

CHAPTER 6 - BEYOND THE METRICS: HUMAN DIMENSIONS OF LANDSCAPE CHANGE

'Dormia produtor, acordava associado'

6.1 - Understanding the human dimensions of landscape change

In modern human history, the loss of forest cover has been a persistent phenomenon. Civilizations have systematically 'cleared' extensive areas previously covered by forests as a way to occupy their territories (FAO 1999). Many causes, consequences, and responses to these processes have been suggested, depending on the culture and environment under analysis. In the tropics, where the trend of deforestation remains consistent, the subject has stimulated violent discussions (Whitmore 1998).

B. Turner et al. (1993) have proposed four categories of driving forces affecting LULC change: variables that affect demand, variables that determine the intensity of land use, variables that reflect access to resources, and variables that create incentives. Others have emphasized specific aspects related to these categories, such as environmental conditions and accessibility, macroeconomic changes, cultural characteristics influencing patterns of colonization and development, economic aspects (i.e. demand and value of timber and non-timber forest products), tenure security, institutional arrangements, among others (Angelsen 1995, Kaimowitz et al. 1999, Mertens et al. 2000). As a counterpart of the process, afforestation dynamics (i.e., the return of forest cover to lands previously deforested) have also been noted (Moran et al. 1996). The ever-increasing information about LULC processes has helped to draw a better picture about past dynamics and future scenarios within forest environments. The attractive subject has been

the focus of several research initiatives (Skole et al. 1994, Turner et al. 1994, B. Turner et al. 1995, National Research Council 1998).

Landscape change in the Brazilian Amazon has been associated with land occupation in agroecological frontiers (Moran and Brondizio 1998, Woods and Skole 1998). Facing the biocomplexity of those lands and the adversity of living there, local communities and migrants to the region have used different strategies to cope with the needs of production and subsistence (Uhl and Subler 1988, Hecht and Cockburn 1990). The subject has attracted a great deal of attention, not because it is a new phenomenon but because important environmental and socioeconomic outcomes are linked to this discussion (Schmink and Wood 1992).

Several causes of deforestation have been discussed for the Amazon region (Fearnside 1989a, Southgate et al. 1991, Moran 1993b, Painter and Durham 1995, Pfaff 1999). In particular, ultimate and proximate causes have been analyzed as variables defining the structure of incentives toward land-use decisions. The latter gives rise to or controls the proximate causes, which have direct effect on decision-making situations regarding the use of natural resources (Turner et al. 1990). Development strategies and socioeconomic dynamics due to geopolitical reasons, population migration, line credits, and tax incentives have been indicated as general ultimate forces driving LULC change within the region (Fearnside 1987, Binswanger 1991). The conversion of forests to pasture seems to be a general outcome in both small and large properties (Hecht 1993, Walker et al. 2000).

Institutional arrangements and rules-in-use among local social actors may function as proximate causes defining opportunities and constraints to individuals in

regard to the use of environmental resources (FAO 1999, Gibson et al. 2000). A broad way to define ‘institutions’ is through a ‘set of formal and informal rules and norms that shape interactions of humans with others and nature’ (Agarwal and Gibson 1999). Institutional factors can influence incentives toward land-use decisions through the implementation of a system of rules or through the rearrangement of rules. The former are given starting (or turning) points that strongly define (or redefine) the social and biophysical context in which land-use decisions take place. They shape incentives to users by delineating the initial boundaries for decision-making processes. The latter are dynamic changes in social and biophysical context that continuously modify the structure of incentives toward the use of natural resources according to each user group.

A major challenge in understanding this double-sided trajectory is to depict how multi-tiered rules affect individual decisions regarding landscape transformation (Moran et al. 1998, Leach et al. 1999). For instance, while the initial establishment of rules, such as the land-titling system, the architectural design of settlements, the access to infrastructure, and rules for the use of natural resources may define land access, other rules shaped during the process of colonization and development may affect the type of use (or lack of use) by each user group. As a result, the diversity of situations involving multiple actors, biophysical features, and rules leads to a mosaic of land-use trajectories and landscape patterns.

