagery analysis and household data. However, we now also considered the main factors presented in the livelihood strategy clustering, as described in section 4.3.2, which have potentially driven livelihood trajectories and, consequently, might also have driven forest dynamics in the study area. We did so to add relevant context, and thus potential explanatory power, to the case studies, which failed to reveal relationships and patterns.

4.4 RESULTS

4.4.1 Using the 2010 livelihood strategies and forest dynamics from 1985 to 2010

Results from the first step are shown in Figure 4.3. In relation to the livelihood strategy clusters identified in 2010, which are assumed to be a stable category over time, forest dynamics present a large variation among and within properties, independent of livelihood strategy adopted.





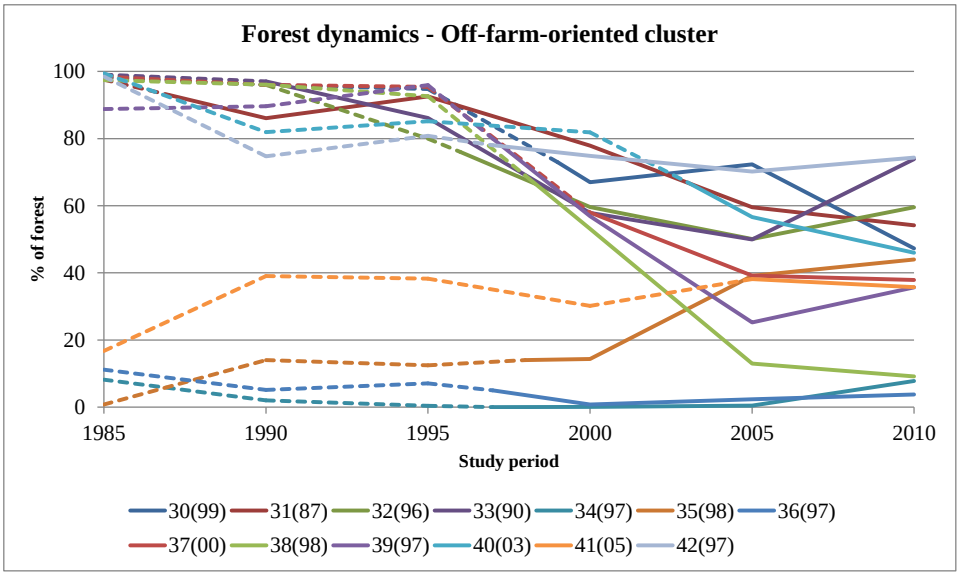


Figure 4.3 Forest dynamics within and among properties as per livelihood strategy cluster identified in 2010
Note: Each line represents a household throughout the study period. Dotted lines indicate the period before the arrival of settlers at the property; solid lines indicate the period from arrival until 2010. In brackets, the year of arrival.

The results of the Kruskal-Wallis test indicated no significant differences in forest cover areas on properties across livelihood strategy clusters in the year of arrival ($H(2) = 0.55$, $p > .05$). The differences in the proportion of forest cover among livelihood strategy clusters in 2010 were not significant either ($H(2) = 0.31$, $p > .05$). In other words, independent of the year of arrival, the amount of forest cover on their properties was not different among the livelihood strategy clusters; and independent of how they made their living in 2010, the amount of forest cover on their properties was not different among the livelihood strategy clusters.

This, however, does not mean that we can conclude that there is no relation between forest dynamics and livelihood strategy clusters. Firstly, comparing the percentage of forest cover among clusters at a particular juncture does not reflect forest dynamics, as we can see in Figure 4.3. Moreover, as a second argument, it is not only forests that are dynamic, livelihood strategies can also change over time under the influence of many factors, such as credit and market. Influenced by these and other factors, for instance, a settler classified as livestock oriented in 2010 might have had another livelihood strategy (e.g. crop-oriented) on arrival. Associated to this argument, arriving in different years (Figure 4.3), settlers have spent different amounts of time on their properties, e.g. some of them arrived 20 years ago, others just five years ago. For instance, depending on the year of arrival, settlers had or did not have immediate access to agrarian reform schemes, such as credit availability (mostly after the 2000s) and market access – both in terms of infrastructure (e.g. roads, bridges, electricity) and

existence (dairy plants were established from the mid-1990s). The combination of these and other factors might have influenced the livelihood strategy adopted and, consequently, forest dynamics. Therefore, the combination of all of these situations makes it difficult to make inferences about the influence of the livelihood strategies on forest dynamics. In conclusion, it is tricky to establish relationships between livelihood strategies and forest dynamics. Therefore, we moved to the second step.

4.4.2 Grouping livelihood trajectories and forest dynamics from 1985 to 2010

In the second step, we changed the focus from livelihood strategies (LS) to livelihood trajectories. We grouped the livelihood trajectory presented among settlers in accordance with the timeline (see Appendix). The initial livelihoods adopted by settlers were mainly cropping (21 or 50% of the total sample – Figure 4.4) or cropping and raising cattle (17 or 40% - Figure 4.5), whereas around 10% had started with other activities such as breeding cattle and off-farm labour. From the total sample, just one settler started with cattle (beef) and changed to dual-purpose cattle two years later, keeping his livelihood trajectory based on livestock since his arrival. See Figures 4.4, 4.5, and 4.6.

Ranging from three to seven years after arrival, settlers who had crops as their main initial livelihood strategy incorporated cattle raising in their livelihood portfolio (Figure 4.4). This expansion in their livelihood portfolio can be linked directly to three factors: the slash-and-burn itinerant agriculture within their properties, resulting in pasture expansion after two or three years, the pasture area already established in some properties on their arrival, and the available beef market in the region. They acquired a few head with their own financial resources, also usually entering into a partnership with a big rancher (*gado de meia*[11]). A few settlers (about 10%) opted to stop cropping and started to dedicate themselves to raising (beef) cattle only. The majority of them (76%), however, combined cropping and raising cattle. Sometime later, this group changed their portfolio again, as new opportunities arose. The main opportunity was the establishment of the dairy plant in the municipality, requiring a growth in milk production, and subsequently official credit for the purchase of cattle became available at the end of the 1990s. Twenty-five percent of them opted to increase their herds, still cropping small areas. Another group (13%) opted to concentrate just on the dual-purpose cattle, aiming at serving both markets (beef and milk). Around 63% incorporated other off-farm livelihood strategies in their portfolio, such as opening a small shop, pensions, and off-

[11] *Gado de meia* is a common practice in southeastern Pará, consisting of a farmer exchanging forage for the equivalent of half a calf or half the weight-earning capacity of an animal (Topall, 1992).

farm labour. Those who had maintained balanced livelihood strategies in their portfolio (60%) were identified as diversified in 2010. Otherwise, those who had off-farm strategies as their main livelihood (40%) were identified as off-farm in 2010.

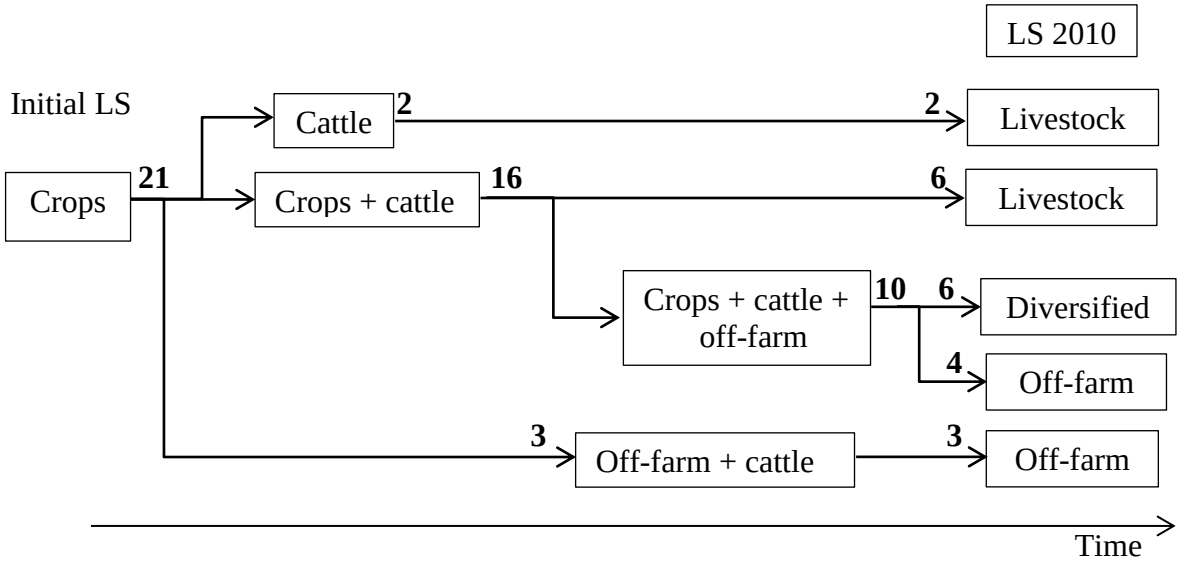


Figure 4.4 Livelihood trajectories initiated with crops on arrival
Note: The number of settlers in each livelihood trajectory is indicated within the relevant text box

Settlers with crops and cattle as their initial livelihood strategies also changed their portfolios over time, even though about 40% of them carried on these activities, enhancing their cattle breeding, resulting in the livestock cluster identified in 2010 (Figure 4.5). Others (18%), who kept the balance between cropping and breeding cattle, were identified as diversified in 2010. Twenty-four percent incorporated off-farm strategies in their livelihood portfolio, keeping the balance with cropping and breeding cattle, being also identified as diversified in 2010. About 12% of settlers incorporated off-farm strategies, mainly pensions, in their portfolio. They were identified as off-farm in 2010, together with those who abandoned all agricultural activities as their livelihood strategy, relying on off-farm activities (small market) as their means of making a living.

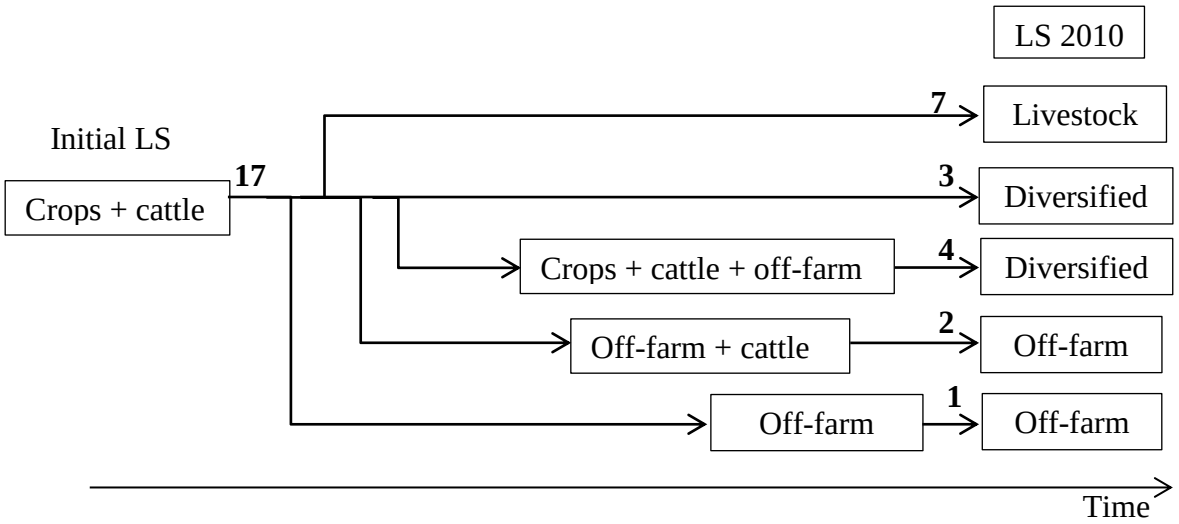


Figure 4.5 Livelihood trajectories initiated with crops and cattle on arrival
Note: The number of settlers in each livelihood trajectory is indicated within the relevant text box

A small group of settlers (7%) started with off-farm activities immediately on arrival (Figure 4.6). They worked for the mining company, the municipality, and as labourers on other properties.

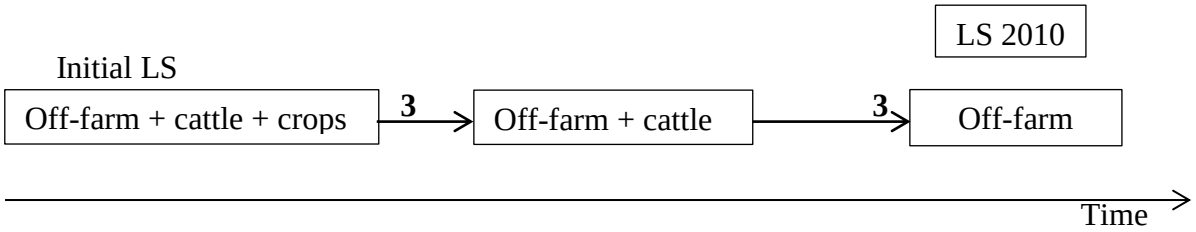


Figure 4.6 Livelihood trajectory initiated with off-farm activities, crops, and cattle on arrival
Note: The number of settlers in each livelihood trajectory is indicated within the relevant text box

Although insightful and useful to identify livelihood trajectories, this approach also shows how widespread the trajectories followed by settlers are. Among the participants in this research (42), 11 different livelihood trajectories were identified. For example, those who initiated with cropping (see Figure 4.4) subsequently followed four different trajectories, reaching three different livelihood strategies identified in 2010.

Combining this complex and diverse livelihood system with forest dynamics makes the analysis even more complicated. Among the top three trajectories in terms of the number of settlers, forest dynamics within and among those properties are very diverse, showing several trends as visualized in Figure 4.7. The picture becomes even more complicated when one considers that settlers arrived at their properties in different years, finding different percentages of forest cover at that time.

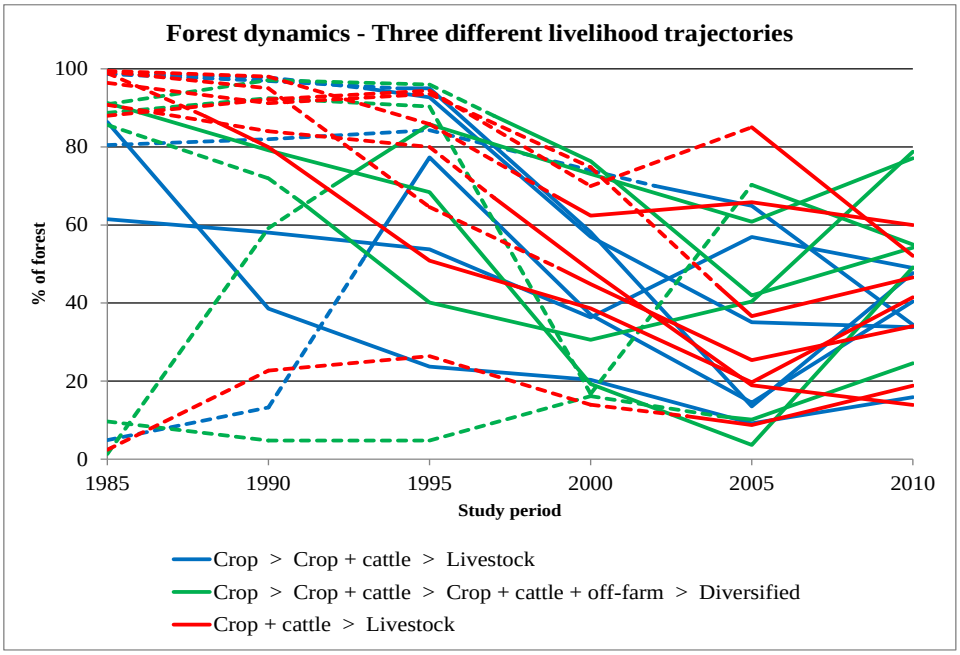


Figure 4.7 Forest dynamics within and among settler properties grouped in three different livelihood trajectories
Note: Different colours represent different livelihood trajectories. Each line represents a household throughout the study period. Dotted lines indicate the period before the arrival of settlers at the property; solid lines indicate the period from arrival to 2010.

All of these challenges and constraints, presented in this and in the previous section, lead to the conclusions that it is not possible to determine the influence of livelihood trajectories on forest dynamics because these are two complex systems interacting in particular ways in each household and at each property. However, some scholars such as Sallu (2010) have used individual cases to describe livelihood trajectories and environmental changes. Therefore, the alternative found to analyse the influence of livelihood trajectories on forest dynamics was to do so at individual level.

4.4.3 The influence of livelihood trajectories on forest dynamics: individual cases

Several particularities linked to livelihood capabilities, assets, and desires are intrinsic characteristics of each household, reflected in different livelihood trajectories. In an attempt to analyse the effect of these livelihood trajectories on forest dynamics at property level, some cases of individual trajectories were selected. The combination of the following criteria determined the selection of individual cases: different years of arrival, different livelihood strategy cluster as identified in 2010, and different forest dynamics. Using individual cases also permits the identification of some individual factors that influenced livelihood trajectories with possible consequences for forest dynamics.

Case 1 *– Mr Leoma, PA Água Fria, aged 70, living with his wife and one daughter. Livestock-oriented background. Property area 140 hectares*

Mr Leoma moved to his property in 1988 (Figure 4.8). He was a squatter/colonist, coming from Bahia (northeast state), looking for a better life for himself and his family. In the first year of occupation, he started to crop rice, beans, and cassava for home consumption and some cash income. His wife was in charge of a small vegetable garden and of chickens for home consumption (they did not raise pigs for religious reasons). He already had a small herd (30 head) of 'white' cattle[12] (beef cattle). His cattle grazed everywhere because there was no fence enclosing the property. In the second year, he cropped mainly the same area, just opening a small new area, making pasture areas after the harvest in both areas. In the third year, he opened a new area to cultivate the same crops again, mainly rice to sell. He drew attention to the fact that, at that time, INCRA was incentivizing settlers to deforest. They had to establish large cropping areas to be able to claim the rights to the land. They were even labelled as lazy if they did not cultivate an area compatible with the labour available in the household. From 1990 onwards, he did not crop the same area more than twice in succession because he perceived that the soil was very 'weak' in the second year of cultivation, with yields dropping dramatically – *mata* (forest) cropping areas produce satisfactorily for only one or two years because the soil fertility is low. He started to produce a small amount of milk from his beef herd in 1993. At that time, there was no local dairy plant, and it was not until 1996 that dairy plants started to buy milk in the region. In the interim, therefore, he sold milk house to house in Eldorado do Carajás, directly to consumers. He started to sell milk to a dairy plant after 1997, now slowly changing his herd to dual-purpose cattle (milk and beef). Although the settlement was officially established in 1992, he was only included on the beneficiary roll (*relação de beneficiarios*, see Chapter 2, section 2.1) in 1996. This means that he was officially recognized as a settler in 1996, after which he was able to access the agrarian reform schemes, such as credit and extension services. He got his first loan to invest in production in 2000. He used this loan to change the remaining beef cattle to dual-purpose cattle, aiming at improved milk production. He stopped cultivating any crops for sale in 2005 because he no longer had any 'fresh' land; the remaining secondary forest regrowth was still too 'young' to be cultivated again, and it was virtually impossible for him to establish crops in pasture areas without mechanization and inputs, such as limestone and fertilizer. He has kept a small area of cassava and corn for home consumption. Furthermore, he and his wife are in

[12] White cattle refers to Nellore cattle (*Bos indicus*), a common breed raised as beef in many parts of the country.

receipt of a pension from the federal government since 2005. In 2007, he hired a cowboy to take care of his herd.

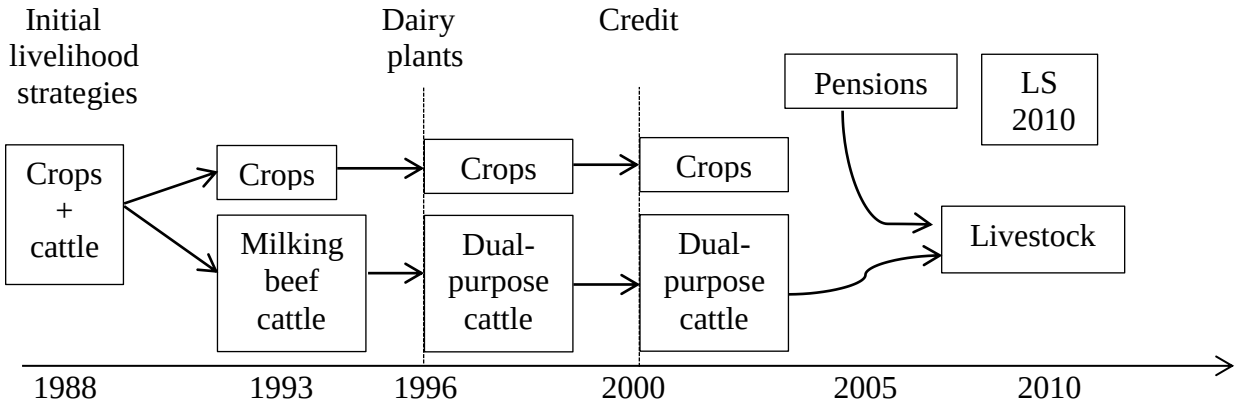


Figure 4.8 Livelihood trajectory, Case 1

The forest dynamics on this property have followed the sequence of livelihood choices and opportunities (Figure 4.9).