In the Brazilian Amazon and particularly in Rondônia, government-sponsored projects of rural settlement represent an illustrative example of how institutions can trigger a complex landscape-change process. These rural settlements have been implemented through a pre-defined institutional design, which includes initial rules

affecting the path to land-use decisions. Despite their primary goal of providing land for small farmers, the establishment of settlements typically brings along a complex social structure including multiple actors, such as loggers, extractivists, and cattle ranchers. As the initial institutional design is adjusted to local realities, new incentives and constraints arise, creating distinct patterns of interaction and variation in land-use decisions. As a result, landscape-change processes vary according to the combination of user groups involved and the ruling system in use. On the other hand, the environmental context including the architectural design in which actors interact defines resources to be used or limits factors with which to cope.

Chapters 4 and 5 discussed the outcomes of colonization processes in Machadinho and Anari regarding LULC dynamics and landscape change. This chapter analyzes factors interfering in these processes from an institutional perspective with focus on how different architectural and institutional designs have produced distinct outcomes in Rondônia. The itinerary includes a discussion of ultimate driving forces and proximate causes of landscape change. Not always is the interrelation between causes and outcomes direct or easily identifiable. However, a hierarchical approach helps to understand the intricate mosaic of interactions between people and environment. In particular, as a study of ‘human-altered landscapes,’ the chapter explores national-to-local level factors affecting the study areas, the historical role of people causing landscape disturbances, and the differences and similarities between the two settlements under investigation.

Most of this chapter is based on extensive fieldwork and interviews with local individuals in both Machadinho and Anari urban and rural areas. More than one hundred people were interviewed during 6 weeks in 1999 and 4 weeks in 2000. The interviewees

included farmers, loggers, rubber tappers, politicians (e.g., mayors, cabinet staff, city councilors), the catholic priest, evangelic ministers, governmental and non-governmental heads, local leaders, and individuals in general.

6.2 - The structure of rules and incentives affecting land-use in Machadinho and Anari

The occupation of the Brazilian Amazon is taking place through several mechanisms, including governmental and private programs, and spontaneous colonization. In all cases, local population growth occurs, mainly through migration during the settlements' implementation phase. Different levels of land-use decision making are involved. International, national, regional, and local incentives, rules, and policies affect the process, the environmental outcomes, as well as the socioeconomic conditions present in that portion of the country of relatively difficult access. Attributes of the local community and biophysical attributes of landscapes set the scenarios for individual decisions. Figure 83 illustrates a multi-tiered framework to address factors affecting landscape change. The approach is based on the Institution Analysis and Development framework (Ostrom 1997), where actors within an action arena interact and adapt according to environmental attributes, community attributes, and rules-in-use. From the operational standpoint, the analysis of these processes within the research in Rondônia was derived from a multi-temporal and multi-spatial approach about the study area and its actors (Figure 84).

The first step was the choice of boundaries. As stated in Ostrom et al. (1994), it is not easy to distinguish where one situation ends and the next one begins. However, for

analytical purposes it is essential to define boundaries in space and time in order to focus on specific events. This chapter, as the rest of the dissertation, focuses on the settlements of Machadinho and Anari, considering their administrative boundaries as implemented by INCRA. The time frame went back to the early 1980s to ensure a broader context about processes and patterns of interactions occurring within the study area.

Figure 85 illustrates a sequence of events occurring at national, regional, and local contexts during Machadinho and Anari implementation and consolidation phases. These events affected the action arena and the actors' decision-making processes through time, leading to social and environmental outcomes. For the purpose of this analysis, the so-called actors (i.e., loggers and settlers in Anari, and loggers, settlers, and rubber tappers in Machadinho) are the direct agents of landscape change. They take actions concerning the land, clearing areas, managing natural resources, and developing production systems. Figure 86 illustrates the main actions taken by settlers, rubber tappers, and loggers on private properties and communal reserves in Machadinho and Anari.

Settlers had access to land through elimination and classification criteria based on socioeconomic assets and carried out by INCRA. The process of choice of property lots was somewhat chaotic and sometimes involved corruption. Conflict resolution between new settlers and previous occupants of the land (*posseiros*) was in general mediated by INCRA, but often involved violence. The action of *grileiros* also caused problems for settlers. They often took over the land from weakened households. The situation involved persuasion (i.e., convincing illiterate settlers that they did not have the right to use the lot) or violence (i.e., expelling families of settlers under threat of murder). In the early 1980s, the general picture in Machadinho and Anari included families of settlers from south and

southeast Brazil coping with their environmental and social opportunities and constraints in searching for a better life at an Amazonian agroecological frontier.

Rubber tappers have lived in the study area since the late 1800s. They are mostly descendants of northeastern migrants to Rondônia during the rubber boom. The saga of rubber tappers in the Amazon has been extensively described and will not be discussed in detail here. One of the most important changes in their function as social actors occurred recently with the creation of extractive reserves throughout the Amazon (Allegratti 1989, Miranda et al. 1990, Anderson 1992). Specifically, they have played a central role in Machadinho, where extractive reserves were included within the settlement design. The right to use natural resources within the reserves is restricted to rubber tappers. They also had the opportunity to apply for property lots. In fact, some reserves have rubber tappers living in the reserves' surroundings. In this case, the distinction between these two groups of actors (i.e., settlers and rubber tappers) is somewhat interrelated. Besides this specific situation, they inhabit the reserves and make their living through a subsistence economy.

Loggers represent another important group of actors at rural settlements in Amazônia (Browder 1986, Almeida and Uhl 1995). They often exploit timber resources in all phases of a settlement according to the availability of economic species and rules of access to forests. Illegal operations are frequent, mainly during early stages of land occupation. Loggers extract timber from unclaimed lands without permission, but also from claimed lands through invasion or accords with local governmental organizations, settlers, and, more recently, rubber tappers. The action of loggers has been often necessary to provide access for the settlers to their lots through road building. Also, loggers have cleared initial portions of the lot where settlers develop their production

systems. The interactions between settlers and loggers have been often based on opportunistic actions by the latter, which quickly exploit the most valuable species without concern for environmental or social impacts. Recently, efforts have been made by the Brazilian government and IBAMA to set up clear policies for timber extraction in the Amazon, mainly through the release of legal permissions consonant with management plans. However, these initiatives are far from being effectively enforced.

Processes of landscape transformation caused by human occupation in Machadinho and Anari are discussed throughout this dissertation. In order to provide a better understanding about the trajectories of each colonization project, the following sections describe historical aspects associated with their implementation and the structure of rules and incentives for each actor taking direct actions over the landscape and its environmental resources.

6.2.1 - Anari: a ‘rapid settlement project’

The implementation phase of Anari started between 1980 and 1982. The settlement was part of a cooperative program between the federal agency INCRA and the State government of Rondônia with the goal of settling 16,000 families. The strategy was called ‘rapid settlement project’ (*projeto de assentamento rápido*), and carried out as an emergency plan. The program succeeded in settling 12,315 households in approximately 800,000 ha in 11 tracts throughout Rondônia (Rondônia 1996d). INCRA was responsible for carrying out part of the implementation phase (including land demarcation and distribution) and the emancipation phase, when land titles were issued. The State government was supposed to provide basic infrastructure and maintenance services.

Thus, INCRA delivered the settlements with just the main dirt road and partially opened feeder trails to provide access to the lots.

Anari was the largest settlement within the 'rapid project' strategy, encompassing an area of 1,246 km². Approximately 2,000 families were settled in lots of 50 ha each (Rondônia 1996d). Anari maintained the blueprint of a fishbone-like design, with a main road crossing the settlement and secondary feeder roads crossing perpendicularly every four kilometers from the main village (Figures 5 and 6). However, since the State government failed to fulfill its commitment to improve the road network, the poorly opened feeder trails provided difficult access to the parcels. The lack of an improved road system created an extra burden to settlers, who had to open the way to their properties. By that time, families were settled at their lots without water, electricity, roads, or assistance for beginning their life at the frontier. The main village had only a few houses and no available infrastructure.

Another infrastructure problem that narrowed the options regarding the use of rural properties in Anari by settlers was the lack of a center with basic services. Improvements to the village and to the main road took place only with the implementation of the Machadinho settlement project years later (1982-1984). Health problems, such as malaria strongly affected the labor force available in the area during the early stages of the settlement (Rondônia 1996b). Land abandonment was frequent, creating opportunities for speculators to aggregate underused lots by clearing them and converting the land to pasture. Although showing an increasing trend during the last five years, the population of Anari after twenty years of colonization consisted of 7,713 inhabitants, 76% of them still living in the rural area (Table 41) (IBGE 2000a).