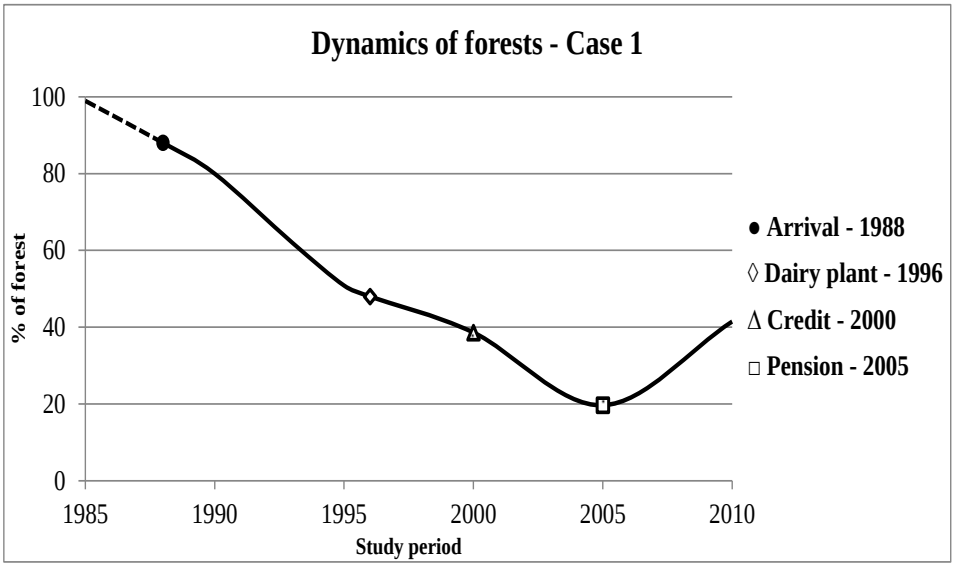


Figure 4.9 Forest dynamics, Case 1
Note: The start of the solid line indicates year of arrival.

When Mr Leoma and his family moved to his property, almost 90% of the area was covered by forest. In the first years, selling some cattle and cropping were his livelihood strategies, expanding the pasture area after one or two years cropping, as already mentioned. From 1990 to 1995, forest decreased dramatically, from about 80% to 50% of the property area, respectively, following the trend of cattle breeding as the main livelihood strategy. After credit became available in 2000, the forest area reduced intensively, almost 20% in a five-year

period. Interestingly, even though cattle production had become the main livelihood strategy in 2010, there was some forest recovery in the last period of analysis (2005–2010). Advancing age of the household heads, associated with their retirement, may have contributed to the abandonment of some areas of the property, with consequent secondary forest regrowth.

***Case 2** – Mr Cosfe, PA Boca do Lago, aged 56, living with his wife, two married sons. Crop-oriented background. Property area 88 hectares*

Coming from Ceará (northeast state), Mr Cosfe arrived at his property in 1993 (Figure 4.10). He was settled by INCRA, even though the settlement project did not start officially until 2001. He was a rural worker and came to the region to seek land where he could settle because no agrarian projects had been established in his homeland. He initially cultivated rice and corn to sell in the first years, in an area of about three hectares per year, using the slash-and-burn system. Cassava and beans were cultivated just for home consumption. He also raised chickens and pigs mainly for home consumption and for eventual sale. In the second year of production, he observed that yields were dropping in his cropping area. Then, he started to establish pastures in the crop areas, opening new forest areas to crop again, mainly rice for sale. In 2000, he started a partnership with a medium farmer, raising about 40 'white' cattle on his property. In his opinion, it was not a good deal for him because he had to wait a long time to earn a profit (about two years). With the profit from this activity, he bought some dual-purpose cattle and started to produce and sell milk to a dairy plant in 2004. From 2005 onwards, he has cropped corn, beans, and cassava just for home consumption. He got his first loan in 2006, when he improved his milk-producing herd. From that time, milk production has been his main livelihood strategy. The household has not had any source of off-farm income so far.

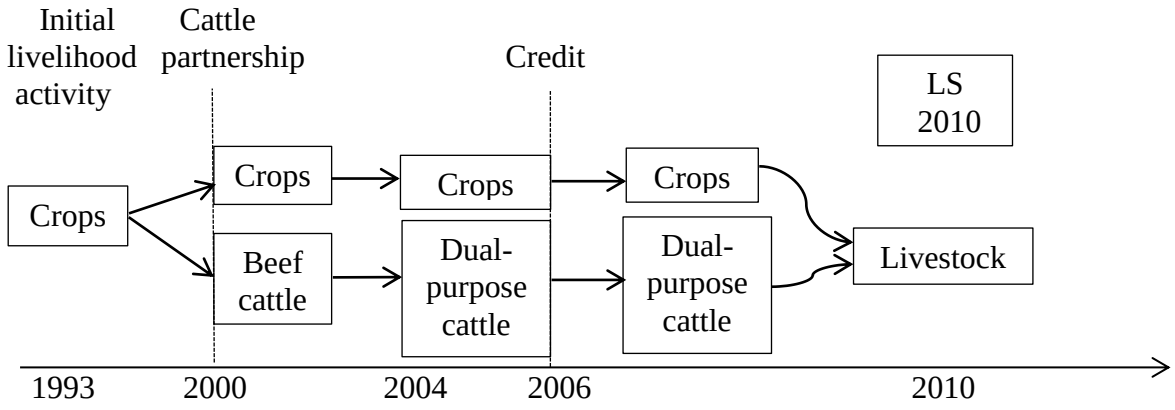


Figure 4.10 Livelihood trajectories, Case 2

Mr Cosfe's property was about 95% covered by forest when he arrived, with only a small opened area with a small shed (Figure 4.11). As his property had a lot of forest, he needed to open up new areas to crop. Consequently, in the first seven years, forest cover reduced dramatically from 95% to 57%. As pasture area became available, Mr Cosfe started the partnership, as mentioned, in 2000. Interestingly, after he started to sell milk (2004) and had access to credit (2005), forest cover started to stabilize, even though covering just about 35% of the property.

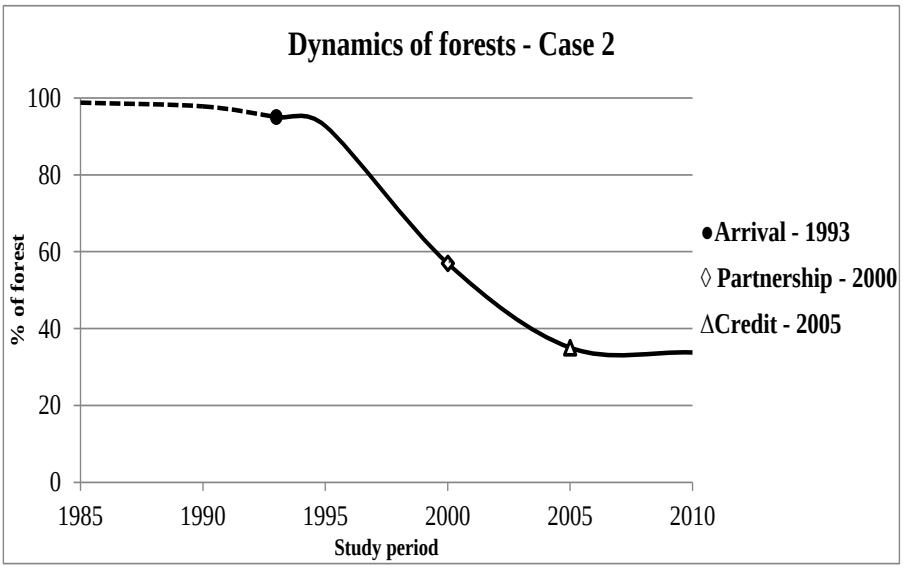


Figure 4.11 Forest dynamics, Case 2
Note: The start of the solid line indicates the year of arrival.

Case 3 *– Mr Henrica, PA Canudos, aged 45, living with his wife, one daughter, and two sons. Crop-oriented background. Property area 45 hectares*

Mr Henrica bought his property in 2004 from another settler (see Chapter 2), when he and his family moved from Maranhão (northeast state) directly to the property (Figure 4.12). Forests covered about 10% of the property on their arrival (this property was established in a former pasture area of an expropriated cattle farm). He started cultivating mainly cassava, producing cassava flour mainly to sell. He also cultivated rice and corn to sell and for home consumption. His wife kept a small garden with vegetables and some fruit trees. In 2005, he bought his first dual-purpose cows, starting to produce milk. He increased the number of his herd in 2007, when he had access to credit. He sold their milk to a local dairy plant. Due to the bad road conditions, however, the sale of milk to the dairy plant ceased in 2009, even though he was waiting for the resumption of sales in 2010. Moreover, he produced about 150 bags of cassava flour each year, keeping this production in pace with milk production. He also

raised chickens and pigs. This livestock has been important mostly for home consumption, but also to have a cash income in case of emergency. Two years after their arrival, he started to receive the governmental family allowance because it was difficult for him (with a crop background) to make his living in a non-forested area. From 2009 onwards, he was milking cows for home consumption (milk and cheese), concentrating his livelihood on marketing cassava flour, some calves, and the family allowance.

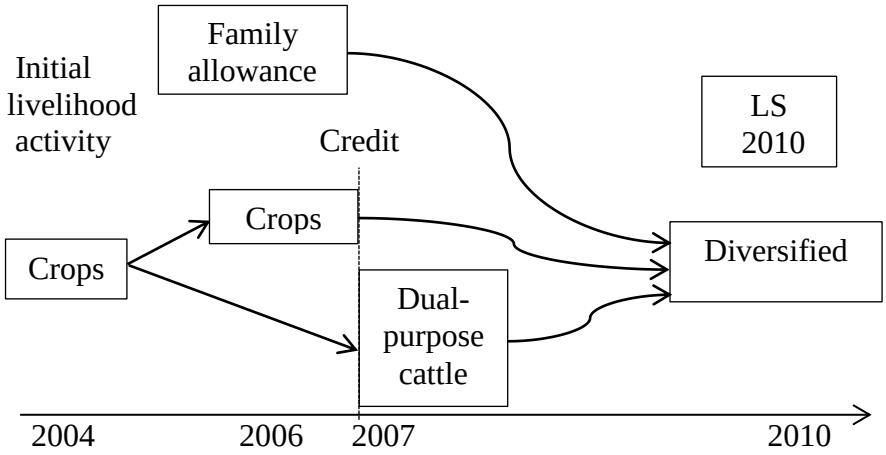


Figure 4.12 Livelihood trajectories, Case 3

Unlike the previous cases, Mr Henrica inherited a property with around 10% forest cover (Figure 4.13). Interestingly, his property displayed forest recovery after his arrival because he concentrated his (small) herd and crops on part of his property. Credit also seems to be positive for forest recovery in this situation.

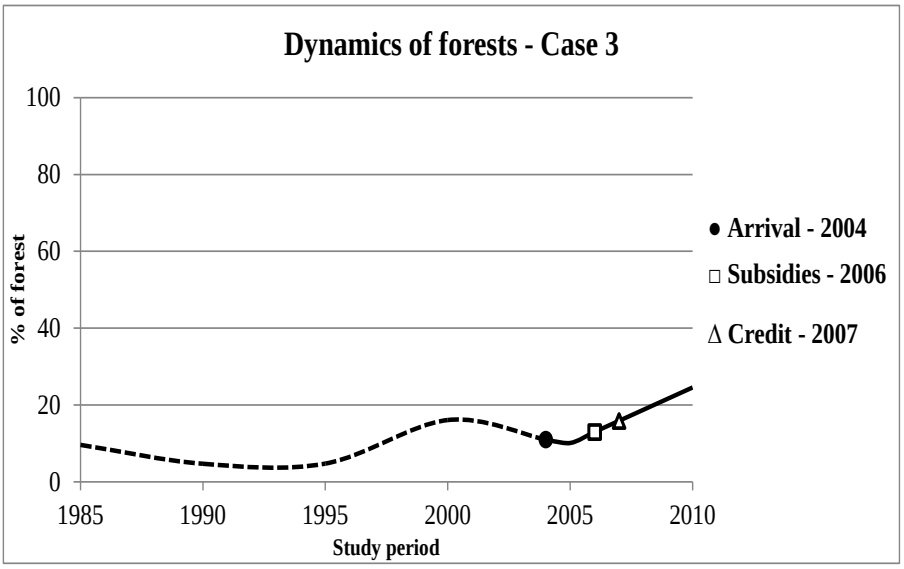


Figure 4.13 Forest dynamics, Case 3
Note: The start of the solid line indicates the year of arrival

4.5 DISCUSSION

The results suggest that the relationship between livelihood trajectories and forest dynamics is complex, involving many factors in different dimensions, such as temporal, social, economic, and environmental. Therefore, it was not possible to identify relationships and patterns of forest dynamics associated with a specific livelihood strategy, or to generalize the link between livelihood trajectories and forest dynamics, respectively. Rather, the results show that individual cases provide the best option to analyse the effects of livelihood trajectories on forest dynamics.

What people do to make a living has many dimensions and multiple causalities, taking different forms for different people in different environments and at different times. Because of this complexity, as pointed out by Chambers & Conway (1992), it is not surprising that livelihoods are not easy to measure or estimate, let alone take account of the temporal dimension. The same complexities apply to forest dynamics, given that deforestation in the Brazilian Amazon agrarian settlements is far from a unidirectional process over time.

Several factors, such as credit availability, market expansion, cropping, and cattle breeding that have shaped livelihoods in the Amazonian agrarian settlements have also been pointed out as underlying causes of Amazonian deforestation (Geist & Lambin, 2002; Margulis, 2004). On the other hand, (Perz & Skole, 2003) suggest that most forest recovery (60%–80%) in the region reflects abandonment rather than management, attributing secondary forest expansion to biophysical impediments (e.g. poor soils and degraded pasture) and social obstacles (e.g. capital scarcity and urbanization).

Although most scholars accept these generalizations about causes of deforestation and reforestation, looking at individual cases makes it possible to observe different ways in which these factors affect forest dynamics. For instance, credit availability has different effects on forest dynamics, as is shown in Figures 4.9, 4.11, and 4.13. After receiving loans, the first settler carried on with deforestation, whereas the second stabilized his forests, and the third induced forest recovery. Of course, the percentage of forest cover at the time of credit availability can also explain these trends: in the first two cases, forest cover at property level was around 40%, whereas in the last case it was less than 20%. The establishment of a dairy plant in the municipality in 1996, as shown in Figure 4.9, apparently did not change the deforestation process in the first case, and it might even have enhanced it. The same logic can be applied to the partnership observed in the second case (Figure 4.11): the deforestation process was already in place, but it may have been further stimulated by this economic

activity. The third case shows the diversity of activities upon which a livelihood strategy can rely. Depending on crop production and dual-purpose cattle as on-farm activities and the family allowance as an off-farm source of income, this household shows a remarkable forest recovery from the year of arrival to 2010. In this case, credit availability was positive for forest recovery. This can be explained by the fact that the settler did not have any cow on arrival, even though his property was almost entirely covered by pasture. In the following years, he bought some cows, but, even with the loan, the size of his herd was too small to use the entire pasture area. In this case, the abandonment of some pasture areas was the cause of forest regrowth.

Therefore, the complexities involved in both dynamic systems, i.e. livelihoods and forests, caused considerable difficulty in assessing the effects of the former on the latter, but their combined dynamics in individual cases provide a better picture of on-going changes in the Brazilian Amazon agrarian settlements.

4.6 CONCLUSION

This paper has drawn on the concepts of livelihood strategies and livelihood trajectories to analyse their effects on forest dynamics on properties within Amazonian agrarian settlements. A combination of primary and secondary data was used to identify three livelihood strategy clusters in 2010. Based on the same data source and on a qualitative analysis, 11 different livelihood trajectories were identified from the time of the settlers' arrival at their properties until 2010. Three different steps were taken to find relationships and patterns of effects of livelihood strategies and livelihood trajectories on forest dynamics. However, due to the complexity involved in these two dynamic systems, i.e. livelihoods and forest, it was not possible to determine relationships and general patterns of effects of the former on the latter. Nonetheless, analysis of individual-, household-, and property-level cases offers insights into factors, such as credit availability, market accessibility, and off-farm income (pensions and family allowances) that have driven both livelihood trajectories and forest dynamics. From these individual cases, it was possible to observe how general underlying causes of deforestation and reforestation interact in different ways at property level, implying deforestation in some cases and forest recovery in others.

Chapter 5

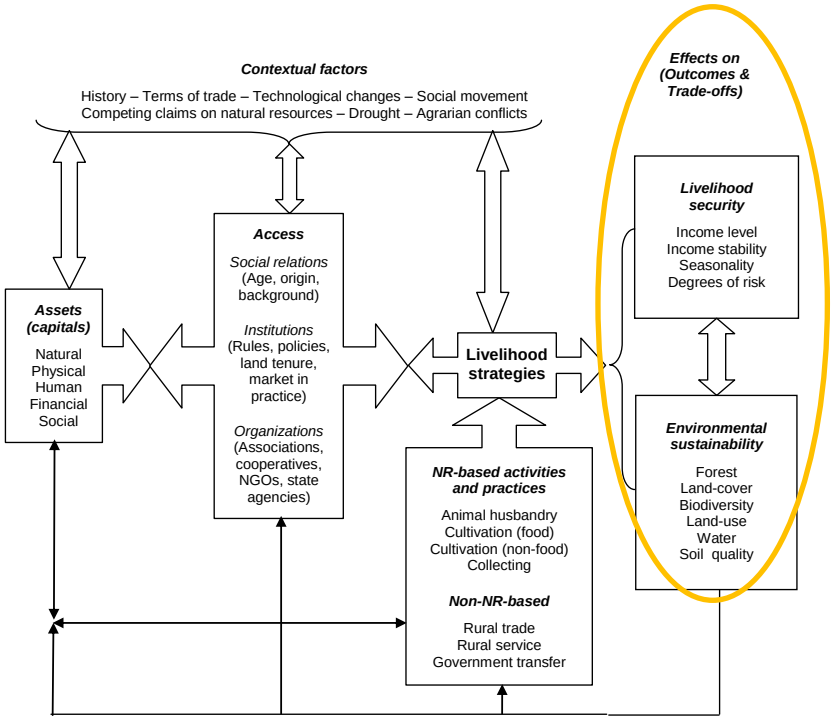
The future depends on what you do today.

(quotation by the Indian leader Mohandas K. Gandhi, known as Mahatma Ghandi)

5 Mapping future changes in livelihood security and environmental sustainability based on perceptions of small farmers in the Brazilian Amazon

Fábio H. Diniz, Kasper Kok, Marjanke A. Hoogstra-Klein, and Bas J. M. Arts

Chapter 5 addresses the question of the extent to which the human–environmental systems in Eldorado do Carajás, Brazil, deliver positive/negative outcomes in terms of livelihood security for the settlers and environmental sustainability in their plots and area. This question is addressed from a local perspective, incorporating settlers' current perceptions about the interaction of factors in the human-environmental systems that affect both these outcomes. Fuzzy cognitive maps were used to capture the settlers' current perceptions. Future analysis was then performed in an effort to give direction to possible policy measures that need to be taken to improve the livelihood and sustainability outcomes. Theoretically, this chapter addresses the outcomes and trade-offs as indicated in the SLA framework.



This chapter has been submitted to the journal, *Ecology & Society*.

Abstract

Deforestation is a widely recognized problem in the Brazilian Amazon. Small farmers play a key role in this process in that they earn their livelihood by ranching and farming. Many studies have addressed the link between deforestation and livelihood strategies adopted by small farmers. Most have focused on advanced monitoring systems, simulation models, and GIS approaches to analyse the interaction of both dimensions, i.e. livelihoods and forest cover change. Although the current toolbox of methods has proved successful in increasing our understanding of these interactions, these models and approaches do not consider small farmers' perspectives. On the assumption that local small farmers are agents of land cover change, understanding how they perceive their own situation is essential to elucidate their actions. The objective of this paper is to explore future changes in livelihood security and environmental sustainability as envisaged by local small farmers in the Brazilian Amazon. Previous livelihood cluster analysis of small farmers located in southeast Pará was integrated with fuzzy cognitive mapping to determine present perceptions and to explore future changes, using global scenarios downscaled to the local situation. Despite some differences in detail, the results indicate a strong trade-off between livelihood security and environmental sustainability in all livelihood systems, as identified by the settlers. However, different outcomes are obtained from the future analysis, depending on the livelihood strategy cluster. Policy effectiveness plays a crucial role in present and future livelihood security and environmental sustainability.

Keywords: mental model; fuzzy cognitive maps; deforestation; scenarios; Pará; Brazil

5.1 INTRODUCTION

Deforestation in the Brazilian Amazon region is a widely recognized problem, with multiple local, regional, and global negative consequences, e.g. biodiversity loss, soil degradation, and climate change (Demiranda & Mattos, 1992; Faminow, 1997; Fearnside, 2005; Hecht, 1993; Moran, 1993; Scouvart et al., 2008; Shukla et al., 1990). In 2012, the cumulative deforested area amounted to approximately 750,000 km^2, or 18.7% of the forested area of the entire region (INPE/PRODES, 2012). Although a substantial slowdown in deforestation from about 27,000 km^2 to less than 5,000 km^2 has been recorded over the past 10 years, the Brazilian Amazon forest remains under threat caused mainly by ranching and farming (Betts et al., 2008; Caviglia-Harris, 2004; INPE/PRODES, 2012). These activities represent about 67% of the deforested area, divided between pasture (62%) and annual agriculture (5%) (EMBRAPA & INPE, 2011).