Besides all the constraints on the establishment of properties, land use was also limited by federal legislation, in which 50% of the parcel was to be kept intact as private forest reserves. In addition, settlers were restrained from bank loans due to lack of information within their settlement, difficult access to the closest urban centers where banks were located (i.e., about 80 km of poorly maintained dirt roads), and lack of political organizations that could mediate the negotiation. At the time, a different scenario was taking place in Machadinho.

6.2.2 - Machadinho: a better design for settlement projects in the Amazon?

Machadinho was implemented between 1982 and 1984 by INCRA as part of a broader development project funded by the World Bank (POLONOROESTE). The original settlement had an area of 2,090 km² with 2,934 plots designated for landless small farmers. Despite a similar demand to accommodate migrants in Rondônia, the settlement project (*projeto de assentamento - PA*) Machadinho, along with two other projects — Cujubim and Urupá — represented an alternative design for rural development, which was meant to overcome past failures (Fearnside 1986, 1989).

As part of this endeavor, Machadinho was a settlement project gifted with distinct architectural and institutional designs in comparison to former initiatives throughout the Amazon. Property lots were defined according to watershed topographic features. The road network was constructed along the ridges, facilitating its maintenance and allowing water access to almost all settlers by including a stream in the rear of the property. The topography-oriented design was combined with an alternative institutional design related to forest reserves (Figure 6). The settlement included 16 communal reserves of different

sizes, which encompassed 33% of the total settlement area (685 km²) with right-of-use to rubber tappers (Table 16). The reserves were created to achieve ecological, economic, and social goals. Ecologically, larger forest areas could be preserved under lower levels of fragmentation. Economically, by ensuring forest preservation within the communal reserves, settlers would be allowed to use the full extent of their properties with no legal constraint.⁴ Socially, the rubber tappers who had lived in 90 extractive locations (*colocações*) distributed throughout the settlement would have their livelihood ensured by the communal reserves.

In addition, settlers counted on a privileged treatment in terms of infrastructure, including gravel roads throughout the rural area. INCRA built 725 km of road network in Machadinho, divided into four hierarchical levels: 11 km of four main roads (access roads), 105 km of feeder roads level 1 (collect roads), 314 km of feeder roads level 2 (feeder roads), and 295 km of feeder roads level 3 (penetration roads). These figures represent the best-served road structure of all regular settlement projects in Rondônia up to this date in both gross and per area of road footage.⁵ INCRA also provided basic services such as one school, one health center, electric and water pipe systems, and an airport (59 ha) within the 2,000 ha urban center. In the rural area, 10 secondary villages (953 ha), 44 schools, 547 houses, 60 wells, and 5 health centers were built (Miranda and Mattos 1993). Agencies related to agriculture and environmental activities were set in the area to provide technical assistance to the farmers (e.g., INCRA, EMATER, EMBRAPA,

⁴ This rule was not supported by federal legislation and recently has been questioned.

⁵ Other special settlement projects — directed settlement projects and integrated colonization projects — were similarly served with larger road infrastructure, but following the fishbone scheme (Rondônia 1996d).

CEPLAC, IDARON, IBAMA, SEDAM). In particular, the extension agency EMATER supported the creation of associations in different tracts throughout the settlement.

The institutional arrangement derived from Machadinho's design led to the existence of three major groups as direct agents of landscape transformation (i.e., settlers, rubber tappers, and loggers). The settler population came mostly from the States of Paraná and Minas Gerais and encompassed 2,934 immigrant households. They occupied 67% of the area (1,415 km²) in private lots of about 44 ha. The outcomes in terms of LULC change at the properties were described in Chapter 4.

The communal reserves house a total of 401 individuals. The reserves are property of the State with the residents having the right-of-use. They are organized in a local rubber tapper association, which is linked to state and federal councils. Their income is centered on the production and commercialization of raw rubber and based on subsistence economy (i.e., slash-and-burn agriculture, forestry, game, and, more recently, small coffee plantations). In 1995, the reserves were decreed State Extractive Reserves, allowing communities to make their own management plans, which may include sustainable logging operations. Just one reserve has a different status with use restricted to the State (*Floresta de Rendimento*) (Olmos et al. 1999).

As mentioned before, loggers also play an important role in modifying forest structure and in clearing forests in Machadinho. Chapter 2 briefly describes the production systems associated with settlers, rubber tappers, and loggers. The sections below discuss the incentives and constraints for each group affecting landscape within the study area.