Most of the deforestation has been attributed to large ranchers and large soybean producers (Godar et al., 2012b; Hecht, 1989; Rosa et al., 2012). Nevertheless, small farmers also have been named as agents of deforestation, since the use of agricultural land is fundamental to them in order to provide their livelihoods (Fujisaka et al., 1996; Marquette, 1998; Salisbury & Schmink, 2007; Vosti et al., 2003). Moreover, livelihoods are influenced by many other factors on different scales and levels, such as contextual factors and various types of capital (human, social, economic, physical, and natural), mediated by a large number of structures and processes (factors that either prevent people from gaining, or support them to gain, access to livelihood assets), such as rules, policies, organizations, state agencies, etc. (Chambers & Conway, 1992; Ellis, 2000; Scoones, 1998). Livelihood security and environmental sustainability are affected by the combination of all of these factors over time. Livelihood security means that people obtain and maintain access to essential resources to ensure their immediate and long-term survival, improving their livelihood condition over time (Chambers & Conway, 1992). In turn, environmental sustainability in the Amazonian situation is indicated by forest cover at property level (forest conservation implies better environmental sustainability in terms of biodiversity, soil conservation, and water availability) (Scoones, 1998). Thus, the trade-offs between livelihood security and environmental sustainability are a day-to-day reality, with possible implications for the future of the Amazonian rainforest (Hecht, 2012; Kirby et al., 2006).

Many studies have addressed the interplay between deforestation, livelihood strategies, agricultural activities, and other direct and indirect drivers (Brondízio, 2005; Line

Carpentier et al., 2000; Moran et al., 2002; Muchagata & Brown, 2003; Pacheco, 2009b; Salisbury & Schmink, 2007; Vosti et al., 2003). Studies of such human–environment interactions in the Brazilian Amazon have used manifold approaches, such as advanced monitoring systems, simulation models, and GIS approaches, to describe the relationships between deforestation and its drivers in time and space, be they biophysical, infrastructural, or demographic (Kirby et al., 2006; Laurance et al., 2001; Malhi et al., 2008; McCracken et al., 2002; Soares-Filho et al., 2006). The growing understanding of the relationships between deforestation and the complex web of drivers is essential to support effective policy and decision-making processes, contributing towards a more balanced interaction between forest cover and local people's livelihoods. Although the current toolbox of methods has proved successful in increasing our understanding of these relationships, methods that attempt to analyse human–environment interactions from the reality perceived by local stakeholders have been scarce in Amazonian studies (Humphries & Kainer, 2006; Muchagata & Brown, 2000; Posey, 1996; Soler et al., 2011). Yet, understanding how stakeholders perceive their own situation could be essential in understanding their actions. Therefore, they can and perhaps should be enabled to conduct their own analysis of their own reality (Chambers, 1994; Lynam et al., 2012). Moreover, recognizing and dealing with the pluralities of stakeholders' perceptions is currently considered a key aspect of effective natural resource management for the sustainability of human–environment systems (Jones et al., 2011; Rajaram & Das, 2010). On the assumption that local stakeholders are in many cases agents of landscape changes, their practice-based knowledge about reality is crucial in better understanding future changes in human–environment interactions, i.e. livelihoods security and environmental sustainability (Fearnside, 2008; Moore, 1979; Schiere et al., 2004).

Recently, mental model studies have emerged as an alternative approach to better understand stakeholders' constructions of how a system functions and what factors might be brought to bear on actual practices (Du Toit et al., 2011; Papageorgiou, 2011). A mental model refers to a simplified cognitive representation of reality, allowing people to interact with the world on the basis of their perceptions (Jones et al., 2011). Using factors and relationships between factors that underpin how people understand, filter, and process information about their realities, this approach seeks to elicit and analyse individual and group cognitive structures (Biggs et al., 2011; Craik, 1967; Du Toit et al., 2011; Jones et al., 2011). Moreover, mental models have the capacity to represent dynamic causes and effects of a phenomenon, enabling people to describe, explain, and explore changes in the system (Jones et al., 2011). Thus, this paper focuses on the exploration of future changes in human–

environment interactions, extrapolating from the current practical knowledge about livelihoods and forest cover change of the local stakeholders, i.e. small farmers, using tools and techniques to capture the cognitive representation (mental models) that these stakeholders have of their reality.

A range of tools and techniques, such as consensus analysis and ARDI (actors, resources, dynamics, and interactions), have been recommended as elicitation approaches to better capture and measure mental models in human–environmental interactions (Cheong et al., 2012; Lynam et al., 2012; Stone-Jovicich et al., 2011). Consensus analysis is designed to elicit fundamental knowledge structures among a given group of people, based on systematic individual interviews (Jones et al., 2011; Lynam et al., 2012; Stone-Jovicich et al., 2011). However, this method has limitations when used to explore complex domains with a high diversity of issues, such as this paper addresses (Stone-Jovicich et al., 2011). In turn, the application of the ARDI process provides an analytical perspective towards understanding the elements shared among people, but it does not provide a shared mental model (Lynam et al., 2012).

Other semi-quantitative approaches, such as fuzzy sets and fuzzy cognitive mapping, have been used as tools to capture the internal representation (mental model) of external realities of stakeholders, taking account of their perception of causes and effects in human–environment interactions (Cheong et al., 2012; Jones et al., 2011; Özesmi & Özesmi, 2004). In fuzzy cognitive mapping, the local stakeholders play the key role in building models that represent human–environment interaction, specifying factors and the causes and effect relationships between factors according to their practical knowledge about the system (Jones et al., 2011; Özesmi & Özesmi, 2004). The method captures a mental model that is not limited by exact values and measurements, and thus it is well suited to represent relatively unstructured knowledge and causalities expressed in imprecise forms (Isak, 2008). Being a dynamic tool, involving cause–effect relations and feedback mechanisms (Kosko 1986), fuzzy cognitive mapping can be used to uncover present realities that can be used to evaluate the effect of future livelihood and forest cover changes. In this context, it has been used as a semi-quantitative tool to indicate future changes, taking account of stakeholders' current perceptions and existing scenarios (Kok, 2009; Soler et al., 2011). Moreover, lately studies have indicated it as a potential tool to capture the complex dynamics of deforestation (Kok, 2009; Soler et al., 2011; Wulms, 2012) and also to analyse the functioning of different livelihoods and the vulnerability of these livelihoods to external changes (Murungweni et al., 2011). Thus, fuzzy cognitive mapping is appropriate to capture mental models of the complex

systems addressed in this paper, i.e. livelihoods and the environment in (de)forested landscapes. Moreover, capturing current mental models of complex systems can contribute towards exploring the potential impact of future changes. Such insight can help to give direction to possible measures that need to be taken today. This is more difficult to reach by studying current systems only. It is in this regard that fuzzy cognitive mapping is particularly powerful.

By considering present and future perspectives in human–environmental interactions, this paper seeks to contribute towards a systemic approach that can be used to structurally analyse trade-offs between two – often conflicting – goals, as presented previously: to enhance the livelihood security of local small farmers and to decrease the rate of deforestation. Therefore, the objective of this study is to use local small farmers' current perceptions of their realities to explore plausible future changes in livelihood security and environmental sustainability in the Brazilian Amazon. With fuzzy cognitive mapping as a tool, the specific objectives are: 1) to identify local small farmers' current perceptions of the factors affecting their livelihoods and the forest; 2) to analyse possible differences in perceptions dictated by their adopted livelihood strategies; 3) to explore plausible future changes in livelihoods and forests.

5.2 PRINCIPLES OF FUZZY COGNITIVE MAPPING

A fuzzy cognitive map (FCM) is a graphical interpretation of a system represented by cause–effect relationships among factors concerning a particular domain at a point in time (Groumpos, 2010; Langfield-Smith & Wirth, 1992; Kok, 2009). When developed using participatory methods, it provides a structured overview of the individual or group perception of reality. An FCM consists of factors joined by weighted arrows. The factors represent the key elements influencing the system; the arrows represent the causal relationships that exist among them (Kok, 2009). Relative weights are used to quantify strengths of causal relationships between the factors (Kosko, 1986). The weights of the interconnections can vary in the interval [-1,1], where the maximum and minimum values indicate a complete causal interrelationship among factors (Groumpos, 2010). All weights attributed to the relationships can be represented as a matrix; initial values of the factors can be represented by a vector indicating the relative change of all factors, which is initially set at zero (see Kok, 2009 for a detailed explanation). Subsequently, a change can be introduced to the system by assigning a non-zero value to one (or more) of the factors. This value indicates the strength of the change

introduced. For example, setting the value of a box 'Environmental Policies' at 0.5 indicates an increase in the influence of those policies that is half as strong as it maximally could be. This change will affect the state of all other factors to which it is related, directly or indirectly, as the effect ripples through the system. Eventually, all factors will have a (stable) new value. Mathematically, this process can be simulated by a simple matrix multiplication (e.g. in Microsoft Office Excel®), which yields a new change vector. This multiplication can then be repeated with the new change vector. This iterative procedure provides a dynamic[13] output of changing values of the factors. In turn, this allows an interpretation of the dynamics of the different factors relative to the other factors, or relative to other system descriptions (Kafetzis et al., 2010; Wulms, 2012).

In order to better illustrate how an FCM works, we have taken the example of an FCM applied to land use changes (Soler et al., 2011). Figure 5.1 represents a simple system, where F2 and F3 (e.g. number of national parks, or environmental policy) influence the amount of forest (F1). In turn, the amount of forest strongly influences F3. In this simple system, this negative feedback loop between F1 and F3 stabilizes the amount of forest in the area. Table 5.1 shows the matrix of all possible relationships between all factors. By giving F2 a value of e.g. 1, the value of F1 becomes 0.6 after one iteration and the value of F3 becomes 1 after two iterations, which in turn will decrease the value of F1 (-0.2), until stable values are obtained for all factors.

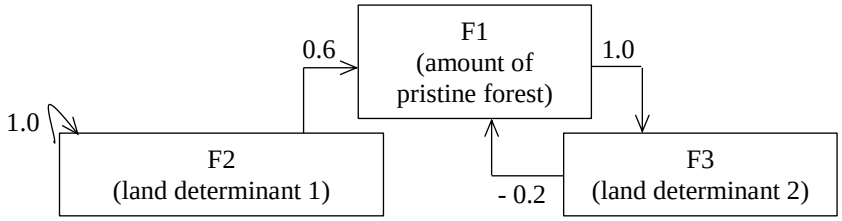


Figure 5.1 Graphical representation of a simple FCM, indicating the factors (F1, F2, and F3), the causal relationship, and weights between factors.
Source: Based on Soler et al., 2011.

[13] Note that we use the word 'dynamic', although strictly speaking we are evaluating the rippling effect of an introduced change, which mathematically is more correctly described as quasi-dynamic, which can lead to a quasi-stabilization of the system. Importantly, this implies that, in the dynamic output, the number of iterations cannot be replaced by time (Kafetzis et al., 2010).

Table 5.1 Tabular representation of all possible relationships between the three factors shown in Figure 5.1 for the initial iteration

	F1: Amount of pristine forest	**F2: Land determinant 1**	**F3: Land determinant 2**
F1: Amount of pristine forest	0	0	1.0
F2: Land determinant 1	0.6	1.0	0
F3: Land determinant 2	-0.2	0	0

Note: The absence of an arrow is represented by a zero in the table.

FCMs can represent a group's shared perceptions about a particular domain in a particular time (Langfield-Smith, 1992; van Vliet et al., 2010). They are helpful in understanding common or diverging priorities and perceptions of a same social group, but also sub-groups; in this case, small farmers with different livelihood strategies. Others have shown that the process of developing participatory FCMs is intensive and sometimes difficult for involved stakeholders (van Vliet et al., 2010). Yet, the same studies report how using the tool can lead to a process that generates a deeper understanding of the factors that affect the system under study, for scientists, policymakers, and other stakeholders alike. Here, we present a case study in Brazil, where we focus on the interactions between livelihood security and environmental sustainability in (de)forested landscapes.

5.3 METHODS

5.3.1 Case study

The case study is located in southeastern Pará State, in the municipality of Eldorado do Carajás (Figure 5.2). Covering about 3,000 km^2, the municipality has undergone an intensive process of deforestation in the past decades. From 1985 to 2010, forest cover shrank from about 85% to roughly 10% of the municipality's total area (INPE/PRODES, 2012). In 2008, pasture areas covered approximately 2,100 km^2 or 78% of the deforested areas in Eldorado do Carajás (EMBRAPA & INPE, 2011). The main agricultural activity in the municipality is cattle ranching, mainly milk production on small farms. About 67% of the municipal area is used by roughly 4,600 small farmers in 21 settlement projects under the Agrarian Reform Program (ARP). The ARP beneficiaries (called settlers or small farmers interchangeably in this paper) are landless rural workers and small squatters/colonists. The ARP aims to help poverty alleviation and to promote socio-economic development by redistributing large public areas and extensive areas held by private landholders to landless people so that settlers can earn their living by small-scale commercial farming, producing an agricultural surplus for the

market (Fearnside, 2001; MDA/INCRA, 2004). Consequently, agricultural land availability is fundamental to the settlers to provide their livelihoods; this is causing huge pressure on the forest. However, settlers also have to fulfil the requirements of the environmental law (Federal Law 12.727/2012 – Brazilian Forestry Code), which implies keeping 80% of the area of their properties covered by forest. Data and models to study the deforestation that has resulted from settlements are abundant (Brandão Jr. & Souza Jr., 2006), but studies on future analysis based on how settlers perceive their realities are hardly addressed. Yet, settlers are agents of forest cover change, and understanding their motives is crucial to grasp environmental change. There is, therefore, a need for a local study to understand the system as perceived through the settlers' eyes.

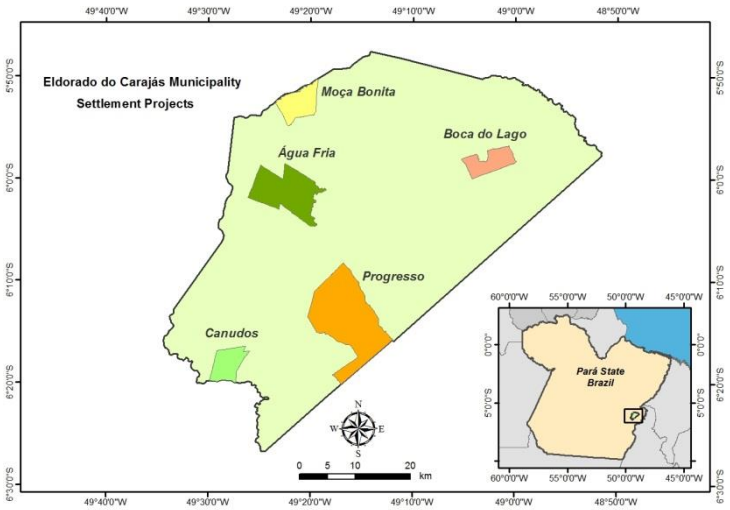


Figure 5.2 Case study municipality and selected settlement projects
Source: INPE, 2011; INCRA, 2012.

5.3.2 Characterization of the livelihood strategies of the local small farmers

This paper builds on a combination of quantitative (factor and cluster analysis) and qualitative methods (content analysis, open-ended recorded interviews) used to cluster 42 households in the same study area, by livelihood strategy (Chapter 2). Carried out in 2010, the study identified three different livelihood strategies: livestock-, diversified-, and off-farm-oriented small farmers. These livelihood strategy clusters are considered sub-groups of small farmers who share views about the factors relating to their livelihood security.

Livestock-oriented small farmers (16 households) base their livelihood on extensive livestock farming. The main source of income is milk production, with crop areas (cassava, rice, corn, and beans) cultivated for home consumption. A livestock background has driven

most of these settlers into this cluster, reinforced by an accessible market (milk and beef) and available credit for cattle breeding.

Diversified-oriented small farmers (13 households) are characterized by a more diverse set of land uses and means to generate income. Small farmers in this cluster have a significantly larger crop area than those in the other two clusters. Crop income is mostly based on the cassava flour and rice markets. Off-farm income, such as pensions and subsidies (*bolsa família*: family allowance) are also significant for this group. The accessible market (milk and beef) and available credit for cattle breeding have also driven the diversification observed in this cluster.

Off-farm-oriented small farmers (13 households) have the most off-farm sources of income for their livelihood. The majority of income comes from labour on other farms, ownership of small shops, and labour in external organizations. Government transfers such as pensions and family allowances also play an essential role in this livelihood cluster.

5.3.3 Constructing the fuzzy cognitive maps

In order to obtain the FCMs, three workshops were conducted in Eldorado do Carajás in 2011 with the small farmers from the three livelihood strategy clusters separately. Not all small farmers from the three clusters participated in the workshop, even though they were all invited. Other commitments prevented the participation of all. Ultimately, the number of participants in each workshop was: 11 from the livestock, eight from the diversified, and seven from the off-farm cluster. On average, each workshop took three hours.

The workshops started with an explanation of the meaning of FCM. It was explained to the participants that the aim of each workshop was to construct a cognitive map with factors affecting, positively or negatively and directly or indirectly, livelihood security and environmental sustainability in their perception. After that, to speed up and systematize the process, we suggested general level factors that took into account many cause–effect factors that potentially affect livelihood security and environmental sustainability (Table 5.2). These general factors were obtained from previous individual open-ended interviews with the same workshop participants. In the workshop, the participants were also free to suggest other factors or general factors to be included in, or excluded from, the FCM. All factors and general factors considered in the analysis were agreed by consensus among the participants.

Together with the relationships made between factors, the quantitative weights of these relationships were also provided. To facilitate the discussion on the exact weights, we initially offered the participants four categorical weights, i.e. very strong, strong, weak, or

very weak. These categories were associated with numerical weights (+/- 1.00, +/- 0.75, +/- 0.50 and +/- 0.25). However, the participants in all three workshops quickly started to refer to the numerical weights.

Table 5.2 General factors and related factors agreed on in the workshops

No.	Factors
F1	Crop production and consumption – this group of factors represents all kinds of crops cultivated within the property for sale or home consumption, mostly cassava, rice, corn, beans, fruits, etc.
F2	Livestock production and consumption – this group of factors represents all kinds of livestock breeding within the property for sale or home consumption. Livestock are mostly dual-purpose cattle (milk and beef) and small livestock such as goats, chickens, and pigs.
F3	Technological innovation of production – this group of factors includes all technological innovation available to increase livestock and crops yields, such as artificial insemination, cultivation of fodder crops (e.g. sugar cane), cooler bulk tanks to store milk, etc.
F4	Policy effectiveness – this group of factors relates to agrarian policies (credit, technological assistance, improvement of infrastructures) and environmental policies (Forestry Code requirements) and the extent to which they achieve their ends.
F5	Intensification of land use – this group encompasses the intensification of current crops and livestock, increasing productivity (higher yields in smaller areas).
F6	**Livelihood security –** this means that people obtain and maintain access to essential resources to ensure their immediate and long-term survival, improving their livelihood condition over time.
F7	Infrastructure and support expansions – this group of factors encompasses infrastructural improvements at local level, such as new roads, bridges, electricity, drinking water, hospitals, schools, and social organizations at settlement project level.
F8	Markets and prices – this group of factors includes market access in terms of the existence of the market and of physical accessibility (roads). This item also includes the price of products and its variation over the year (e.g. milk price variation in the rainy and dry seasons).
F9	**Environmental sustainability –** this group is basically indicated by forest cover at property level (forest conservation implies better environmental sustainability in terms of biodiversity, soil conservation, and water availability).
F10	Reduction of off-farm labour – this item indicates whether people are making their living from on-farm activities or whether they depend on off-farm labour for livelihood security.
F11	Migration – this item refers to the necessity for people to leave their properties to go to other regions for a couple of months to make their living.
F12	Intensification of drought – this item means the increase in dry periods per year (the current dry season is from May to September).
F13	Pensions and subsidies – this group encompasses social welfare programs from the government such as pensions (on retirement or in the event of illness) and subsidies (*bolsa família* – a specific program of cash transfer for poor people with children).

Note: The target factors (livelihood security and environmental sustainability) are in bold.

The outputs of the workshops were three 'raw' fuzzy cognitive maps, one for each livelihood strategy, representing the participants' current perceptions of the factors affecting their livelihood security and environmental sustainability (Figure 5.3).

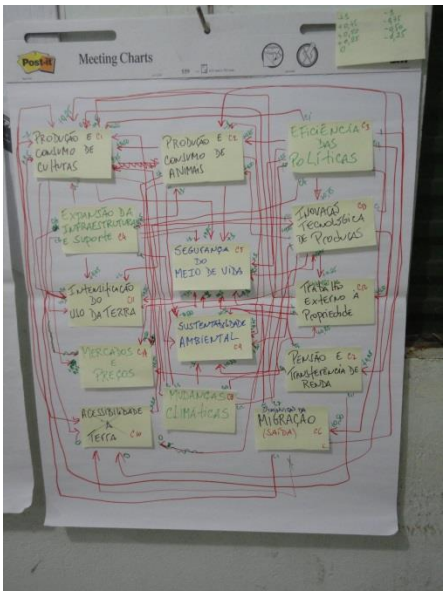


Figure 5.3 Example of an FCM obtained in the off-farm workshop

5.3.4 Post-processing the fuzzy cognitive maps

The FCMs were post-processed in three steps. Firstly, all factors and their respective relationships from each map obtained in the workshops were listed. After that, the weights of the relationships were slightly changed. The main reason for this was that the initial dynamic results proved to be very instable. As indicated in Table 5.3, it was decided to change the values of the classes used. In particular, the 'very strong' and 'very weak' relationships were weakened. This had a stabilizing effect on the dynamic output without fundamentally changing the values provided by the workshop participants.

Table 5.3 Redesigned table of categorical and numerical weights

Categorical change	Numerical change
Very strong	+/- 0.90
Strong	+/- 0.70
Weak	+/- 0.40
Very weak	+/- 0.10
Related factors, but not weighted	0.00

Then, tables were made listing the relationships and the respective weights (Table 5.4). These tables were used to execute a detailed content analysis of the causal relationships between factors present in the maps, discarding redundancy; including missing arrows; and changing values of weights. Redundancy occurred when the same relationship was represented twice, removing arrows that describe the same interactions. For instance, the participants in the livestock workshop connected technological innovation (F3) directly to livelihood security (F6). At the same time, F3 relates to crop production (F1), which in turn

relates to F6. In this way, the process of technological innovation that leads to increasing crop production, which leads to increased livelihood security, is included twice. The direct relationship from F3 to F6 was therefore removed. Missing arrows are those that were not included, even though relations were mentioned during discussions.

Table 5.4 Example of the relationships and weights from the livestock workshop

From		To		Signal	Check and update weight	Calibration: assigning values
F3	Technological innovation of production	F1	Crop production and consumption (cassava, rice, corn, beans, fruits, etc.)	+	0.90	0.70
F3	Technological innovation of production	F2	Livestock production and consumption – involving milk, beef, and small livestock (e.g. goats, pigs, and chickens)	+	0.90	0.90
F3	Technological innovation of production	F6	**Livelihood security**	**+**	**Out**	**Out**
F3	Technological innovation of production	F9	**Environmental sustainability**	**+**	**Out**	**Out**

The second step was to calibrate the weights in the relationships by assigning values. The calibration consisted of stabilizing the change vector by varying the strength of the additional feedback, assuming that the systems were in or near equilibrium (see Kok, 2009). In this step, some values were slightly changed with the aim of getting a stabilized graph at the end of the interactions (see Table 5.4).

After the FCMs were calibrated, a sensitivity analysis was performed. This third step served a double purpose. On the one hand, it provided insights into the behaviour of the system and the relative importance of the various factors. On the other hand, knowledge on relative importance was crucial for determining factors that were to be changed in the next analysis. The sensitivity analysis was performed by systematically changing the values of the change vector for each factor (Kok, 2009).

After these three steps, the resulting maps and matrixes from the three FCMs, based on small farmers' perceptions broken down by livelihood strategy cluster, were compared, identifying main similarities and differences among them.

When two or more FCMs are compared, three types of difference can be identified: (1) existence or non-existence of factors: one FCM regards certain aspects within a domain as important, whereas the other FCM does not; (2) representation of different belief systems in a

given domain: one group holds certain beliefs that the other group does not hold; (3) identical factors held with differing strengths: two FCMs have the same factors, but one FCM deems the interaction between factors to be stronger than the other FCM does (Langfield-Smith and Wirth, 1992). These types of difference were used to compare the three FCMs obtained in this study.

5.3.5 Exploring future changes using the fuzzy cognitive maps

We used the three livelihood strategy-specific and post-processed FCMs to explore future changes under plausible future scenarios. Future scenarios are understood here as a set of changes to the context of the system as captured by the FCMs. The intention, therefore, is to evaluate the effect of these sets of changes on the dynamics of the system. Instead of developing plausible future scenarios from scratch, we decided to build on the most recent set of global scenarios available, the Shared Socio-economic Pathways (SSPs) that are currently being drafted for inclusion in the next assessment report of the IPCC (IPCC, 2012; Kok & Laurence, 2012; O'Neill et al., 2012). SSPs focus on mitigation and adaptation processes relating to people, livelihoods, infrastructure, ecosystems, services, and resources among other dimensions that could be adversely affected by climate change (IPCC, 2012). One of the key characteristics assumed by the SSPs is that a narrative of future global development elaborated under global assumptions should also be relevant for local and regional scale scenarios (IPCC, 2012).

From the key characteristics, Kok & Laurence (2012) downscaled to Latin America the driving factors from the global SSPs of alternative developments. Among the five scenarios developed in terms of socio-economic challenges for mitigation and adaptation, two exploratory scenarios were chosen for this study, i.e. SSP1 – sustainability – and SSP3 – fragmentation (Kok & Laurence, 2012). They were chosen to reflect the small farmers' current expectation as captured in the FCMs, with two extremes: an optimistic and a pessimistic scenario, respectively.

Focusing on mitigation and adaptation potential, SSP1 represents an optimistic scenario toward sustainability where rapid technological innovation towards crop and livestock production will reduce the demand for land, improve degraded grasslands, increase yields, improve drought resistance, etc. In this scenario, policies are effective, providing infrastructure for the settlers, timely credit access, and adequate technological assistance. Secondary forest is expanding because of land use intensification and the effectiveness of monitoring and enforcement systems by national institutions such as the National Institute for

Space Research (INPE) and the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), respectively, reaching the parameters of forest cover indicated in the Forestry Code. In this scenario, positive and negative values (1 for policy effectiveness and -1 for intensification of drought) are attributed to the change vector of these sensitive factors in each FCM matrix, and a positive value (1) is attributed to an external factor. This external factor is considered as a set of factors that can cause disturbance in the equilibrium of the system, affecting its resilience (Kok, 2009). As an example, in our study this external factor includes a radical political change or natural disasters.

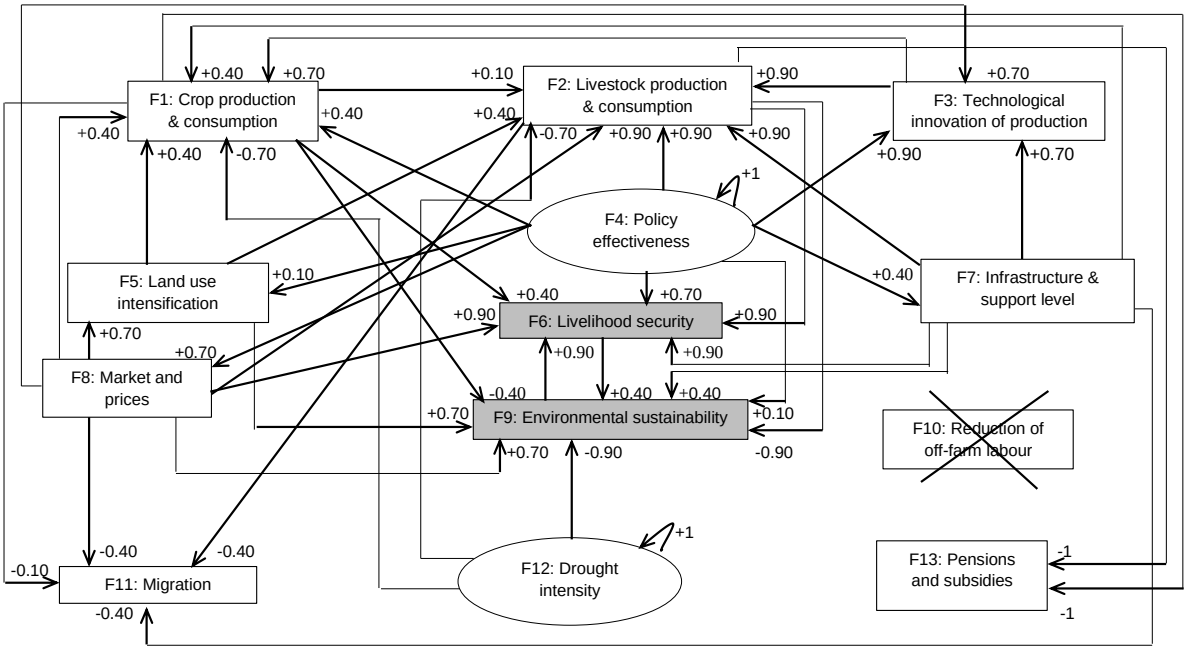
SSP3, in turn, is a pessimistic scenario looking towards a fragmented situation where settlers are not able to access technological innovation because of the weakness of policies and institutions. Low investments in human capital cause more deforestation and soil degradation. Drought becomes intensive, and settlers do not have options to earn their livelihood on their properties from agricultural activities, provoking a massive migration to the cities or to other unplanned settlements established in new Amazon frontier areas, causing more deforestation. In this alternative development, positive and negative values (1 for intensification of drought and -1 for policy effectiveness) are attributed to the change vector of these sensitive factors in each FCM matrix, and a negative value (-1) is attributed to an external factor as well.

5.4 RESULTS

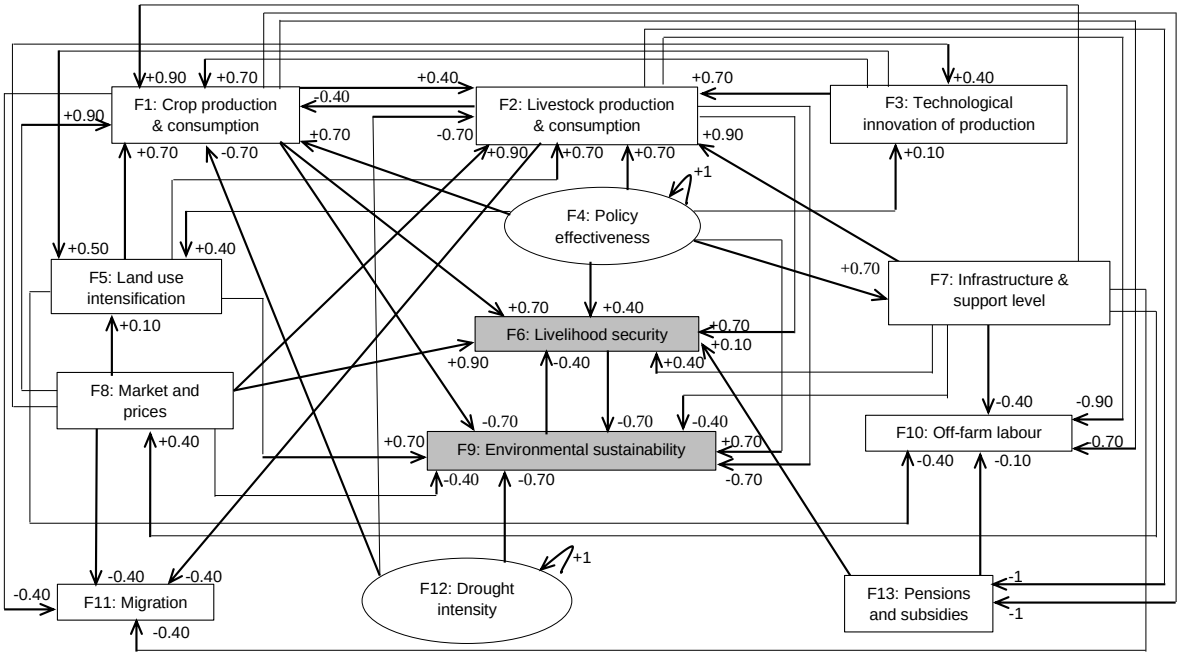
5.4.1 Small farmers' current perceptions among livelihood strategy clusters: similarities and differences

Figure 5.4 presents the post-processed FCMs from the three workshops, by livelihood cluster. These FCMs express, therefore, the current perception of the participants about their reality, as reconstructed in the three workshops. These maps indicate that the participants agree with the general factors suggested in Table 5.2. There is just one exception: the participants in the livestock workshop consider factor F10 (reduction of off-farm labour) not relevant to them, so there are no arrows to or from that factor in their FCM.

OUTCOME OF THE WORKSHOP WITH PARTICIPANTS FROM THE LIVESTOCK CLUSTER



OUTCOME OF THE WORKSHOP WITH PARTICIPANTS FROM THE DIVERSIFIED CLUSTER



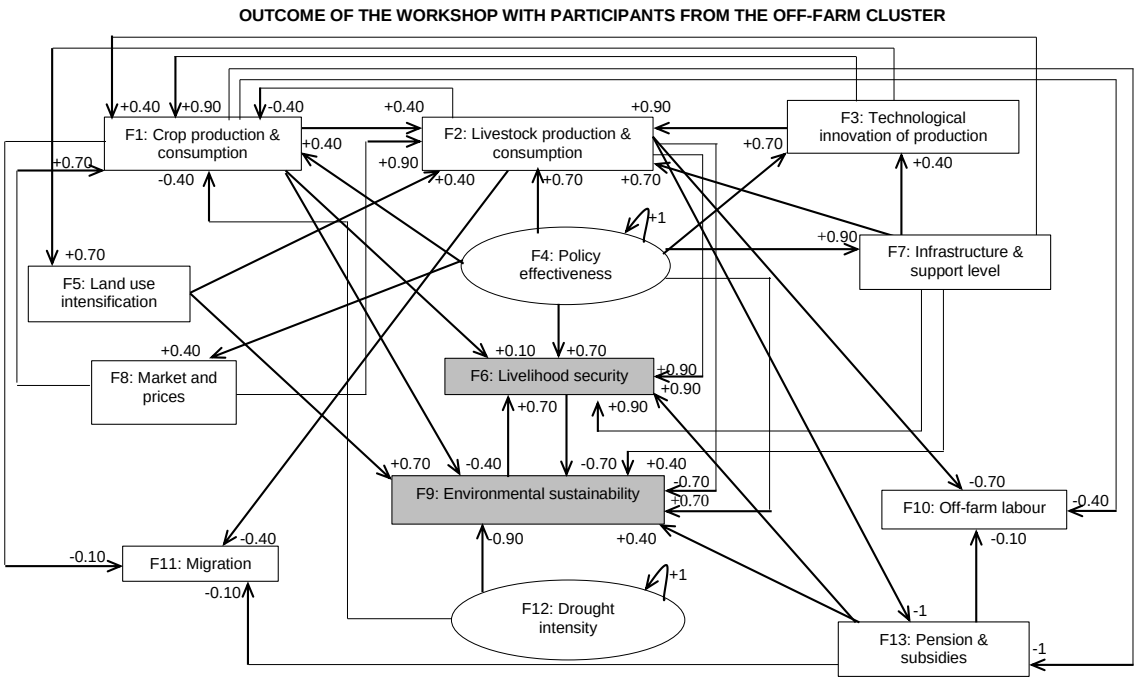


Figure 5.4 Post-processed fuzzy cognitive maps resulting from the three workshops (livestock, diversified, and off-farm, respectively)
Note: Grey boxes are the target factors of the analysis; white boxes are the general factors; white circles are the drivers of the system. Numbers given are the weights between factors, indicating positive and negative relationships. The crossed out box in the livestock FCM indicates the factor excluded by the participants.

Table 5.5 shows the key characteristics of the resulting maps, presenting the most important similarities among them. The three clusters have a similar number of factors and relationships. As already stated, the workshop participants from the livestock cluster did not consider factor F10 (reduction of off-farm labour) important for them. The number of relationships in the diversified cluster is higher than in the others, indicating that small farmers within this cluster have a broader view of their system since they are involved in more activities, dealing with a higher number of institutions, such as government offices and markets. This cluster also presents more negative relationships than the others, but the number of receiving and transmitting relationships is similar to the other clusters. One factor (F11 – migration) was not considered as a causal factor in any of the three FCMs. Reduction of migration is considered an effect of other factors in all livelihood clusters.

Table 5.5 Key characteristics of the maps

Characteristics	Livestock	Diversified	Off-farm
Number of factors (N)	12	13	13
Number of relationships (R)	42	49	41
Maximum of relationships (MaxR)	132	156	156
Density (C/MaxR) (D)	0.32	0.31	0.26
Positive relationships	31	29	27
Negative relationships	11	20	14
Number of receiving factors	2	3	3
Number of transmitting factors	2	2	2

Although most factors and key relationships are very similar for the three clusters (Figure 5.4), there are also important differences, as the participants gave different system descriptions. The main differences are not so much in the existence or absence of relationships, but rather in the weight a relationship is given. For instance, the causal relationship F1 (crop production and consumption) → F6 (livelihood security) was assigned a strength of +0.40 in the livestock cluster, +0.70 in the diversified cluster, and +0.10 in the off-farm cluster, expressing the importance of the former factor to the latter one for each cluster. The consequences of these different weightings are reflected in different system dynamics obtained by changing the vectors. These different dynamics are the main reason for keeping the three FCMs separate, despite their large similarities.

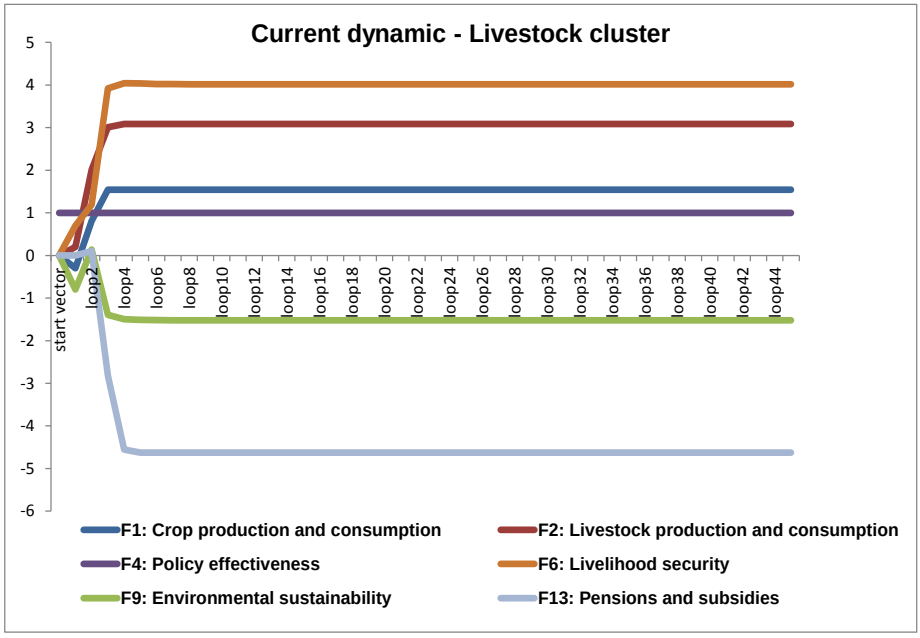
The number of incoming and outgoing relationships of a factor provides an indication of its importance. The more relationships, the more central a factor is in the system's description, and thus the more important it is in the farmers' perception. A large number of relationships in all FCMs relate mainly to policy effectiveness (F4), crop production and consumption (F1), and livestock production and consumption (F2). The assumed importance of the first factor relates to the fact that the small farmers are beneficiaries of the ARP, depending on its schemes to establish their farming enterprise. Additionally, policy effectiveness is a key driver, because it influences a number of other factors, but is not influenced by any factor. Therefore, it influences the system without being part of it. The other two factors relate to the small farmers' perceptions about ranching and farming, which are fundamental livelihood activities for most of them. Despite the low number of relationships, pensions and subsidies (F13) is also considered important because it has the most negative value in all FCMs and thus strongly influences the system. Therefore, these four factors together with the target factors – livelihood security and environmental sustainability (F6 and F9, respectively) – are considered the most important factors in the system descriptions.

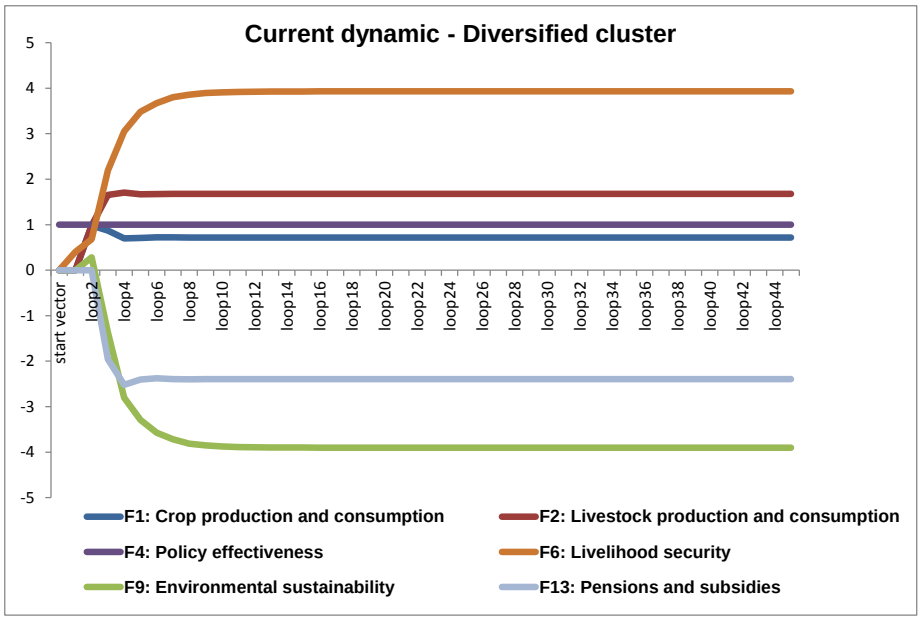
5.4.2 Dynamics of the FCMs in terms of small farmers' current perceptions

The current dynamics outputs for each livelihood cluster in relation to the four selected factors (F1, F2, F4 and F13), together with the target factors in the FCM analysis (F6 and F9), are presented in Figure 5.5. After stabilization, the graphs indicate the current dynamic situation of each factor, allowing a comparison among them.

Small farmers within the livestock and diversified clusters perceive that they are achieving livelihood security (orange line – highest positive). However, this is happening at the expense of environmental sustainability (green line – negative). Livestock activities are important to both groups of small farmers. The pension and subsidies factor is also negative for these clusters. Interestingly, small farmers in the off-farm cluster perceive livestock and crop production as important factors for them, but they are achieving neither livelihood security nor environmental sustainability (both negatives).

The key driver, policy effectiveness, is stable in all three clusters. However, the results obtained from the sensitivity analysis show that the three FCMs are extremely sensitive to policy effectiveness. When the start vector of this factor was changed from a positive (0.1) to a negative value (-0.1), for instance, the charts of all three FCMs changed in position and degree, reinforcing its importance as key driver (Kok, 2009).