6.3 - Actors and resources: the underlying processes of landscape change

Anari and Machadinho represent two radically different cases of settlement design strategy in the Amazon. In spite of biophysical and historical similarities, their implementation differs due to the political context in which each settlement was conceived. As discussed earlier, the population growth in the 1980s due to rural and urban development in Rondônia created a demand for new colonization projects in order to settle the landless population coming mostly from southern and southeastern Brazil. On the other hand, the constant critique of settlement projects in the Brazilian Amazon created a need to implement a more socially and ecologically consonant model of colonization.

It was between these two political pressures — demand to settle landless migrants and demand for a more sustainable settlement model — that Anari and Machadinho were conceived. As an effort to ameliorate social problems resulting from waves of migration, Anari was part of an emergency initiative led by INCRA and the State government of Rondônia. According to this joint program, INCRA would demarcate and distribute 50 ha lots with their respective land titles. The State government would assume the responsibility of providing basic infrastructure and institutional support. Two years later, INCRA and international donors teamed up to establish Machadinho as part of a pilot initiative to create a settlement model that would lower social and ecological impacts. The agreement, in this case, established that INCRA would provide all infrastructure and institutional support during the project implementation through financial support from the World Bank. While the State government failed to accomplish its commitment in Anari, Machadinho was implemented as planned.

As a result of the distinct institutional and architectural scenarios, social development following the implementation phase took different paths in each settlement. From a pristine situation when the region was mostly forested to the current mosaic of LULC patches, the human footprint has established new landscape patterns in the last twenty years. Different processes of forest clearing and land use are outcomes of both the settlement architectural design and the distinct institutional arrangements within the settlements. The implementation strategy, when a set of rules was defined during the initial phase of the settlements, and the consolidation phase, when systems of rules were rearranged due to internal and external pressures, were key components in the complex process driving local populations to make land-use decisions that are reflected in the current landscape patterns.

6.3.1 - Implementation phase

The initial architectural and institutional design in which a settlement is conceived defines opportunities and constraints toward land-use decisions at households and communities. Such land-use decisions reflect directly in the land cover. Settlement designs in the Amazonian frontier are a case in point. Often, the implementation of settlements has taken place through government-sponsored projects based on blueprint fishbone road networks, occupied by migrants claiming rights to land through forest clearing. Among several negative social and ecological consequences, this settlement implementation strategy has produced high deforestation rates to ensure land occupation, frequently followed by land aggregation for cattle ranching after abandonment by smallholders (Hecht 1993). Moreover, social conflicts have also been reported between

newcomers and local populations, such as indigenous residents (Schmink and Wood 1992), *caboclos* (Moran 1981), and rubber tappers (Allegretti and Schwartzman 1986).

Anari and Machadinho are extreme examples of how implementation design can influence LULC change within a rural development project. Anari illustrates the classic blueprint settlement model carried out in the Amazon Basin and particularly in Rondônia. Machadinho illustrates how settlement implementation can incorporate ecological (topography-based), economic (infrastructure), and social (accountability to local populations) attributes that have usually been overlooked in other development projects.

In regard to ecological accountability, orthogonal road networks often create unequal access to fertile soil, relatively flat terrain, and sources of water (McCracken et al. 1999). In Machadinho, the property grid design based on topography has produced major implications in the efficiency of land-use systems and landscape outcomes. First, forest reserves were defined in steeper areas where farming production is more difficult. Private lots were laid out in less rugged terrain in such a way that most lots have access to at least one stream. In this sense, water access is relatively equal compared to fishbone designs, in which straight lines do not take topography or watershed boundaries into account. Although streams in Machadinho are usually placed in the back of the property, which may create some limitations to water access, the distribution of this resource among landowners is far more effective than in Anari. As a result, in Anari few settlers have been granted lots served by water springs and flatter areas, while many received lots with hilly terrain and no water access.