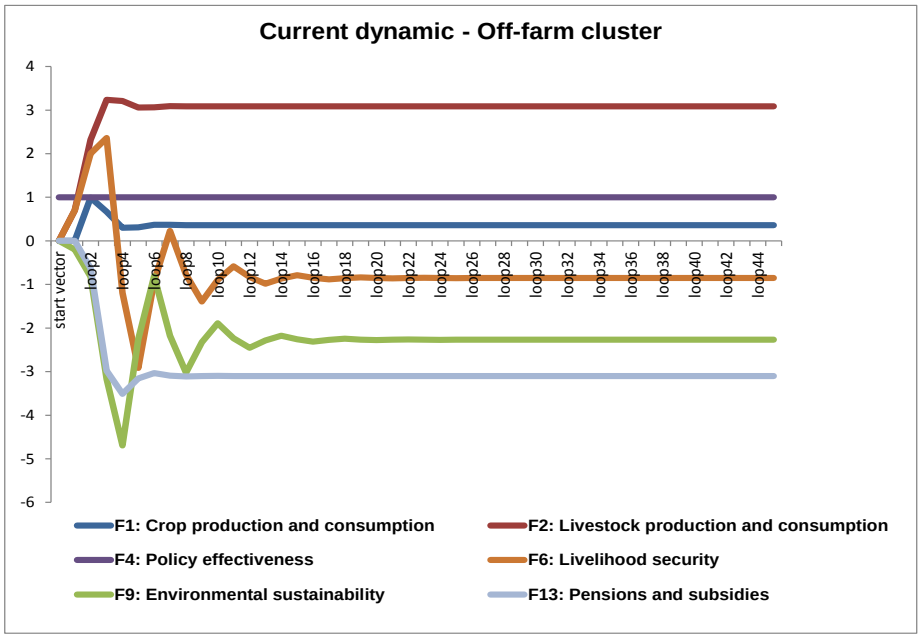


Figure 5.5 Outputs of the three FCMs
Note: *X* axis: number of iteration steps; *Y* axis: value of factors.

5.4.3 Dynamics of the FCMs in terms of the SSPs scenarios

The outputs of the FCMs can be presented in tabular or graphical form. Here, we present these two options. Table 5.6 shows the final values of stabilization of the change vectors for all factors in the three FCMs, taking account of the current situation and the SSP scenarios. Figure 5.6 shows the outputs of the off-farm cluster represented graphically, taking account of the two scenarios.

The table (or graph) is interpreted by comparing the current situation and the SSP scenarios, observing the changes in position and degree of each factor. In the optimistic scenario (SSP1) of future changes in the livestock cluster, small farmers assure their

livelihood security (13.2) from livestock (9.2) and crop production (5.9), while being independent from subsidies (-15.1). This result, compared with the chart of the current situation (Figure 5.5), indicates that small farmers within the livestock cluster perceive that, in the sustainable scenario, livelihood security is enhanced by livestock and crop production. The outcome on environmental sustainability (-1.3) is slightly attenuated compared with current situation (-1.5), although it is still negative. Pension and subsidies are less important because small farmers are achieving their livelihood from livestock and farming. In the pessimistic scenario (SSP3), crop and livestock production become negative (-2.9 and -4.6, respectively), affecting livelihood security negatively (-6.6). In this scenario, small farmers depend largely on subsidies (7.6) to provide their livelihoods; however, environmental sustainability is positive (0.6), because of the fall in agricultural production.

Table 5.6 Final values of stabilization of the change vectors for the factors in the three FCMs

Factors	**Livestock**			**Diversified**			**Off-farm**		
	Current situation	SSP1	SSP3	Current situation	SSP1	SSP3	Current situation	SSP1	SSP3
F1: Crop production and consumption	**1.5**	**5.9**	**-2.9**	**0.7**	**2.2**	**-1.2**	**0.4**	**1.4**	**-0.8**
F2: Livestock production and consumption	**3.1**	**9.2**	**-4.6**	**1.7**	**5.0**	**-2.8**	**3.1**	**6.4**	**-3.5**
F3: Technological innovation of production	1.7	3.3	-1.7	0.20	0.40	-0.20	1.1	2.1	-1.2
F4: Policy effectiveness	**1.0**	**2.0**	**-1.0**	**1.0**	**2.0**	**-1.0**	**1.0**	**2.0**	**-1.0**
F5: Intensification of land use	.60	1.2	-0.6	0.5	1.0	-0.60	0.7	1.5	-0.8
F6: Livelihood security	**4.0**	**13.2**	**-6.6**	**3.9**	**9.2**	**-4.7**	**-0.3**	**-1.1**	**0.9**
F7: Infrastructure and support expansions	0.4	0.8	-0.4	0.7	1.4	-0.80	0.9	1.8	-1.0
F8: Market and prices	0.7	1.4	-0.7	0.3	0.60	-0.30	0.4	0.8	-0.4
F9: Environmental sustainability	**-1.5**	**-1.3**	**0.6**	**-3.9**	**-7.6**	**3.3**	**-2.6**	**-3.9**	**1.9**
F10: Reduction of off-farm labour	0.0	0.0	0.0	-2.6	-6.3	3.5	-1.9	-4.4	2.4
F11: Migration	-1.8	-5.2	2.6	-1.4	-3.6	2.0	-0.9	-2.0	1.1
F12: Intensification of drought	1.0	-2.0	1.0	1.0	-2.0	2.0	1.0	0.0	0.0
F13: Pensions and subsidies	**-4.6**	**-15.1**	**7.6**	**-2.4**	**-7.2**	**4.0**	**-3.1**	**-7.1**	**3.9**

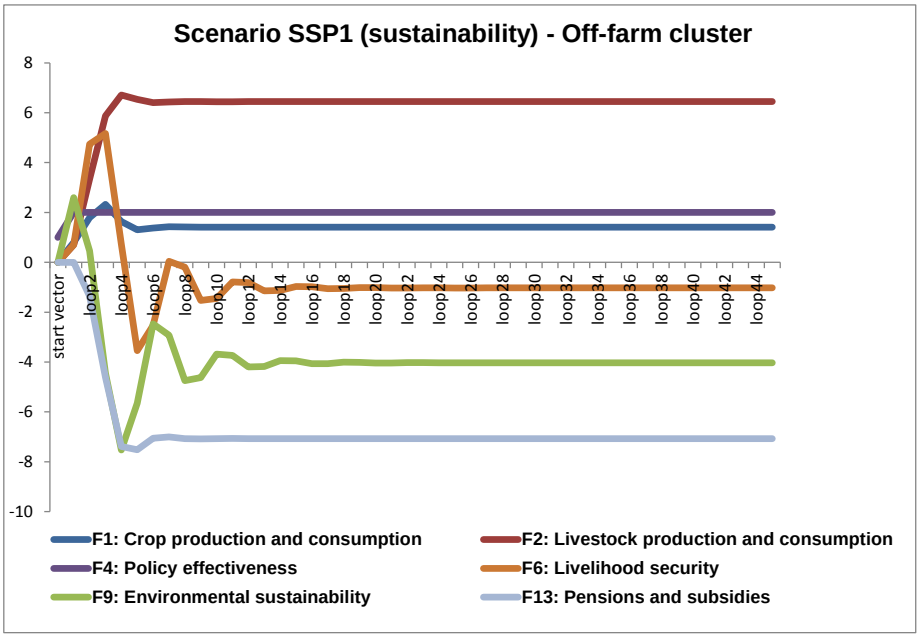
Note: The key factors and target factors are in bold.

In turn, in the optimistic scenario (SSP1) of future changes in the diversified cluster, small farmers assure their livelihood security (9.2) from livestock (5.0) and crop production (2.2), not depending on subsidies (-7.2). This scenario, however, is very negative for environmental sustainability (-7.6). In turn, in the pessimistic scenario (SSP3), crop and livestock production become negative (-1.2 and -2.8, respectively), affecting livelihood

security negatively (-4.7). In this scenario, small farmers depend on subsidies (4.0) to provide their livelihoods. On the other hand however, environmental sustainability has its best outcome (3.3), precisely because of the decrease in agricultural production and the increased abandonment of agricultural areas.

As a graphical interpretation of the FCMs outputs, Figure 5.6 shows the outcomes of the small farmers in the off-farm cluster. When the chart of the current situation (Figure 5.5) is compared with the SSP scenarios (Figure 5.6), it is clear that the dynamics of the factors change in position and degree.

In the optimistic scenario, small farmers in the off-farm cluster enhance livestock and crop production, but they are still not achieving livelihood security. Environmental sustainability also decreases in this scenario, despite this being a 'sustainable' scenario. In the pessimistic scenario (SSP3), pensions and subsidies are the basis for livelihood security. Surprisingly, small farmers in this situation have positive livelihood security, but livestock and other agricultural production are negative. These factors affect environmental sustainability positively.



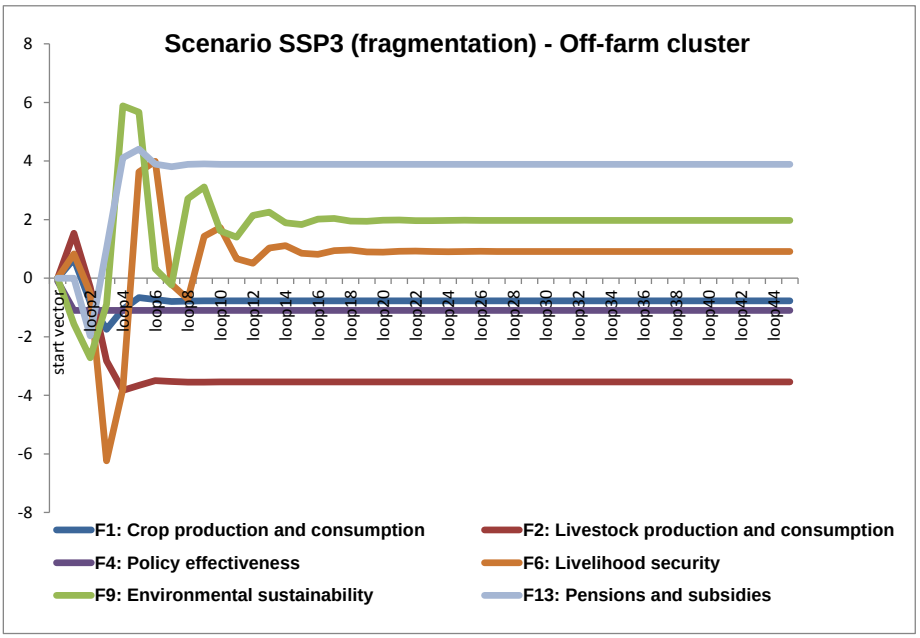


Figure 5.6 Output of the SSP1 scenario (sustainability) and of the SSP3 scenario (fragmentation) for the off-farm cluster
Note: *X* axis: number of iterations of vector matrix; *Y* axis: value of the factors.

5.5 DISCUSSION

5.5.1 Small farmers' current perceptions and scenarios: similarities and differences in the three FCMs

It was not unexpected that the FCMs constructed by the three livelihood strategy sub-groups were very similar in terms of factors and relationships. The specific group of small farmers considered in this paper are subject to the same set of ARP policies, they are in the same geographical region, and they all depend on livestock to some extent. So, small farmers with different livelihood strategies perceive the same factors as affecting their livelihood security and environmental sustainability. Small farmers in the livestock cluster did not consider reduction of off-farm labour (F10) as an important factor for them because, in general, livestock activities, mainly dairy cattle, are labour intensive (Tourrand et al., 2004; Vosti et al., 2003). However, some relationships and most weights between relationships are different among the three FCMs. In other words, the majority of small farmers agree on the same factors, and by and large also on the same cause and effect relationships. Nonetheless, relatively subtle differences in the weights attributed to these relationships have given rise to very different system behaviour. This could indicate that the system perspective differs among the three livelihood strategies, depending on how small farmers perceive the interaction of factors in terms of relationships and the weight of each interaction.

Different perceptions of their realities resulted in the small farmers making different trade-offs between livelihood security and environmental sustainability, depending on their livelihood cluster. As pointed out by Sunderlin et al. (2005), many plans of action aim for *win-win* outcomes, where livelihood improvements are matched by gains in environmental protection. However, the results indicated *win-lose* outcomes in the livestock and diversified clusters, in terms of the current situation and of the sustainable scenario. This means that small farmers are achieving their livelihood security at the expense of environmental sustainability. This can be attributed to the necessity to keep the pasture areas cleared to assure livelihoods in the livestock cluster and to the fallow agriculture in the diversified cluster (Fujisaka et al., 1996; Vosti et al., 2003). The impact of crop production on environmental sustainability is minor because livestock production has a bigger role for the small farmers (Vosti et al., 2003). As suggested by Sunderlin et al. (2005), policy lessons should be guided by the analysis of this type of outcome in terms of two principal types of solutions. The first would involve reducing the trade-offs and, in essence, seeking outcomes of the type *winning more and losing less*. It could be associated with technological innovation and implementation of agro-ecological systems in the settlement projects (Altieri, 2002; Monteiro Novo, 2012). The second would involve identifying the appropriate point on the trade-off curve, for example, the optimal level of well-being, or the optimal level of forest cover, cognizant of the biophysical, economic, and political consequences of forest conversion (Kaimowitz et al., 1998; Sunderlin et al., 2005). We know from a previous study (Chapter 3) that signs of forest transition appeared in the municipality and on some properties in the period from 2005 to 2010, showing the possibility of a win-win outcome between livelihood security and environmental sustainability in the livestock and diversified clusters. Consequently, policies such as the Ministry of Environment's 'green grant' (*bolsa verde*) (MMA, 2013) that maintain and expand secondary forest in the municipality are recommended.

The situation for small farmers in the off-farm cluster is even worse: the outcome is *lose-lose* in the current situation as well as in the sustainable scenario because they are achieving neither livelihood security nor environmental sustainability. Curiously, however, the unique situation of *win-win* outcomes is observed precisely in the pessimistic scenario for small farmers in the off-farm cluster: in this case, both livelihood security and environmental sustainability are achieved. This can be attributed to the farmers' dependence on the government to provide their livelihoods and the abandonment of agricultural areas in this scenario, respectively. Although achieving a win-win outcome, this situation cannot serve as

an example to be reproduced, as suggested by Sunderlin et al. (2005); rather, this apparent win-win outcome could cause more social and environmental problems because the small farmers might migrate to the outskirts of the cities (or to *favelas*) or to a new forest frontier, causing more deforestation elsewhere.

To sum up, analysis of the livelihood strategies of sub-groups of small farmers proved useful to uncover differences in perceptions about the system. The combination of livelihood strategies and system dynamics is powerful in gaining understanding of how various groups of small farmers perceive the system. Moreover, different trade-offs were observed, implying different necessities for actions and policies. Achieving win-win outcomes does not necessarily imply a positive scenario, especially if small farmers are dependent on income transfers from the government to provide their livelihood.

5.5.2 Pros and cons of exploring system dynamics using FCMs

Fuzzy cognitive mapping was designed to be applied to stakeholders with a relatively good understanding of system dynamics, usually those with a higher education level (Soler et al., 2011; van Vliet et al., 2010). In fact, local stakeholders, such as small farmers, were said to, in principle, often struggle with the concept of a system diagram. It was believed that they would have difficulty understanding the wider conceptual meanings, such as causes of deforestation; and their perceptions were often narrowed down to very localized factors (Wulms, 2012). On the other hand, they are part of the system addressed in this paper, and therefore it is crucial to understand and analyse their perceptions (Chambers, 1994; Schiere et al., 2004). Although the literature, generally, advises not to develop FCMs with local small farmers, this paper has shown that, under certain conditions, they do work. Specific reasons include firstly that most local small farmers were in some way engaged in social movements in the land struggle, making them more aware of social and land issues, and this probably resulted in more active participation in the workshops. In addition, the prior mutual knowledge among participants and the facilitator of the workshops helped in getting a positive outcome. Because of the facilitator's previous knowledge about the small farmers and their livelihood strategies, it was possible to propose general factors at the beginning of the workshops. This facilitated a smooth process because the small farmers did not have very much time (or patience) to discuss all possible factors present in their context, despite their willingness to participate in the construction of the maps. However, we did not develop scenarios or even discuss future changes with the small farmers mostly due to their time availability. From the experiences of the three workshops discussed in this paper, it can be

stated that organizing workshops with local stakeholders to develop FCMs quickly has proved possible. However, more research is needed to know the extent to which special circumstances made this experience an exception rather than a rule.

Although not a direct objective of this paper, it has been proved that fuzzy cognitive mapping can be an important tool in the process of exchanging information and co-producing knowledge, and thereby contributing towards social learning (Isak, 2008). The main contributory factor is the fact that practical implicit knowledge has been structured and made more explicit. The learning process can be illustrated by a quote from a participant in the livestock workshop. When asked what he thought of the outcomes of the workshop, he said: 'It is a map that is in our head for a long time, but we did not stop to think about it and organize it yet.' Thus, the mapping exercise was positive in terms of both capturing the current perception of the system and social learning.

An advantage of using fuzzy cognitive mapping as a method is the possibility of obtaining new insights into the behaviour of livelihood systems, uncovering relationships between factors that would not be noticed using other methods alone, such as household surveys. Moreover, the method becomes stronger if used in combination with other methods, such as individual open-ended interviews, as we did. Thus, a mixed methods approach is more adequate to investigate mental models in the human–environment interaction, as also suggested by Lynam et al. (2012). Using FCMs to study the dynamics of a system can reveal differences that are hidden when only the factors of importance or the sensitivity of the system are taken into account. The dynamics of the system also reveal the heterogeneity of a group of stakeholders such as small farmers in agrarian settlement projects.

Despite its advantages, fuzzy cognitive mapping has drawbacks as well. In our case, the workshops were limited to a small number of participants as not all farmers participated in them. Moreover, only a limited number of factors can be included in the discussion. On the one hand, a strong focus on numbers might relegate discussions on less tangible issues to the background, and the semi-quantitative character of the outcomes in the FCMs may limit their use as input in mathematical models. As highlighted by Kok (2009), in this case, semi-quantification can be a blessing or a burden.

Post-processing can also be considered a drawback of the tool. Contrary to other participatory methods and tools, FCMs need a large amount of post-processing and reworking, thus increasing the role of the scientist. It would have been more appropriate to discuss the post-processed versions of the FCMs with the participants again, as a validation process, obtaining more accurate maps. However, due to time and financial resources

constraints, this was impossible. We therefore opted to provide a very detailed insight into all steps in the post-processing stage, thus maximizing the transparency of the overall process.

In short, there are important advantages and disadvantages of using fuzzy cognitive mapping as a main participatory tool. This paper has, hopefully, shown that the advantages of structuring mental models and exploring dynamics outweigh the disadvantages of post-processing and somewhat limited stakeholder participation.

5.6 CONCLUSION

Small farmers in the study area all have a similar perception of the factors that affect their livelihood security and environmental sustainability, independent of the livelihood strategy they adopt. All farmers perceive agricultural activities (livestock and crop production); policy effectiveness; and pensions and subsidies as being the most important factors. Nevertheless, opinions differed substantially on how factors related to each other, in terms both of the existence of relationships and of the weights attributed to the relationships. These often seemingly subtle differences, however, gave rise to fundamentally different system dynamics between livelihood strategies, importantly represented by clear differences in trade-offs between livelihood security and environmental sustainability. The scenario analysis showed how these trade-offs can change but generally become more pronounced in both futures explored. Hence, the goals of sustainable development seem not easy to realize in the area, given the characteristics and drivers of the human–environment systems, as identified by the settlers.

Although all findings within this study point towards a situation where either livelihoods or the environment benefit, but not both, there might be light at the end of the tunnel as previous work has demonstrated that there are signs of a forest transition in the municipality and in some settlement projects. Such transitions can be enhanced by policies such as the ‘green grant.’

Despite potential disadvantages of using fuzzy cognitive mapping as a main participatory tool, it facilitates the description of the system as a whole, rather than merely listing factors. In this study, it helped to uncover differences between various livelihood strategies that would otherwise have remained hidden. It might be useful to support policies towards (more) win-win outcomes, acknowledging the fundamentally different dynamics of specific human–environmental contexts.

Chapter 6

It is good to have an end to journey toward;
but it is the journey that matters, in the end.

(quotation by the American writer Ernest Hemingway)

6 Synthesis and conclusions

6.1 INTRODUCTION

In the past decades, thousands of people have been settled in settlement projects in the Brazilian Amazon under the Agrarian Reform Program (ARP). Several studies have indicated the negative environmental consequences of these projects, pointing to the role of the program beneficiaries (the settlers) as key agents of Amazonian deforestation (Brandão Jr. & Souza Jr., 2006; Soler & Verburg, 2010). Settlers, however, are not able to make a livelihood and at the same time comply with the Forestry Code, which indicates that 80% of forest area in each property has to be preserved. Yet, fundamental questions about why deforestation takes place in settlement projects, what drivers are behind it, and why it exceeds the requirements of the Forestry Code have not been exhaustively addressed.

The general objective of this thesis was to investigate in more detail how settlers have made their living; how their activities and practices have affected forest cover changes within the settlement projects; and how future prospects for both, i.e. people and forest, were to be envisioned. Four research questions were addressed:

1) What livelihood strategies are adopted by settlers in Amazonian settlement projects?

2) To what extent are forest cover changes occurring in areas where settlement projects were established?

3) To what extent have different livelihood strategies and trajectories led to different effects on forest cover changes?

4) How do settlers perceive the factors that affect their current livelihood security and environmental sustainability in their area and what are the future prospects?

This chapter presents the main findings of this thesis as reported in the various chapters. In doing so, it aims to synthesize them and situate them within the perspective of the wider academic field. In addition, it reflects on the study objectives, theoretical concepts, and the literature on livelihoods and forest dynamics. Moreover, building upon the sustainable livelihoods approach (SLA), it discusses how this study might contribute to science,

policymaking, and local practices. The chapter is divided into six sections and an epilogue. The second section presents the findings relating to each chapter, answering the research questions. The third section discusses how this thesis tackled the drawbacks of the SLA. The fourth section discusses the challenge faced by the use of mixed datasets and methods. The fifth section describes the lessons learnt from this thesis. The sixth section presents the overall and final conclusions. The epilogue, finally, explains the rationale behind the thesis title, thus bringing this thesis full circle.

6.2 LIVELIHOOD PERSPECTIVES AND FOREST DYNAMICS IN THE AMAZONIAN SETTLEMENT PROJECTS

6.2.1 Livelihood strategies adopted by settlers

What settlers do to make their living in agrarian settlements is a result of many factors that interact in many different ways. Chapter 2 identified and described three different livelihood strategy clusters found in the study area, namely, livestock-oriented, diversified-oriented, and off-farm-oriented (Tables 2.2 and 2.3). The main on-farm activity in all clusters is cattle breeding, predominantly dairy cattle, although other activities such as crops (bean, rice, cassava, and corn) and small livestock (pigs, chickens, and goats) are undertaken. Off-farm activities and sources of income relate mainly to off-farm labour and subsidies (pensions and family allowance – *bolsa família*).

Thus, even in one region, influenced by a similar context (struggle for land) and affected by the same set of specific policies (from the ARP), settlers have developed *different* strategies to make a living. These differences are strongly linked with settlers' background and origin. It is recommended to incorporate this specific and crucial finding in the agrarian reform process, as explained in Chapter 2. Settlers should be placed together according to their skills and backgrounds, before land is actually distributed. This could help to avoid deforestation, for instance, by preventing livestock-oriented farmers from being settled in forested areas.

Moreover, environmental conditions, social organization, market availability, and some facilitating mechanisms of agrarian reform, i.e. credit policy, technological assistance, and land access, have all played key roles in directing the livelihood strategy choices towards (dairy) cattle breeding. Although it is not often acknowledged in the literature, the settlers are well integrated in the market because of the dairy and beef chains already established in the region.

In general, settlers are achieving their livelihood goals, because they are earning a relatively good income (national average). They earn this income independent of livelihood strategy adopted, although settlers in the off-farm cluster are not reaching the agrarian reform premise, i.e. living from agricultural activities only. All in all, livelihood strategies adopted by settlers result from the combination of different factors, such as background and agrarian reform mechanisms, rather than from isolated factors.

6.2.2 Forest dynamics at the municipal, settlement project, and properties levels

This thesis has demonstrated the importance of studying forest dynamics, i.e. deforestation *and* reforestation, rather than the unidirectional approach towards deforestation (Chapter 3). Moreover, the use of mixed datasets and methods, such as satellite imagery and participatory mapping, was appropriate to show and analyse forest dynamics in the study area.

The forest dynamics analysis at municipal level showed a clear recent increase in forest (2005–2010). This forest recovery proved to be independent of the year of establishment of the settlement projects, including the project that was established last (Canudos/2004). In addition, all properties sampled in this study presented secondary forest (classified imagery). This finding suggests that the first steps of a forest transition are taking place in Eldorado do Carajás.

However, settlers do not perceive secondary regrowth as 'real' forest, even in areas that have been recovering for 10 years or more. These 'resting' areas can be understood in two ways. On the one hand, these areas will be the first to be cultivated again, either when inputs become available or when there is need to increase production. Therefore, they can be regarded as areas at high risk of future deforestation. On the other hand, they can be seen as having a high potential of remaining forested. The latter, however, requires technological innovation and intensification of agricultural activities and practices to prevent the clearance of new forest areas for agricultural lands in the (near) future (Altieri, 2002; Monteiro Novo, 2012).

6.2.3 Combining livelihood perspectives and forest dynamics

Acknowledging that livelihood strategies are dynamic processes, this thesis used the concept of livelihood trajectory to uncover the factors that have affected livelihoods over time (Chapter 4). From the dataset used to identify the livelihood strategies in Chapter 2, 11 different livelihood trajectories were identified from the time of the settlers' arrival at their properties until 2010. Comparing these results with forest dynamics at property level, three

different steps were taken to find relationships and patterns of effects of livelihood strategies and livelihood trajectories on forest dynamics. However, because of the complexity involved in these two dynamic systems, i.e. livelihoods and forest, it was not possible to determine one-to-one relationships and general patterns of effects of the former on the latter. Pre-settlement environmental histories (Chapter 1), different years of arrival, and settlers with similar trajectories spread over different settlement projects are relevant explanations for this outcome.

Nonetheless, analysis of individual household- and property-level cases offered insights into factors, such as credit availability, market accessibility, and off-farm income (mainly pensions and family allowances), that have driven both livelihood trajectories and forest dynamics. From these individual cases, it was possible to observe how general underlying causes of deforestation and reforestation interact in different ways at property level, implying deforestation in some cases and forest recovery in others.

6.2.4 Current perceptions and future perspectives for livelihoods and the environment

Fuzzy cognitive mapping was used as a tool to capture current settlers' perceptions about their realities. From this it was concluded that they have similar perceptions of the factors that affect their livelihood security and environmental sustainability, independent of the livelihood strategy adopted (Chapter 5). However, differences were found in the relationships among factors and the weight attributed to each relationship, giving rise to fundamentally different system dynamics for each livelihood strategy cluster (Chapters 2 and 5). As a result, strong trade-offs exist between livelihood security and environmental sustainability in all clusters, and in (nearly) all future analyses. However, the nature of the trade-offs and whether livelihood security or environmental sustainability is favoured differs between the three livelihood strategies. Hence, the goals of sustainable development seem difficult to realize in the area, given the characteristics and drivers of the human–environment systems, as identified by the settlers. However, the emerging forest transitions as shown in Chapter 3 picture a slightly more optimistic future outlook in which livelihood security and environmental sustainability can – at least to some extent – be achieved together. Additionally, as shown in Chapter 2, policies (agrarian reform, credit, technological assistance, etc.) are among the key drivers of the human–environment systems in the settlements. Thus, effective policy reforms could soften the strong trade-offs between livelihoods and the environment (Chapter 5). An initiative in this direction is the Brazilian government's Environmental Conservation Support Program, the so-called *bolsa verde* (green

grant program), aiming at poverty reduction and forest conservation within settlement projects (MMA, 2013).

6.3 THE SUSTAINABLE LIVELIHOODS APPROACH: DEALING WITH DRAWBACKS

The SLA framework, as shown in Figure 1.3 (Chapter 1), provides a comprehensive view of factors that potentially determine or influence livelihood strategies. It has thus been an important starting point for the work in this thesis. However, drawbacks of the SLA have also been reported. Scoones (2009) indicated four challenges in the SLA relating to knowledge, politics, scale, and dynamics (see Chapter 1). This section presents and discusses the contribution of this thesis to the debate on these drawbacks. It focuses on two drawbacks – the two that were mainly addressed in this thesis – i.e. dynamics and scale.

6.3.1 Dynamics

The analysis of livelihoods as snapshot events at a certain point in time is useful to identify and analyse the several multi-level forces (e.g. economic, political, social, etc.) that drive livelihoods strategies (Chapter 2). It was also important as a starting point for future analyses based on current settlers' perceptions (Chapter 5). However, livelihoods result from a series of choices and opportunities that have emerged over time and have been dealt with by settlers, either intentionally and consciously or routinely (de Haan, 2006; Scoones, 1998). These dynamics are, to some extent, already dealt with in the SLA framework, using both stable concepts (like livelihood strategy) and feedback mechanisms through arrows. However, the framework does not fully capture the dynamics of livelihoods (de Haan, 2006). Even settlers who maintain the same livelihood strategy over time still have to adapt to continuous changes, whether these relate to the markets or technological innovation, for instance. Therefore, using the concept of livelihood *trajectory* is much more appropriate to uncover the factors that have affected livelihoods over time (Chapters 1 and 4). Moreover, the approach used in Chapter 5 to capture settlers' perceptions and to analyse the future of livelihood security and environmental sustainability gave more dynamism to the sustainable livelihoods analysis in this thesis. By considering future scenarios, Chapter 5 responded to the challenge of bringing more dynamism into SLA research. In addition, Chapter 5 debunked the myth of the potential win-win outcomes between livelihood security and environmental sustainability as envisioned

in the SLA framework, since such win-win outcomes do not seem to be easily attainable in the study area.

In general, forest cover change has been addressed in a unidirectional process towards deforestation, in which deforestation increases over time (Brandão Jr. and Souza Jr., 2006; Fearnside, 2008; Pacheco, 2009b). This perspective is important to reveal the reduction of pristine primary forest in the Amazon, which indeed has several negative environmental impacts, such as a decrease in biodiversity and soil degradation. However, the study of forest cover *change* urges us to shift our focus towards forest *dynamics*, considering forest recovery as well (Chapter 3). Despite the unquestionable environmental and ecological value of primary forests, the secondary forests also provide conservation services as well as biomass build-up for carbon sequestration (Barlow et al., 2007; van Breugel et al., 2011). Besides being effective in reducing greenhouse gases, forest recovery has a potentially important role in the future livelihoods of settlers, if they are paid for environmental services for instance.

Therefore, this thesis tackled the drawback of a (relatively) static perspective implicit in the SLA framework by considering livelihood *trajectories* and forest *dynamics* (Chapter 4), as well as the *temporal* dimension, i.e. past (Chapter 3), present (Chapter 2), and future (Chapter 5).

6.3.2 Scale

Settlers are subject to federal policies, resulting in a direct link with the national government. Local and state governments do not have responsibility for maintaining or improving infrastructure (roads, bridges, electricity etc.), credit lines, or technological assistance within settlement projects, at least until the settlement projects achieve autonomy. Therefore, the multi-scale driving forces model proposed by Giller et al. (2008) (see Figure 1.4, Chapter 1) has to be redesigned in the agrarian reform analysis, since the power relations among the various scales are different in the study area compared to the original model. In this case, the feedback represented by the weak and dotted arrow from the bottom to the upper scales in the original model (Figure 1.4, Chapter 1) should be replaced by *solid* arrows as proposed in Figure 6.1, thus addressing the scale, politics, and power challenges of the SLA, as discussed in Chapter 1. These bottom-up solid arrows represent the political and organizational power of the settlers in demanding support from the government.

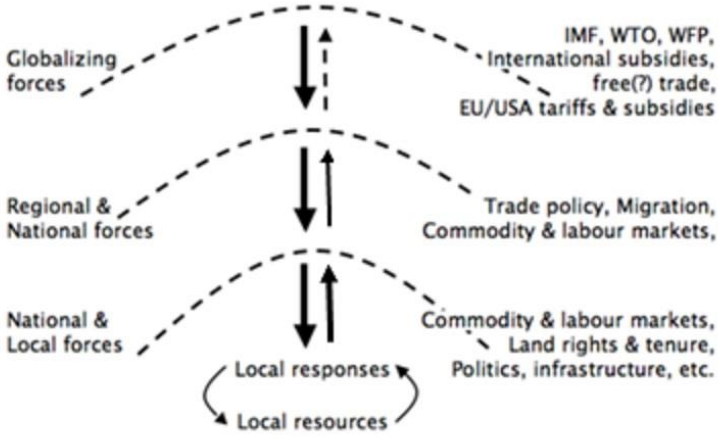


Figure 6.1 Multi-scale driving forces model
Source: Based on Giller et al., 2008.

Curiously enough, however, social organizations, such as associations and cooperatives, have a relatively small role in the support of the settlers' production systems. As shown in Chapter 2, this is reflected in settlers' strong dependence on the market to solve questions that they potentially could have solved themselves, for example the logistics of the milk industry providing the bulk tanks to collect milk, leading to lower prices for farmers. There are examples from other regions in the country where settlers have themselves organized such collection and selling of milk, thus creating a better position to negotiate better prices (Diniz, 2007). In Eldorado do Carajás, this option could be realized as well, all the more so since the dairy chain is well established in the municipality, including the presence of a number of competing milk buyers, thus potentially facilitating negotiations for better prices.

6.3.3 Knowledge and politics

In Chapter 1, I briefly introduced how this thesis would deal with the role of knowledge, politics, and power in the SLA framework, being topics heavily debated in the literature. Although I did not go into depth, I to some extent addressed the criticisms. In Chapter 2, livelihood knowledge was not used to formulate ideal-type livelihood models for the region; instead, knowledge gained was used to identify and analyse the human–environmental systems in the area as well as the (combination of) factors that constrain settlers from attaining, or enable them to attain, livelihood security and environmental sustainability. I also identified the historical events and political forces that led to the existing social networks and institutions, as suggested by O'Laughlin (2002) and Small (2007). This political history indicates the empowerment of social movements in the struggle for land and their capacity to

demand support from the government, but at the same time it shows how the social organization to support the agricultural production has remained weak (Chapters 1 and 2).

6.3.4 Limitations of the SLA framework in this thesis

Evidently, this thesis has limitations in tackling all SLA drawbacks in depth. The scale challenge from local to global is still open. Despite the claims of some authors (e.g. de Haan, 2002), the consequences and interactions between local livelihood strategies and globalization (e.g. worldwide market and social relations and 'glocalization') – global forces that directly or indirectly shape settlement projects – were not identified. For instance, international fair trade and green trade organizations were not found in the study area – perhaps because the main produce of the settlement projects (milk) is directed towards the domestic market. Another global process which could impact local people relates to environmental issues. Although I used downscaled global scenarios to analyse future changes in livelihood security and environmental sustainability in the Amazonian settlements (Chapter 5), the analysis of global programs, such as the REDD+ mechanism, which could bridge the gap between local needs and global demands, was not addressed.

The challenge relating to long-term changes was limitedly addressed in this thesis, too. Although the medium-term (25 years) was considered as the period of analysis, a longer-term period, perhaps far-away future generations, as suggested by Scoones (2009), especially to analyse the future trade-offs between livelihood security and environmental sustainability, was not considered. Matching the (rather short) time horizons of local settlers with the long-term dynamics that might also be important is, therefore, an important challenge.

6.4 FACING THE CHALLENGE OF WORKING WITH MIXED DATASETS AND METHODS

The purpose of mixing methods is to obtain a fuller picture and deeper understanding of reality, maintaining the logics and process of both quantitative and qualitative methods, or altering, combining, and adapting them to fit the research (Chen, 2006). This thesis pointed out that many researchers have studied the interplay between deforestation, agricultural activities, livelihood strategies, and other direct or indirect drivers (Chapter 1). Most of these studies, however, consider local people as mere informants and 'databases,' as local people did not participate actively in the scientific reconstruction of their own realities. This thesis criticizes this approach, assuming that settlers are active local agents of social and

environmental change, enabling them to conduct their own analysis of their own reality, as suggested by Chambers (1994). This was done in two separate chapters. Firstly, settlers expressed their perception of what forest means for them (Chapter 3). Secondly, settlers made a comprehensive analysis of the factors that affect their livelihood security and environmental sustainability in their area (Chapter 5). This research approach facilitated the reconstruction of local realities through the eyes of the agents involved, implying a new, perhaps more valid, view on reality.

This thesis aimed to enrich the debate about livelihoods and forest cover changes in the Amazonian settlement projects by bringing together different databases and knowledge claims. This enrichment was achieved by the combination of data from household surveys and satellite imagery (Chapters 2, 3, and 4) with settlers' perceptions captured by participatory mapping and fuzzy cognitive mapping (Chapters 3 and 5). However, working with mixed methods brings its own challenges. For instance, the results in Chapter 5 showed that, in the current situation, settlers perceive strong trade-offs between livelihood security and environmental sustainability, resulting in win-lose outcomes in the livestock and diversified clusters, and even lose-lose outcomes in the off-farm cluster. However, if I compensated for their perception that secondary forest areas are not 'real' forests (Chapter 3), thus *including* – instead of excluding – forest regrowth in the fuzzy cognitive maps, then the trade-offs would present a different and less negative outcome. This example indicates that the differences among methods are not to be construed as a barrier to the integration of the data sources, but as a means of sophisticating the analysis of livelihoods and forest dynamics (D'Antona et al., 2008). Moreover, settlers' knowledge reveals forms of orientation and spatial representation that can and perhaps should be compared with technical and scientific knowledge. This finding reinforces the necessity of combining a set of methods, instead of using one or two in isolation, if the aim is to start reconstructing the puzzle of settlers' realities.

6.5 LESSONS LEARNT

In this section, I address some lessons learnt from this thesis, which could be helpful for future studies in the same domain. The implications are mostly addressed in methodological terms. In general, spending more time in face-to-face meetings with settlers could improve the analytical processing and validating of the data, although care has to be taken not to overburden them. Stakeholder fatigue is one of the most common problems with participatory methods, and, once stakeholders' attention has been lost, it is close to impossible to enthuse

them again (Lebel et al., 2005). Therefore, a careful balance has to be maintained between stakeholder meetings and data collection/analysis. Nonetheless, the following paragraphs indicate point-by-point improvements that could be made in (more or less) similar studies.

The SLA has to be seen as a dynamic framework. Therefore, the concept of livelihood trajectory rather than livelihood strategy should be used in future studies, thus including more dynamics. Despite the fact that in-depth recorded open-ended interviews can be used to get full and detailed life histories, as required by the livelihood trajectory approach, the use of other methods, such as an event history calendar (Belli, 1998; Belli et al., 2007), could be more appropriate, if time and financial resources are available. Moreover, the analysis of livelihood trajectories rather than strategies shows how many different paths can be taken by households. As a direct result, the number of households that needs to be studied to capture this increased variation also needs to increase. Thus, if the focus is on trajectories, the number of interviews, focus groups, observations, etc. will need to be expanded significantly, perhaps with the support of a group of students; this might help to tackle time and labour constraints.

The outcomes of the comparison of participatory maps with satellite imagery could be improved if it was done by settlers *themselves*, in another workshop. So, for future studies I would suggest organizing one workshop to produce the participatory maps and a second one to compare these with classified images. The results would then indicate forest and non-forest areas within each property, based *both* on GIS technology and on the settlers' perceptions.

Classified images were used in this study to indicate two classes of land cover: forest and non-forest. However, settlers possess the knowledge of different categories of secondary forests present on their properties (Homma et al., 1993). Future studies could consider this knowledge to show in more detail the different classes of secondary forest on the plots. It would help to indicate more precisely the directions of, and variations in, forest transitions in the study area.

A last point that could be improved relates to fuzzy cognitive maps (FCMs). Because of the settlers' time constraints, I myself suggested most of the general factors at the start of each FCM workshop, even though the farmers were free to agree or disagree. Although my selection of factors was based on previous interviews with the same people, an open brainstorming session with them about the factors that affect their livelihood security and environment sustainability would have been more appropriate. After processing the FCMs, another round with settlers, to validate the resulting cognitive maps, would be preferable, aimed at reducing the effects of post-processing analysis. However, I could not do this in the context of this study. Finally, a scenario exercise with the settlers themselves to see if their

opinions on livelihoods and forests in the future match with the SSP scenarios that we used would have been a much better approach. Again, this was not possible in this study.

A key challenge to implementing all recommendations, particularly the recommendation to increase the interaction with settlers through interviews and workshops, is to maintain the balance between understanding the settlers' perception and methods that facilitate other types of analysis.

6.6 FINAL CONCLUSIONS

This chapter presented the main findings of this thesis, linking them to the general literature and the theoretical approach used in this study. Now, I synthesize these into the five key messages of this thesis:

1. Small farmers within the ARP settlement projects in the study area are less poor than often assumed; they do achieve livelihood security, through both on- and off-farm income (Chapters 2 and 4).
2. There exists a strong trade-off between livelihood security and environmental sustainability (Chapters 4 and 5), hence deforestation of primary forests continues, although the first signs of secondary forest transitions have been observed (Chapter 3).
3. The contribution of settlers to deforestation is less than often assumed; first, because they contribute to emerging forest transitions; second, because the peak of deforestation in the area took place before the settlement projects (Chapter 3).
4. Policies strongly affect the settlers' realities; hence their views are crucial for effective policymaking (Chapters 3 and 5). This includes both the Forestry Code and the agrarian reform policies.
5. Livelihood trajectories and forest dynamics models are more appropriate to capture the realities of the human–environment systems in the Brazilian Amazon than livelihoods as snapshots and unidirectional deforestation models (Chapters 3 and 4). .

EPILOGUE – EXPLAINING THE THESIS TITLE

Both academic studies and the common view in Brazil associate landless people with conflicts, disturbances and land occupation (Alston et al., 1999, 2000; Simmons et al., 2007). This label carries a negative connotation to the point that people outside of the land reform movement feel offended when called landless, although people within the social movements

are not. However, after receiving their properties under the ARP, landless people became settlers, and they have tried to get rid of that negative label. However, settlers have now been ascribed another negative label: forestless. They have been continuously blamed for destructing the Amazon rainforest, mainly by the media. This is not justified in my view. Of course, I cannot deny that settlers are partly responsible for deforestation, but, as shown in this thesis, their role in forest destruction in the study area is less than often claimed, as for example shown by the temporal satellite imagery series (Chapter 3). The findings from the various chapters therefore confirm that reality is much more complex and nuanced than the labels people often tend to use. Therefore I hope that this thesis contributes not only to science and policy, but also to a more realistic and thus positive image of the settlers.