Interestingly enough, the accountability for ecological features in the settlement design of Machadinho has not affected the decision of settlers to clear forest, at least in

terms of the percentage of the property. As mentioned in Chapter 4, landowners from both settlements have cleared an average of 54% of their lots to date (Tables 19 and 22). According to Brondizio et al. (in press), the behavior of groups of settlers (cohorts) in frontier lands can be predicted and often is affected by the time of arrival. Cohorts of settlers tend to produce similar outcomes in terms of forest clearing. This pattern seems to be reproduced in the study area. However, as also pointed out in Chapter 4, the area cleared per property is higher in Anari because the lot is generally larger and the settlement was implemented two years earlier than Machadinho. Perhaps, the major differences in terms of LULC change in Anari and Machadinho are related to decisions regarding production systems. Anari settlers have produced a higher rate of forest conversion to pasture than in Machadinho (Table 14). Moreover, it seems that better water access as well as less rugged terrain in most lots improved the efficiency of agricultural systems in Machadinho. This is corroborated by productivity indices measured by the Brazilian government (IBGE 2000b). As a result, settlers have had less incentive to convert forest to pasture.

In regard to infrastructure, the topography-sensitive road network in Machadinho contrasts with the fishbone-like road network in Anari. Besides accounting for relief variability, Machadinho roads were well established in three hierarchical levels, reaching the most remote lots. In addition, the road network allocation along the ridges has lowered the maintenance costs when compared to the fishbone design. Orthogonal roads crossing the drainage system perpendicularly demand bridge building and higher levels of erosion control, which is often neglected in the region. As seasonality is an important variable affecting trafficability, many settlers remain isolated during the wet months. The

relative high transportation cost also influences smallholders to choose pasture over cash cropping in Anari. Besides the fact that ranchers can drive cattle herds even on poorly maintained dirt roads, ranching is an easier activity to manage whenever market access and incentives toward agricultural activities are unstable. Two other important aspects of infrastructure provision in Machadinho are related to the allocation of an urban center with many facilities and the strong presence of governmental agencies accelerating rural development. This has helped smallholders to have access to credit lines (banks), social organization (associations), technical information (extensionists), health aids (health centers), and general market goods.

Finally, social sensitivity toward forest dwellers was a major institutional novelty in the settlement design of Machadinho. In general, settlement projects carried out by the Brazilian government have focused solely on migrant settlers. However, the existence of a more heterogeneous group of actors regarding land-use interests can lead to different patterns of interaction depending on the social context. For example, the interaction between loggers and settlers in frontiers where road access is poor follows a singular pattern. In this case, loggers usually take advantage of the situation and extract timber cheaply from private lots in exchange for providing machinery and labor to open roads and trails for the landowners. Anari was more vulnerable to this process due to the need of improving the road network.

Another intricate interaction occurs between local populations and migrant settlers. While landowners were allowed to clear only 50% of their lots in other settlements (regardless of the lot size), Machadinho settlers were allowed to clear 100% of their lands as a result of the creation of communal reserves within the settlement. By

the same token, rubber tappers could choose to stay in their area or to receive a private lot in the reserve surroundings. The establishment of forest reserves produced positive ecological outcomes in Machadinho. The reserves helped to maintain larger forest patches spatially spread throughout the landscape as opposed to smaller and fragmented forest remnants within the fishbone-like settlements. The consolidation process that followed the implementation phase led to other changes that further affected each actor regarding land-use decisions and landscape transformation.

6.3.2 - Consolidation phase

The previous section discussed how the implementation phase of Machadinho and Anari defined the initial social and ecological arena where local decisions were taken. In addition to initial incentives, internal variations emerged according to different social assets among actors. Smallholders turned into subsistence cultivators, perennial crop cultivators, and cattle ranchers according to different portfolios of production systems, as illustrated by Table 4. The co-existence of loggers and rubber tappers in Machadinho complete the social mosaic that is directly reflected on the landscape. However, the landscape outcome differed within the settlements as they are related to how the structure provided in the implementation phase affected the institutional changes carried out during the consolidation phase. The variation in land-use decisions is related to both external and internal changes. Figure 85 includes a general overview of events affecting the consolidation of Machadinho and Anari. For example, Machadinho was emancipated in 1988, while Anari became a municipality only in 1995. Recently, new settlements have been established in both municipalities, a process that still occurs in a dynamic fashion.

Although some social and economic links still remain, the two municipalities have increasingly taken independent economic and political paths. In addition, land tenure system, product prices, and provision of bank loans have changed in the last decade, each affecting differently the three main actors in the region.

In regard to settlers, the initial rule providing alienation rights to the lots was promptly violated. According to INCRA, settlers hold right-of-use during the first five years, receiving the title if land use is demonstrated. However, turnover in parcel ownership took place informally right after the parcels were allocated to settlers. Land aggregation for cattle ranching was the expected consequence, as in other settlement projects within the Brazilian Amazon. The results on LULC suggest that this process was more prominent in Anari. The maintenance of larger areas in crops rather than pasture in Machadinho is related not only to original design but also to how settlers responded to bank loans. The support of EMATER, combined with relatively organized associations in Machadinho have supported smallholders to continue cash cropping along with other activities in their farming system as opposed to Anari, where the lack of institutional support and infrastructure encouraged pasture conversion.

The large number of associations does not mean that effective social organization is occurring. The variation of individual interests and the increasing level of internal conflicts among members have weakened the sense of association, formerly promoted by governmental initiatives as well as religious efforts (particularly by the Catholic Church). Thus, the growing number of associations in recent years has been mainly due to incentives to create legal entities to apply for bank loans. Following loan approval, the organizations are left purposeless and weakened. An alternative form of organization that

has emerged in the region combining both political strength to claim rights and the economic goal of marketing achievements is the cooperative located in Machadinho. With more than 200 members, it is the strongest association within the settlements.

Regardless the weak political strength of local associations in the region, the more expressive presence of such organizations in Machadinho is an important social capital that has helped settlers to be more resilient to external influences such as product prices, bank loans, and land conflict issues. In Anari, some initiatives are taking place, as EMATER and IDARON have also installed offices in town. An important trend to follow is the trajectory in coffee cultivation, as most of these associations are improving the production of coffee seedlings and stimulating the use of new technologies such as agricultural mechanization and irrigation. In Machadinho, a research project analyzing the role of associations in LULC change is currently under way (Sydenstricker-Neto 2000).

As land-use strategies have been changing rapidly in the region, a major challenge for the maintenance of forest stands within the private lots in Machadinho exists. Recently, IBAMA has disclosed a claim that the 100% deforestation permission in Machadinho parcels was mistakenly taken and has no legal value. In other words, despite the implementation of communal forest reserves within the settlement, settlers should follow similar restrictions in their lots as in other Amazonian areas. Therefore, INCRA agents have erroneously passed an informal permission that was not considered detrimental twenty years ago. International and national concerns toward monitoring deforestation in the Brazilian Amazon and the recently decreed Land Zoning for the State

of Rondônia have faced this institutional misunderstanding by enforcing the 50% forested area rule in Machadinho.

Other trends have influenced land use in terms of labor force, technology, access to bank loans, and new market demands. In regard to labor force, during the earlier years of settlement, the average family size in Machadinho was approximately five people with three members of working age. Family labor constituted the main source of agricultural labor, while contracted labor was rare (Miranda and Mattos 1993). More recent studies have shown that families now frequently contract labor outside the household, employing an annual average of five temporary and two permanent workers per family (Miranda et al. 1997). In regard to technology, mechanization, irrigation techniques, as well as weeding machines have recently enabled households to cultivate larger areas. The release of small bank loans has allowed settlers to more easily have access to those technological innovations. As a result, while forest clearing in both settlements at the property level has reached an average of approximately 54% after fifteen years of occupation, only now do settlers feel the weight of this land-use restriction. It is still unclear how the combination of these new internal and external changes will fit with the fact that the 50% forest reserve rule that had been lifted until recently will suddenly be effective. Recent discussions are taking place in congress for a new Forestry Code, in which the percentage of land to be preserved could be even higher. However, it is questionable if these rules will be successfully enforced.

While settlers face new trends in land-use restrictions, rubber tappers in Machadinho face new opportunities regarding the management of natural resources. Perhaps, the major flaw of the Machadinho design as far as rubber tappers activities are