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Appendix: Timeline table of individual livelihood trajectories and the percentage of forest over time (*per* year), representing forest dynamics

Set.		85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10
																											LS
1	LS				Crops + BC						Crops + DPC						DPC						DPC + pen				LV
	F%	99			88		80					51					39					20					41
2	LS															Crops		DPC					DPC + BP				LV
	F%	15					10					30				37	39					43					37
3	LS									Crops						Crops + BC			DPC + crops								LV
	F%	5					13			52		77					37					14					40
4	LS				Crop						Crops + BC						DPC						DPC + sub				LV
	F%	61					58					54					36					57					49
5	LS		Crops			Crops + BC							Crops + DPC												DPC + pen		LV
	F%	86					39					24					20					9					16
6	LS															Crops + DPC											LV
	F%	99					98					65				49	45					25					34
7	LS									Crops							Crops + BP					DPC + crops					LV
	F%	99					98			95		93					57					35					34
8	LS										Crops								DPC + crops								LV
	F%	99					97				95						58					13					48
9	LS															DPC + crops							DPC + crops + sub				LV
	F%	99					98					86				67	62					66					60
10	LS																	Crops					DPC + crops + sub				LV
	F%	81					82					84					74		70			65					34
11	LS																				DPC + crops						LV
	F%	96					91					94					75				44	37					47
12	LS																					DPC + crops					LV
	F%	88					92					94					70					85					52

13	LS														Beef				Dual-purpose						LV
	F%	44			64			62			38			46			59								57
14	LS															Crop + BC			DPC + crops						LV
	F%	2			23			26			14			11			9								19
15	LS											BC + crops							DPC + crops						LV
	F%	91			84			80			67			48					19						14
16	LS											Crops							DPC						LV
	F%	99			84			93			97			49					17						18
17	LS													BP + crops							Crops + DPC + sub				DV
	F%	99			98			91						74					37						4
18	LS										Crops + DPC										Crops + DPC + sub				DV
	F%	96			97			96		94				87					26						20
19	LS											Crops							DPC + crops						DV
	F%	91			97			96			88			76					42						54
20	LS	Crops						Crops + DPC									DPC + pen									DV
	F%	91			79			68						19					4						49
21	LS							Crops							Crops + DPC						Crops + DPC + sub				DV
	F%	1			59		70			86				73					61						77
22	LS							Crops								Crops + small market					DPC + small market + crops + sub				DV
	F%	86			72		66			40				31					40						79
23	LS														Crops + BC						Crops + DPC				DV
	F%	71			39			45					20	25					23						17
24	LS																		Crops			Crops + DPC + sub			DV
	F%	10			5			5						16					11	10					25
25	LS													Crops + BP					Crops + DPC				Crops + DPC + BP		DV
	F%	89			93			90					5	17					70						55

26	LS											Crops + DPC		DV
	F%	89		67	59					48	46	54		66
27	LS												Crops + charcoal + DPC	DV
	F%	93		97	97					60	63		49	39
28	LS										Crops		Crops + DPC + subsidies	DV
	F%	89		92	90					17	70			55
29	LS												Crops + DPC	DV
	F%	93		94	90					42	31		29	27
30	LS								Crops			Small market + DPC + crops		OF
	F%	98		96	95				73	67	72			47
31	LS		DPC + crops									DPC + pen		OF
	F%	97	93	86	78					60	39			54
32	LS					Crops			Crops + BP	Charcoal + DPC + crops + sub				OF
	F%	99		96	80	76				60	50			60
33	LS			Crops						Pensions + DPC				OF
	F%	99		97	86					58	50			74
34	LS						BC + crops			DPC + crops			Off-farm work + sub + DPC	OF
	F%	8		2	0		0			0	8			24
35	LS							DPC + crops				Small market + sub		OF
	F%	1		14	12			14		14	39			44
36	LS							Off-farm work + crops				Off-farm work + DPC		OF

	F%	11		5		7		5		1			2						4
37	LS									Crops			Crops + DPC			Off-farm work + DPC + crops			OF
	F%	98		96		95				58			39						38
38	LS							Crops					Pen + DPC						OF
	F%	97		96		93		69		53			13						9
39	LS							Crops					DPC + crops			Pen + DPC + crops			OF
	F%	89		90		96		80		57			25						36
40	LS											Off-farm work + DPC + crops							OF
	F%	99		82		85				82		67		57					46
41	LS												Off-farm work + Crops			Off-farm work + DPC + crop			OF
	F%	17		39		38				30			38						36
42	LS							Off-farm work + crops					Off-farm work + DPC + crops + sub						OF
	F%	98		75		81		78		75			70						74

LS: livelihood strategy
F%: percentage of the property area covered by forest
LV: livestock-oriented
DF: diversified-oriented
OF: off-farm-oriented
DPC: dual-purpose cattle for milk production, selling male calves as beef
BC: beef cattle
BP: beef partnership – settlers raise the cattle for one or two years and, after this period, split the weight gained by the cattle with the owner of the herd
Crops: mainly rice, cassava, beans, and corn
Pen: pensions mostly from retirement
Subsidies (sub): mostly *bolsa-família*, a monthly support from federal government aiming at income distribution

Summary

Despite its global importance, the Brazilian Amazon is under threat of deforestation. Deforestation in the region has been reported in the last fifty years as one of the most serious environmental problems, reaching approximately 750,000 km^2 in 2012, or 18.7% of the forested area, concentrated along the so-called Arc of Deforestation. In the past decades, settlement projects, designed to give land to the landless under Brazil's Agrarian Reform Program (ARP), have been established mainly in the Brazilian Amazon region (designated the Legal Amazon by the Brazilian government). However, their establishment is also associated with deforestation. Settlers within these projects have to fulfil environmental obligations that require them not to deforest more than 20% of forests on properties located within the Legal Amazon, so 80% of the total area of each property must remain a legal reserve. Therefore, the government's assumption in the ARP is that a household can make a sustainable living by deforesting up to 20% of their total property areas within settlement projects. However, studies have shown that average deforestation is higher than permitted, reaching 49% of the property area in some cases. Therefore, fundamental questions addressed in this book relate to why deforestation takes place in settlement projects, what drivers are behind it, and why the reasons deforestation in these areas is higher than formally permitted. Answers about human–environment interactions are fundamental to elucidating the process that results in higher or lower deforestation in Amazonian settlement projects. In this context, there is a need to examine settlers' practices at the household level over time and the consequences for forest cover changes. Identifying and understanding the link between settlers' practices and forest cover changes would contribute to developing sustainable farming systems that simultaneously enhance the well-being of settlers and promote environmental sustainability. Therefore, this thesis addresses the specific problem relating to the competing claims on natural resources presented in the Brazilian Amazon agrarian settlements, i.e. making a living and forest cover change.

In settlement projects within the municipality of Eldorado do Carajás, located in southeast Pará State, this research investigated in more detail how settlers have made their living; how their activities and practices have affected forest cover changes within the settlement projects; and how future prospects for both, i.e. people and forest, are to be envisioned. Based on this general objective, and theoretically grounded in the Sustainable Livelihood Approach, the following four research questions were formulated (**Chapter 1**):

1) What livelihood strategies are adopted by settlers in Amazonian settlement projects?

2) To what extent are forest cover changes occurring in areas where settlement projects were established?
3) To what extent have different livelihood strategies and trajectories led to different effects on forest cover changes?
4) How do settlers perceive the factors that affect their current livelihood security and environmental sustainability in their area and what are the future prospects?

The research reveals that settlers rely on three livelihood strategies: livestock, diversified, and off-farm (**Chapter 2**). Livestock-oriented settlers base their livelihood on extensive livestock farming. The main source of income is milk production, and crop areas (cassava, rice, corn, and beans) are cultivated for home consumption. A background in livestock has driven most settlers into this cluster, reinforced by an accessible market (milk and beef) and available credit for cattle breeding. Diversified-oriented settlers are characterized by a more diverse set of land uses and means to generate income. Settlers in this cluster have a significantly larger crop area than the other two clusters. Crop income is mostly based on the cassava flour and rice markets. Cattle breeding (mainly dairy cattle) and off-farm income such as pensions and subsidies (mainly the family allowance known as *bolsa família*) are also significant for this group. Off-farm-oriented settlers have the most off-farm sources of income. The majority of this income comes from labour on other farms, ownership of small shops, and labour in external organizations. Government transfers such as pensions and subsidies also play an essential role in their livelihoods. These clusters have been shaped by a large number of additional factors and processes emanating from the ARP. All in all, the settlers have an annual income close to the national average, being less poor than often thought; they are beyond subsistence level; most of them do not rely on subsidies such as the *bolsa família*; some of them are integrated into a (dairy) market chain; beef marketing is important for income composition, although not the primary activity; and land conflicts and violence are rare nowadays, and insofar as these emerge, they are not evenly spread over all settlement projects.

Deforestation is far from being a unidirectional and linear process, with secondary forest regrowth being recorded within settlement projects. **Chapter 3** demonstrates the importance of studying forest dynamics, i.e. deforestation and reforestation, rather than deforestation, especially to observe and better understand possible forest transitions at municipal level. The forest dynamics analysis at municipal level showed an increase in forest in the last period (2005–2010), suggesting that forest transition is taking place in Eldorado do Carajás. However, future studies are needed to confirm or refute this trend. Most of the areas

where settlement projects were established displayed forest recovery in the last period of analysis (2005–2010). Moreover, settlers do not perceive secondary regrowth as forests, even when they have been recovering for 10 years or more. These 'resting' areas can be understood either as potential sites for re-cultivation – when new inputs become available – or as having a high potential to remain forested. Agricultural intensification in areas already deforested might also foster conservation of the current secondary forest and stimulate new regrowth areas, and therefore strengthen forest transition in the municipality.

Livelihood *strategies* adopted by settlers can be identified and understood as snapshot events, where they are considered as a sequence of actions in the present. Livelihood strategies, however, might also be considered dynamic and moving targets, changing according to opportunities and constraints faced by settlers over time. Thus, the concept of livelihood *trajectories* needs to be considered as well, referring to the changing ways in which individuals construct a livelihood over time. **Chapter 4** draws on the concepts of livelihood strategies and livelihood trajectories to analyse their effects on forest dynamics on properties within Amazonian agrarian settlements. Three different steps were used to find relationships and patterns of effects of livelihood strategies and livelihood trajectories on forest dynamics, respectively. However, because of the complexity involved in these two dynamic systems, i.e. livelihoods and forest, it was not possible to determine direct relationships and general patterns of effects of the former on the latter. Nonetheless, the analysis at individual, household, and property level offers some insights into factors, such as credit availability, market accessibility, and off-farm income (including pensions and subsidies) that have driven both livelihood trajectories and forest dynamics. From these individual cases, it was possible to observe how general underlying causes of deforestation and reforestation interact in different ways at property level, implying forest loss in some cases and forest recovery in others.

An increased understanding of the relationships between deforestation and the complex web of drivers is essential to support effective policy and decision-making processes, contributing towards a more balanced interaction between forest cover and local people's livelihoods. However, methods that attempt to include human–environment interactions from the perspective of local stakeholders are scarce. Moreover, settlers' practice-based knowledge about their daily reality is crucial to better understand future changes in human–environment interactions. **Chapter 5** therefore explores future plausible scenarios in livelihood security and environmental sustainability based on current perceptions of local small farmers in the Brazilian Amazon deduced from interactive stakeholder workshops.

Settlers in the study area all have a similar perception of the factors that affect their livelihood security and environmental sustainability, independent of the livelihood strategy they adopt. All settlers perceive agricultural activities (livestock and crop production); policy effectiveness; and pensions and subsidies as being the most important factors. Differences relate to the perceived interactions among those factors and the weight attributed to them by workshop participants. These often seemingly subtle differences, however, gave rise to fundamentally different system dynamics between livelihood strategies, importantly represented by clear differences in trade-offs between livelihood security and environmental sustainability. The scenario analysis showed how these trade-offs can change but generally become more pronounced in both futures that were explored. Hence, the goals of sustainable development seem not easy to realize in the area, given the characteristics and drivers of the human-environment systems, as identified by the settlers. Although all findings within this study point towards a situation where either livelihoods or the environment benefit, but not both, there might be light at the end of the tunnel as previous chapter has demonstrated that there are signs of a forest transition in the municipality and in some settlement projects. Such transition can be enhanced by policies, such as ‘ green grant’.

Using fuzzy cognitive mapping as a main participatory tool, it allows to describe the system as a whole, rather than a list of factors, which helped uncovered differences between various livelihood strategies, that would otherwise have remained hidden. It might be useful to support policies towards (more) win-win outcomes, acknowledging the fundamentally different dynamics of specific human-environmental contexts, within.

Finally, **Chapter 6** provides a synthesis and general discussion based on the findings of the preceding chapters. This chapter reflects on the research objectives and theoretical concepts used in the study, as compared with the general scientific literature.

Samenvatting

De Braziliaanze Amazone regenwouden worden bedreigd met ontbossing ook al zijn ze om diverse redenen van wereldbelang. Gedurende de laatste vijftig jaar wordt de ontbossing in de Amazone gebieden genoemd als één van de grootste milieu problemen. Het gaat inmiddels om ca. 750.000km^2, dat is 18.7% van het totaal beboste areaal, vooral langs de z.g. 'ontbossings-boog'.Onder de Braziliaanse Landhervorming (ARP) zijn de laatste decennia veel nederzettingsprojecten (kolonies) begonnen om grond te geven aan landloze boeren (kolonisten), vooral in wat de regering benoemd als 'Legal Amazon'. Deze kolonies betekenen echter ook voortschrijdende ontbossing en de betrokken boeren mogen daarom niet meer kappen dan 20% van het totale areaal bos in de 'Legal Amazon'. Volgens die regels moet 80% van het grondoppervlak op elk nieuw bedrijf dus blijven als reservaat (legal reserve). Daarom en op die manier denkt de regering in de ARP dat een gezin in haar levensonderhoud kan voorzien door slechts 20% van het totaal toegewezen areaal in de kolonies te ontbossen. Onderzoek toont echter aan dat de gemiddelde ontbossing hoger is dan wettelijk toegestaan, soms wel 49% van het toegewezen areaal. Vanwege deze spanning tussen 'verwacht' en 'geraliseerd' gaat dit proefschrift in op fundamentele vragen over ontbossing in deze nederzettingen, op de bepalende factoren (drivers) en redenen voor te hoge ontbossing. Antwoorden op vragen over de interacties tussen mens en omgeving (hier 'mens en natuur') zijn belangrijk om beter te begrijpen welke processen leiden to meer dan wel minder ontbossing in de Amazone. Daarom houdt dit proefschrift zich bezig met het onderzoek naar het effect van gebruiken en beslissingen op gezinsniveau op de bebossing. Herkenning en begrip van verband tussen die gebruiken en beslissingen en bebossing kan helpen bij het ontwikkelen van duurzame bedrijfssystemen die zowel gunstig uitpakken voor de ecologie als voor het welzijn van de bewoners van de nederzettingen. De focus in dit proefschrift is dus de specifieke problematiek van tegenstrijdige belangen (*Competing Claims*) in de kolonies van het Braziliaanse regenwoud, zoals tussen levensonderhoud voor bewoners en gewenste bebossing.

Het onderzoek speelt zich af in de gemeente Eldorado do Carajás in het zuiden van de staat Pará. Het probeert na te gaan hoe nieuwe kolonisten in hun levensonderhoud voorzien, hoe hun activiteit de bebossing in en rond de klonies beinvloedt en wat de vooruitzichten zijn voor de beide partijen: mens en natuur (in casu: bos). Binnen deze doelstelling en gebruik

makend van concepten uit de *Sustainable Livelihood Aproach* als theoretisch kader stelt het onderzoek zich vier vragen:

1) Welke strategiën hebben kolonisten om in hun levensonderhoud te voorzien?

2) In welke mate verandert de bebossing in gebieden met kolonisten?

3). In welke mate hebben verschillende strategiën van levensonderhoud geleid tot verschillen in ontbossing?

4) hoe ervaren kolonisten de factoren die effect hebben op hun huidige zekerheid van levensonderhoud en wat zijn de vooruitzichten?

Het onderzoek laat zien in hoofdstuk 2 dat de kolonisten drie hoofdsporen hebben om zich in hun levensonderhoud te voorzien. Die drie sporen (ook: clusters) zijn resp. veehouderij, diversificatie (diversified) en inkomen van elders (off-farm)

Veehouders komen aan de kost op basis van extensieve veeteelt met melk als voornaamste bron van inkomen en akkerbouwgewassen zoals cassave, rijst, mais en bonen voor gebruik binnen het gezin. Het is vooral de achtergrond van deze kolonisten als veehouders waardoor ze dit spoor kiezen, versterkt door een goede markt voor melk en vlees, samen met goede kredietvoorzieningen voor veehouderij. De kolonisten van het 'diversificatie'-spoor hebben, zoals in de naam besloten, een meer diverse manier om aan de kost te komen. Ze hebben beduidend meer grond voor akkerbouw dan kolonisten van de andere twee sporen (clusters). Hun inkomen uit gewassen komt vooral uit verkoop van cassave meel en rijst. Daarnaast krijgen ze inkomen uit veehouderij, vooral melkvee, is ook belangrijk naast inkomen uit pensioenvoorzieningen en toelages met daarin vooral een toelage bekend als de 'bolsa familia'(letterlijk de zak van de familie'). Kolonisten met 'inkomen van elders' voorzien in hun onderhoud vooral uit arbeid bij anderen, kleine winkelnering, werk elders en/of bij andere organisaties, maar ook met geld uit pensioenen en toelages. De drie sporen (clusters) zijn gevormd door factoren van buiten en de ARP. In het algemeen hebben deze kolonisten een inkomen dat niet ver afwijkt van het nationale gemiddelde. Daarmee zijn ze minder arm dan vaak wordt gedacht en zitten ze boven het bestaansminimum. De meerderheid van deze kolonisten is niet afhankelijk van de '*bolsa de familia*' en sommigen zijn goed geïntegreerd in de rest van de economie (o.a. de melkveeketen). Inkomen uit vleesvee belangrijk is maar vleesvee is geen primaire activiteit. Conflicten over landbezit, soms gewelddadig, beginnen minder algemeen te worden.

Ontbossing is beslist geen eenrichtingsverkeer en lineair process, o.a. door algemeen voorkomende hergroei van secundair bos in de gekoloniseerde gebieden. In die zin bespreekt hoofdstuk 3 het belang van de studie en beter begrip van dynamiek in ontbossing en hergroei

in plaats van eenzijdige focus op ontbossing. Het gaat vooral in op de dynamiek (veranderingen) van bebossing op gemeentelijk niveau. Daaruit blijkt toegenomen bebossing over de periode van 2005 – 2010, op zijn minst een aanwijzing dat het beter is te spreken over verandering in bebossing dan eenzijdig over ontbossing, in dit geval in Eldorado do Carajás ook al is meer onderzoek daarover gewenst om definitiever uitspraken te kunnen doen. De trend is ook zichtbaar in meer kolonies ook al zien de kolonisten zelf de secundaire hergroei niet als echt 'bos' zelfs als de regeneratie meer dan tien jaar duurt. Deze regeneratiegebieden (*resting areas*) kunnen echter wel degelijk gezien worden als mogelijke plekken voor 'her-ontginning' (als er nieuwe inputs beschikbaar komen) hoewel ze ook definitief teruggegeven kunnen worden aan de natuur als vernieuwd bos. Intensivering van landbouw in reeds gekoloniseerde gebieden zou zo een mogelijkheid kunnen zijn om nieuw secundair bos dóór te kunnen ontwikkelen en zo de herbebossing te versterken.

Aandacht voor verschillende strategiën om aan de kost te komen kan leiden tot een benaderingen van momentopnames waarin een strategie gezien worden als lineair en definitief gevolg van gebeurtenissen en beslissingen in het verleden. Zulke strategiën kunnen echter ook dynamischer worden opgevat, als fase in een dóórgaand *trajectory* waarin strategiën steeds veranderen naar gelang zich kansen en bedreigingen voordoen aan de kolonisten. Deze notie van trajectories is besproken in hoofdstuk 4 met aandacht voor dynamiek in veranderende manieren van kolonisten om aan de kost te komen. Noties van trajectories en strategiën worden gebruikt om hun effect te analyseren op veranderde bebossing in de kolonies. Drie stappen waren de basis van de poging om verbanden en patronen te vinden tussen overlevings strategieën en trajectories op bebossing. Door de complexiteit van interacties tussen het 'aan de kost komen' en 'bebossing' (tussen mens en natuur) was het niet mogelijk om duidelijke relaties en duidelijke patronen van interactie te herkennen. Echter. de analyse op niveau van individu, gezin en bedrijf geeft wel enig inzicht in het effect van factoren zoals kredietverlening, markttoegang en *off-farm* inkomen (incl. pensioenen en uitkeringen) op *livelihood* strategie en veranderende bebossing. Uit enkele cases kan men inzicht krijgen in relaties tussen onderliggende oorzaken van ontbossing en herbebossing op bedrijfsniveau, leidend tot ontbossing enerzijds en tot herbebossing (hergroei) in andere gevallen.

Beter begrip van relaties tussen patronen van bebossing is cruciaal voor betere besluitvorming en voor het maken van beleid met gebalanceerdere interacties tussen bebossing en inkomen voor de bevolking, tussen mens en natuur. Er zijn weinig methodes bekend om interacties tussen 'mens en natuur' te bekijken vanuit het gezichtspunt van de lokale bevolking terwijl het wel belangrijk is meer te weten over die inzichten van kolonisten

zelf, in dit geval over de toekomst van de 'mens-natuur interactie'. Daarom gaat hoofdstuk 5 door op mogelijke scenarios in de relatie tussen inkomenszekerheid en duurzame ontwikkeling van de omgeving (mens-natuur), vanuit het gezichtspunt van kolonisten, gebaseerd op interactieve workshops met betrokkenen. Daaruit blijkt dat kolonisten, in dit geval de kleinere boeren uit het studiegebied, allen vergelijkbare opvattingen hebben over factoren die hun inkomen en de duurzaamheid van de omgeving bepalen, onafhankelijk van de strategie die ze zelf kiezen. Allemaal beschouwen ze de agrarische activiteit (vee en gewassen), beleid, pensioenen en andere toelages als meest belangrijk. Verschillen worden echter toegeschreven aan gevoelde relaties tussen die factoren en het relatieve belang dat workshop-deelnemers er ieder voor zich aan gaven. Zulke ogenschijnlijk subtiele verschillen gaven een wezenlijk andere dynamiek in keuze van overlevingsstrategie via verschillen in afweging (*trade-off*s) tussen belang van overleven (inkomen) en duurzame ontwikkeling van de omgeving. De scenarios tonen hoe deze afweging kan veranderen, maar ook hoe ze duidelijker kan worden in de gestelde scenarios. Alles in dit onderzoek lijken te leiden naar situaties waarin dan wel de veehouderij dan wel de natuur voordeel haalt, maar niet beide. Desalniettemin is er een mogelijk lichtpuntje omdat eerdere resultaten wijzen op dynamiek van zowel ontbossing en herbebossing in de gekoloniseerde gebieden van deze studie. Zulke transitie en dynamiek kan worden verstrekt door beleidsmaatregelen zoals via 'groene fondsen'.