concerned, was posing the burden of forest conservation on them while economic support to use forest resource was scarce. Rubber tappers were granted a large area of 685 km² where only 401 individuals live. Those who chose to leave the reserve and receive a private lot are accused of taking advantage of both figures (private lots and communal reserves). Yet, a major problem posed to those living at communal reserves was the limited use of land for subsistence and lack of economic activity, while some companies illegally carried out logging operations. Rubber tapping has become increasingly uneconomic and the lack of alternatives has created incentives for residents to search for other activities. Only recently, when these forests were decreed State Extractive Reserves, rubber tappers were enabled to formulate their own forest management strategy with support of agencies and grassroots organizations to use the forest for commercial purpose, including sustainable logging (Olmos et al. 1999). As a result, incentives to monitor poaching by illegal logging activities have increased. In addition, rubber tappers have been provided with infrastructure to patrol the area. The outcome of this new institutional turn is too recent to be evaluated. Within the following years, land cover within the communal reserves, where landscape change was practically null during the last twenty years, will probably reflect in different landscape patterns. Whether this change will affect the ecological stability of the landscape depends on the ability of rubber tappers to develop a coherent management plan and a monitoring system to keep up with the system.

The development of forest management plans by rubber tappers has been relatively isolated from settlers' activities. Yet, loggers have been affected by rubber tappers' decisions. The ability of rubber tappers to manage their own reserves is not only

essential in providing social justice to these local populations who have been deprived from economic alternatives, but they have also helped to halt the illegal activities of several logging companies. In addition, new rules of timbering included in the National Forestry Code have required management plans for every logging activity. Although the enforcement of these rules is still not effective, there is a chance for better use of forest resources if surveillance operations are carried out within the settlements. Despite the restrictions regarding forest reserves, logging has represented an important part of the economy in Machadinho, where a new industrial area is being established to house several logging companies. In addition, the implementation of other settlement projects has opened new frontiers to logging activity within the municipality. Therefore, while communal reserves may be maintained by rubber tappers' management plans, a better institutional strategy is still to be found that will ensure forest protection from illegal logging in other areas close by.

6.4 - Toward better interactions among actors in the frontier

Identifying the human dimensions of landscape change in Machadinho and Anari is as complex as comparing the effects of different settlement architectural designs in land-use decision making processes. This double-sided puzzle underlies multiple sections of this dissertation, but it is in this chapter that a more institutional-based analysis was carried out. The rationale behind this approach is that addressing the human dimensions of ecological processes within the settlements' landscapes allows a better understanding not only about local people's social trajectories, but also about interrelated causes, consequences, and outcomes of LULC change.

Land-use decisions in the study area are influenced by two major sets of events. The scenario has a starting point (establishment event) when initial rules delineate the structure of incentives to the actors. In Machadinho and Anari, the establishment of different architectural and institutional designs during the settlement implementation phase defined distinct opportunities and constraints for settlers, rubber tappers, and loggers. The second set of events took place as dynamic changes, affecting the structure of incentives toward land use and resource management. In the study area, land tenure arrangement, bank loans mediated by associations and governmental organizations, and the establishment of communal extractive reserves, represent major events affecting LULC dynamics and landscape change.

While some institutional arrangements have taken place in order to adjust land-use activity to an ecologically and socially sound plan, many other institutional changes have created incentives for uncontrolled use of resources. Changes have taken place at different tiers of actions (e.g., technology and labor force at the household level, bank loans, land tenure, forest-use rules at the group level, and policies and infrastructure at the regional level). Each factor has synergistic effects on the landscape and depends on the pace and intensity of change that reflect land-cover outcomes. In this sense, recent trends are important. While some land-cover changes have been related to institutional and architectural design through incentives for land-use activities to date, many changes are only beginning to take place.

Following these trends may bring new elements to the understanding of the important role of interactions among actors during the implementation and consolidation phases of settlements in Rondônia. Moreover, as rural development, LULC change,

urbanization, and social class differentiation take place, it is important to watch for possible conflicts among actors and how they are mediated. In particular, actions causing or increasing forest fragmentation and environmental degradation should be followed with attention.

This discussion highlights the importance of the management of common-pool resources (Ostrom 1990, Hardin 1998). Recent integrative works have advocated the need of governance over resources by local people (i.e., institutions-centered approaches) rather than focusing on community-centered approaches (Agrawal and Gibson 1999). The communal reserves in Machadinho are exemplary. In Chapter 4, multi-temporal LULC assessments have shown that forest cover within these reserves has not decreased. This has happened not only because of the reserves per se, but because of their management by rubber tappers organized in associations and with clear strategies regarding their rights over these lands. Perhaps, the answer for a more sustainable environmental outcome in rural Amazonian areas depends on more sustainable interactions among actors using natural resources.