Fuzzy cognitive mapping helpt om het systeem als geheel beter te beschrijven in plaats van als 'lijst met factoren'. Dat hielp ook om verschillen te vinden tussen *livelihood strategies* die anders verborgen waren gebleven. Dat kan nuttig zijn om beleid te ondersteunen voor meer win-win resultaten, met inachtneming van de ogenschijnlijke fundamentele tegenstelling tussen mens en natuur. Daardoor lijken doelstellingen voor duurzame ontwikkeling moeilijk te realiseren, gezien de karakteristieken en relaties binnen mens-natuur systemen zoals gezien door de kolonisten.

Als laatste geeft hoofdstuk 6 een synthese en discussie van de onderdelen van dit proefschrift. Het kijkt terug op de onderzoeksvragen en theoretische concepten die gebruikt zijn in deze studie, tegen de achtergrond van literatuuronderzoek en resultaten van dit onderzoek.

Sumário

Apesar de sua importância global, a Amazônia brasileira está sob ameaça de desmatamento. O desmatamento na região tem sido relatado nos últimos 50 anos como um dos problemas ambientais mais graves, atingindo em 2012 cerca de 750 mil km^2, ou 18,7% da área do bioma de floresta, concentrados ao longo do chamado 'Arco do Desmatamento'. Nas últimas décadas, projetos de assentamento, concebidos para dar terra aos sem-terra no âmbito do Programa de Reforma Agrária (PRA), foram estabelecidas principalmente na região Amazônica (designada pelo governo brasileiro como Amazônia Legal). No entanto, a criação dos assentamentos é também associada ao desmatamento. Assentados dentro destas áreas têm de cumprir obrigações ambientais, as quais exigem que eles não desmatem mais de 20% da área de florestas em propriedades situadas dentro da Amazônia Legal; ou seja, 80% da área total de cada propriedade deve ser mantida como reserva legal. Portanto, a suposição do governo no PRA é que uma família pode ter uma vida sustentável desmatando até 20% de suas áreas. No entanto, estudos mostram que o desmatamento médio é maior do que o permitido, atingindo 49% da área da propriedade, em alguns casos. Diante deste quadro, as questões fundamentais abordadas neste livro referem-se a: por que o desmatamento ocorre em projetos de assentamento, quais fatores estão por trás disso, e por que razões o desmatamento nessas áreas é maior do que permitido legalmente. Respostas sobre as interações humanas-meio ambiente são fundamentais para elucidar o processo que resulta em maior ou menor desmatamento em projetos de assentamento na Amazônia. Neste contexto, há uma necessidade de examinar as práticas dos assentados no âmbito das famílias ao longo do tempo e as consequências para as mudanças da cobertura florestal. Identificar e compreender a relação entre as práticas dos assentados e as mudanças de cobertura florestal contribuirão para o desenvolvimento de sistemas agrícolas sustentáveis que, simultaneamente, aumentem o bem-estar dos assentados e promovam a sustentabilidade ambiental. Portanto, esta tese aborda o problema relacionado com as demandas conflitantes sobre o uso dos recursos naturais presentes nos assentamentos da reforma agrária na Amazônia brasileira, ou seja, meios de vida e a floresta.

A área de estudo foi delimitada em projetos de assentamento oficiais sob o Programa de Reforma Agrária no município de Eldorado do Carajás, localizado no sudeste do Estado do Pará. Esta pesquisa investiga como os assentados desenvolveram seus meios de vida, como essas atividades e práticas afetaram a mudança da cobertura florestal nos projetos de

assentamento e as perspectivas futuras para ambos, isto é, pessoas e florestas. Com base neste objetivo geral, e teoricamente fundamentada na abordagem *Sustainable Livelihoods*, os objetivos específicos deste estudo são:

1) Que estratégias de meios de vida são adotados por assentados em projetos de assentamento na Amazônia?

2) Quais as alterações da cobertura florestal ocorreram nas áreas onde os assentamentos foram estabelecidos?

3) Em que medida as diferentes estratégias e trajetórias de meios de vida afetam a cobertura vegetal nestas áreas?

4) Como os assentados percebem os fatores que afetam a sua segurança de meios de vida e a sustentabilidade ambiental e quais são as perspectivas futuras para ambos ?

A pesquisa revela que os assentados contam com três estratégias de meio de vida: criação animal, diversificação e atividades fora da propriedade (**Capítulo 2**). Os assentados cujo meio de vida é a criação animal, baseiam sua subsistência na pecuária extensiva. A principal fonte de renda é a produção leiteira, e as áreas de culturas (mandioca, arroz, milho e feijão) são cultivadas para consumo doméstico. Uma experiência prévia na criação animal, tem levado a maioria dos assentados para este grupo reforçada por um mercado acessível (leite e carne) e crédito disponível para a criação bovina. Os assentados cujo meio de vida é diversificado, são caracterizados por um conjunto mais diversificado de usos da terra e meios para gerar renda. Assentados neste agrupamento têm uma área de cultivo significativamente maior do que os outros dois grupos. O rendimento agrícola se baseia principalmente na produção e comercialização de arroz e de farinha de mandioca. A Pecuária (principalmente bovinos de leite) e fontes de renda externas à propriedade, como as pensões e subsídios (bolsa família) também são significativas para este grupo. Os assentados cujo meios de vida dependem de atividades fora da propriedade, têm as maiores fontes não-agrícolas de renda. A maioria dessa renda vem do trabalho em outras fazendas, pequenos comércios, e ocupações em outras áreas. Transferências governamentais, como pensões e subsídios também desempenham um papel essencial no meios de vida deste grupo. Estes três grupos foram moldadas por um grande número de fatores e processos oriundos do próprio programa de reforma agrária. No geral, os assentados têm uma renda anual próximo da média nacional, sendo menos pobres do que muitas vezes indicados; eles estão além do acima da subsistência; a maioria deles não dependem de subsídios como o Bolsa Família; uma boa parte deles são integrados em uma cadeia de mercado (principalmente leite); a comercialização de gado de corte é importante para a composição da renda familiar, embora não seja atividade primária. Os conflitos de terra

e violência são raros hoje em dia, e na medida em que estes surgem, eles não estão uniformemente distribuídos por todos os projetos de assentamento.

O desmatamento está longe de ser um processo unidirecional e linear, com o aparecimento de floresta secundária ocorrendo dentro de projetos de assentamento. O **Capítulo 3** demonstra apresenta a importância de estudar a dinâmica florestal, ou seja, desmatamento e reflorestamento, em vez de somente desmatamento, sobretudo para observar e entender melhor as transições florestais possíveis no âmbito municipal. As análises da dinâmica florestal no âmbito municipal mostraram um aumento na cobertura florestal no último período (2005-2010), sugerindo que uma transição florestal está ocorrendo em Eldorado do Carajás. No entanto, estudos futuros são necessários para confirmar ou refutar essa tendência. A maioria das áreas onde os projetos de assentamento foram estabelecidos apresentaram recuperação florestal no último período de análise (2005-2010). Além disso, os assentados não percebem florestas secundárias como florestas, mesmo aquelas com de 10 anos ou mais de recuperação. Estas áreas em repouso podem ser entendidas tanto como potenciais áreas para serem cultivadas novamente ou como áreas que têm um elevado potencial para permanecerem florestada. A intensificação da agricultura em áreas já desmatadas também pode promover a conservação da floresta secundária, além de estimular o estabelecimento de novas áreas, fortalecendo a transição floresta no município.

Estratégias de meios de vida adotadas pelos assentados podem ser identificadas e compreendidas como eventos instantâneos, onde são considerados como uma sequência de ações no presente. Estratégias de meios de vida, no entanto, também podem ser consideradas dinâmicas e em movimento, mudando de acordo com as oportunidades e adversidades enfrentadas pelos assentados ao longo do tempo. Assim, o conceito de trajetórias de meios de vida deve ser considerado, assim, referindo-se as mudança que os indivíduos constroem seus meios de vida ao longo do tempo. O **Capítulo 4** discute os conceitos de estratégias e trajetórias de meios de vida para analisar os seus efeitos sobre a dinâmica florestal em propriedades na área de estudo. Três passos diferentes foram usados para encontrar relações e padrões de efeitos entre estratégias e trajetórias de meios de vida sobre dinâmica florestal, respectivamente. No entanto, devido à complexidade envolvida nestes dois sistemas dinâmicos, isto é, meios de vida e florestas, não foi possível determinar as relações diretas e padrões gerais de efeitos do primeiro sobre o segundo. No entanto, a análise no âmbito individual, oferece alguns *insights* sobre o efeito de alguns fatores que influenciam na dinâmica florestal, tais como a disponibilidade de crédito, a acessibilidade ao mercado, e a renda externa à propriedade (incluindo as pensões e subsídios). A partir dos casos individuais,

foi possível observar como causas gerais e subjacentes ao desmatamento e reflorestamento interagem de formas diferentes no âmbito de propriedades, implicando perda da cobertura florestal em alguns casos e recuperação de florestas em outros.

Uma maior compreensão das relações entre o desmatamento e a complexa teia de *drivers* é essencial para elaborar políticas públicas eficazes e processos de decisão adequados, contribuindo para uma interação mais equilibrada entre cobertura florestal e os meios de vida da população local. Entretanto, os métodos que tentam incluir as interações humanas-ambientais a partir da perspectiva dos agentes locais ainda são insuficientes. Além disso, o conhecimento prático dos assentados baseado na sua realidade diária, é crucial para entender melhor as mudanças futuras nas interações humanas com o meio ambiente. O **Capítulo 5**, portanto, explora os cenários futuros plausíveis para a segurança de seus meio de vida e a sustentabilidade ambiental com base em percepções atuais dos assentados, obtidas de workshops participativos. Os assentados na área de estudo têm uma percepção semelhante dos fatores que afetam a sua segurança de seus meios de vida e a sustentabilidade ambiental, independente da estratégia de meio de vida que adotam. Todos os assentados percebem que atividades agrícolas (produção animal e vegetal); eficácia das políticas públicas e as pensões e subsídios como sendo os fatores mais importantes para sua seguranaça nos meios de vida e sustentabilidade ambiental. As diferenças estão relacionadas às interações entre os fatores e o peso atribuído a eles pelos assentados. Essas diferenças muitas vezes aparentemente sutis, porém, deram origem a dinâmicas fundamentalmente diferentes entre estratégias de meios de vida, principalmente representados por diferenças claras em *trade-offs* entre segurança dos meios de vida e a sustentabilidade ambiental. A análise de cenários mostrou como esses *trade-offs* podem mudar, mas geralmente tornam-se mais pronunciado em ambos os futuros que foram exploradas. Apesar de todas as descobertas deste estudo apontarem para uma situação em que a segurança dos meios de vida e a sustentabilidade ambiental sejam difíceis ao mesmo tempo, pode haver possibilidades de conciliação entre ambas dimensões, como o capítulo anterior demonstrou que há sinais de uma transição florestal no município e em alguns projetos de assentamento. Tal transição pode ser reforçada por políticas públicas, tais como ‘bolsa-verde’.

Utilizando *fuzzy cognitive mapping* como principal ferramenta participativa, que permite descrever o sistema como um todo em vez de uma lista de fatores, ajudou a descobrir diferenças entre as estratégias de meios de vida, que teriam permanecido desconhecidas. Esta ferramenta pode ser útil para apoiar as políticas públicas para resultados (mais) positivos para a segurança dos meios de vida e a sustentabilidade ambiental ao mesmo tempo, reconhecendo

as dinâmicas fundamentalmente diferentes na interação humana com o meio ambiente em específicos contextos.

Finalmente, o **Capítulo 6** apresenta uma síntese e a discussão geral com base nas conclusões dos capítulos anteriores. Este capítulo faz uma reflexão sobre os objetivos da pesquisa e os conceitos teóricos utilizados no estudo, em comparação com a literatura científica geral.

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Fábio Homero Diniz
Wageningen, the Netherlands
18 June 2013

Short biography

Fábio Homero Diniz was born on 30 January 1970 in Rio de Janeiro, Rio de Janeiro State, Brazil. He is the son of Pedro Homero Diniz (*in memoriam*) and Therezinha de Barros Leite Diniz, and is married to Elisângela Maria Campos Diniz; they have two daughters, Bárbara and Rebecca. In 1987, he obtained his regular high school diploma in Guanabara Institute in Rio de Janeiro. In 1993, Fabio obtained his major Agronomy from the Rural Federal University of Rio de Janeiro (UFRRJ). In the same year, he joined the trainee program of the Holstein Association of America, spending nearly a year on a dairy family farm in Branch, Arkansas. After that, in 1994 Fabio took over the dairy company owned by his family in Carvalhos, Minas Gerais State, for four years. In 1997, he was employed by the state corporation EMATER-MG (Technological Assistance and Rural Extension Corporation of Minas Gerais) as technician to support rural development in communities with small farmers. In 2002, he was employed by the Brazilian Agricultural Research Corporation (EMBRAPA) as research analyst. In 2006, Fabio completed his MSc in Rural Extension at the Federal University of Viçosa, in Minas Gerais State. His master's thesis was on the milk quality in communities' bulk cooler tanks, used to store milk from small farms. In 2007, Fabio participated in a major initiative of the Ministry of Agriculture, Livestock, and Supply, involving several institutions from the entire country, which resulted in the Good Production Practices document for dairy production. In 2009, he started his PhD in Wageningen University at the Forest and Nature Conservation Policy Group, participating in the Competing Claims Program on Natural Resources program.

After obtaining his doctorate, Fábio intends to return to the EMBRAPA Dairy Cattle unit in Juiz de Fora, Minas Gerais State, to work on improving the farming systems of small farmers in Brazil. With the aim of establishing partnerships in future research, he hopes to keep in touch with Wageningen University and other European, African and Latin American research institutes.

List of publication

(from 2009 to 2013)

Peer Reviewed Journal Papers

Teixeira, S.R., de Paula Moreira, M.S., Diniz, F.H., da Silva, V.A., 2011. Transferência de tecnologia: o que pensam os produtores de leite que visitaram a Embrapa Gado de Leite sobre produtos da pesquisa. *Cadernos de Ciência & Tecnologia*, 28(2), 607–624.

Diniz, F.H., Hoogstra-Klein, M., Kok, K., Arts, B. Livelihood strategies in the settlement projects at the Brazilian Amazon frontier: determining drivers and factors within the Agrarian Reform Program. *Journal of Rural Studies* (Under Review).

Diniz, F.H., Kok, K., Hoogstra-Klein, M., Arts, B. From space and from the ground: determining forest dynamics in settlement projects at the Brazilian Amazon. *International Forestry Review Journal* (Under Review).

Diniz, F.H., Kok, K., Hoogstra-Klein, M., Arts, B. Mapping future changes in livelihood security and environmental sustainability based on perceptions of small farmers in the Brazilian Amazon. *Ecology & Society* (Submitted).

In preparation

Diniz, F.H., Hoogstra-Klein, M., Kok, K., Arts, B. Analysing the influence of livelihood trajectories on forest dynamics at property level: Do livelihoods make a difference for forests?

Book chapters

Schiere, H., Diniz, F.H., 2011. Dairy farming in North-western Europe: the case of Dutch dairy development. In: L. Stock, R. Zoccal, G. Carvalho, K. Siqueira (eds), *Competitividade do agronegócio do leite brasileiro*. Brasília, DF: Embrapa Informação Tecnológica, pp. 235–260.

Others (technical magazines, workshops and conferences)

2012, Andrade, T. G.; Fonseca, L.; Rabelo, M. C.; Hott, M. C.; Diniz, F. H.; Kok, K.; Arts, B. Análise de alterações na cobertura florestal e pecuária no assentamento água fria no município de Eldorado do Carajá/PA. Panorama do Leite. v. 62 (Janeiro). Availabe in: www.cileite.com.br.

2012, Hott, M.C., Andrade, T.G., Fonseca, L.D.M, Rabelo, M.C. Diniz, F.H., Kok, K., Arts, B. Processamento de imagens de satélite: Cobertura florestal e pecuária de leite em assentamentos no município de Eldorado dos Carajás (PA). Leite & Derivados. v. 133, p. 76 – 84.

2011, Teixeira, S.R., de Paula Moreira, M.S., Diniz, F.H. Dados bons e amostragem adequada, mas realidade não correpondeu, o que fazer?. Presented at International

workshop on survey for policy evaluation, 2, Programa e resumos... Recife: Fundação Joaquim Nabuco.

2011, Teixeira, S.R., de Paula Moreira, M.S., Diniz, F.H., da Silva, V.A. Pesquisa em gado de leite: benefícios dos resultados e demandas de técnicos de campo. Presented at Reunião Anual da Sociedade Brasileira de Zootecnia, 48, Anais… Belém: SBZ.

2011, Andrade, T.G., Rabelo, M.C., Hott, M. C.; Diniz, F.H.; Kok, K.; Arts, B. Correção geométrica de imagens Landsat-5 em análise espaço-temporal do uso das terras de assentamentos em Eldorado do Carajás. 8° Workshop de Iniciação Científica da Embrapa Gado de Leite. Anais. Juiz de Fora. Embrapa Gado de Leite. v.8. 8 p. CD.

2009, Pires, M. de F.A., Pimenta, D.S., Sales, T.A. de, Ramos, A.S., Diniz, F.H., Cheidier, L.M. Plantas medicinais utilizadas na etnoveterinária bovina em Minas Gerais. Presented at Reunião Anual da Sociedade Brasileira de Zootecnia, 46, Anais... Maringá: SBZ.

2009, Teixeira, S.R., Helena, A., Telles, M.A., Wadt, L.G.R., Diniz, F.H. Identificação de demandas para o setor agropecuário do município de Lima Duarte, MG. Presented at Simpósio Brasileiro de Agropecuária Sustentável, 1., Anais... Viçosa: UFV.

International scientific oral and poster presentations

2012, Diniz, F.H. People and forest in settlement projects in the Brazilian amazon: combining livelihood strategies and forest dynamics under the Agrarian Reform perspective. Presented at Meeting of Researchers and Analysts of Embrapa in Europe. LabEx Europe Programme. Montpelier. France (17–18 October).

2012, Diniz, F.H. Analysing the influence of livelihood strategies on deforestation at the Brazilian Amazon settlement frontier. International Union of Forest Research Organizations. Forest for People Conference. Alpbach, Austria (22–24 May).

2011, Andrade, T. G.; Fonseca, L. D. M.; Rabelo, M. C.; Hott, M. C.; Diniz, F. H.; Kok, K.; Arts, B. Análise de Alterações na cobertura florestal e pecuária no assentamento Água Fria no município de Eldorado do carajás / PA. X Congresso Internacional do Leite. Embrapa Gado de Leite, Maceió, Brasil (26 – 28 October).

2010, Diniz, F.H. Deforestation in settlement projects: an integrated approach of livelihood and land use dynamics in the Brazilian Amazon frontier. Land Reforms and Management of Natural Resources in Africa and Latin America Conference. Centre de Cooperació per al Desenvolupament Rural. Lleida University, Lleida, Spain (25–27 November).

2010, Diniz, F.H. Deforestation in settlement projects: exploring an integrated approach of livelihood and land use dynamics in the Brazilian Amazon frontier. Scaling & Governance Conference. Wageningen University, Wageningen, The Netherlands (10–12 November).

2010, Diniz, F. H. Dinâmica do uso da terra e estratégias de sustentabilidade em projetos de assentamento rurais na fronteira da Amazônia brasileira. Presented at Pará Fest Leite. Associação Comercial e Industrial de Eldorado do Carajás. Eldorado do Carajás, Brasil (18–20 June).

Fabio Homero Diniz

Wageningen School of Social Sciences (WASS)

Completed Training and Supervision Plan

Name of the activity	Department/Institute	Year	ECTS*
A) Project related competences			
Writing Research proposal	WASS	2010	6.0
Scaling and governance	PE&RC	2010	1.5
WASS introduction course	WASS	2011	1.0
'Dinâmica do uso da terra e estratégias de sustentabilidade em projetos de assentamento rurais na fronteira da Amazônia brasileira'	Pará Leite, EMBRAPA, Brazil	2010	2.0
Land reform and management of natural resources in Africa and Latin America	Lleida University, Spain	2010	2.0
'Analysing the influence of livelihood strategies on the dynamics of forests in the Brazilian Amazon settlements'	Conference Forest for People, IUFRO, Austria	2012	2.0
'People and forest in settlement projects in the Brazilian Amazon: combining livelihood strategies and forest dynamics under the Agrarian Reform perspective'	1st Workshop EMBRAPA, France	2012	2.0
B) General research related competences			
Cognitive issues in survey response	WASS	2010	3.0
Qualitative data analysis: procedures and strategies	WASS	2010	6.0
Fundaments of geo-processing	INPE/Brazil	2010	4.0
C) Career related competences/personal development			
Scientific publishing	WGS	2009	0.3
Techniques for writing and presenting a scientific paper	WGS	2010	1.2
Academic writing I	WGS	2010	2.0
Science, the press and the general public: communication and interaction	WGS	2010	1.0
Academic writing II	WGS	2011	2.0
Workshop presentation skills (PS)	WGS	2011	1.0
Scientific writing	WGS	2011	1.8
Total			38.8

*One ECTS on average is equivalent to 28 hours of course work

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