

# CHAPTER 1 - MOTIVATIONS FOR THE STUDY OF LANDSCAPE CHANGE IN RONDÔNIA, BRAZILIAN AMAZON

*‘O amanhecer em uma terra distante pode ser o crepúsculo diante de nossos olhos’*

## 1.1 - Introduction

Sometimes the easiest way to say what a dissertation is about is to emphasize what it is not about. This dissertation is not about vegetation ecology, remote sensing, land use/land cover (LULC), landscape metrics, or human dimensions of landscape change. Although these topics are present throughout the research, they are used as lenses focusing on different aspects of the Amazonian colonization rather than as ultimate objects of study. The investigation of trajectories and consequences of occupation in a region known mostly by its agroecological failures than by its successes is appealing. In recent years, this challenge became even more fascinating, as the human dimensions of environmental change started to be recognized not just as a new field of research, but as a way of understanding ecological causes, consequences, and outcomes. These latter three terms portray a dynamic character and lead to responses of both people and the environment.

The analyses described in this dissertation represent an effort to better understand how colonization processes within the Brazilian Amazon affect landscape change and LULC dynamics. More specifically, it focuses on one area of the well-known State of Rondônia, a land of change and challenge that deserves an impartial approach. Throughout the pages of this work, Rondônia is not considered just a ‘frontier’, as the Amazon is not just a ‘jungle.’ Anacondas, myths, and catastrophic views we leave for the

poets. Explicit boundaries were defined to control the research questions and the search for answers. The rationale behind this initiative was to understand that a remote region is not just an object of study, but also a home for millions of people coping with a heterogeneous and diverse environment on a daily basis.

Landscape transformation and its implications to problems such as global change, biogeochemical cycles, LULC dynamics, deforestation, and biodiversity have become central issues in environmental science (Turner et al. 1994, B. Turner et al. 1995, Kaimowitz and Angelsen 1998, National Research Council 1998). As a consequence, new ecological theories (Wilson 1998), modern methods to study spatial dynamics (Costanza et al. 1993, M. Turner et al. 1995) and many applications to natural resources planning and monitoring have taken place (Goodland et al. 1993). To address the process of landscape change by using a spatial-temporal integrative methodology is highly important to regions such as the Brazilian Amazon, where deforestation has attracted international attention (Moran 1993a, Skole and Tucker 1993). The integration of remote sensing data, GIS techniques, and landscape ecology methods have emerged as a promising area to help us understand deforestation dynamics and land use, and their ecological and social impacts (Mausel et al. 1993, Lambin 1997, Liverman et al. 1998).

Within the Amazon Basin, some particular areas offer great potential for such studies. One of these areas is located in the State of Rondônia, where deforestation rates have been the highest in the Amazon during the last twenty years (Dale and Pearson 1997, Alves 1999). A number of studies about colonization projects in the Brazilian Amazon have taken place (Moran 1981, Smith 1982, Uhl and Vieira 1989, Schmink and Wood 1992, Browder and Godfrey 1997, Miranda et al. 1997). The processes of

deforestation associated with human occupation in the region have also been studied. Research has focused on the amount and rate of deforestation (Malingreau and Tucker 1988, Skole and Tucker 1993, INPE 2000) and on social, economic, and ecological processes related to the phenomenon (B. Turner et al. 1993, Brondizio et al. 1994, Moran 1994, Walker et al. 2000). Understanding LULC changes to achieve a sustainable strategy is a matter of growing interest to communities in the Amazon, to regional and national policy makers, and to all those concerned with the consequences of deforestation (Goodland et al. 1993, McCracken et al. 1999). However, no comparative research has been made about the role of different settlement designs on landscape change and fragmentation.

In Rondônia, the demand to settle migrants induced the establishment of rural development projects. Often these projects include an orthogonal road network known as 'fishbone' and have been implemented without considering the environmental constraints and landscape characteristics of each region. The settlement called Vale do Anari (Anari) is a typical example. During the early 1980s, the Brazilian Agency for Colonization and Agrarian Reform (INCRA) tried a new model of settlement, in which the road network and the property grid follow the watershed topography and communal forest reserves were allocated for local populations. This settlement is called Machadinho d'Oeste (Machadinho). The study area totals approximately 3,000 km<sup>2</sup> and is located approximately 400 km from Porto Velho, the capital of the State, encompassing both Anari and Machadinho. A period of ten years (1988-1998) was defined for the satellite image-based analysis, so the trajectory of land occupation could be followed. To carry out the comparative study between the two designs of colonization (i.e., fishbone and

topography-oriented designs), the environmental setting is an ideal laboratory to test hypotheses about the role of settlement architecture and institutions on LULC dynamics and landscape structure change.

In this sense, this dissertation contributes to two gaps in research about the Brazilian Amazon. First, it attempts to address LULC change at an intermediate scale, between the farm and the region, making the necessary link between local and regional processes. Second, it is concerned with colonization settlements in Rondônia, in an area at a transitional stage of occupation; that is, they are not along Highway BR-364, where older farms dominate the landscape, nor in marginal zones of the State, which are still without access and infrastructure. In addition, the research uses an innovative, comparative approach. Two adjacent settlements of similar age, with similar biophysical features in their landscapes and similar assets among colonists, were compared to assess the role of their different architectural and institutional designs in LULC dynamics and landscape change. Thus, this dissertation is about the study of trajectories of change within Amazonian landscapes under distinct yet concurrent regimes of colonization.

## **1.2 - Hypotheses and research questions**

Preliminary studies in Rondônia suggest that settlement design may affect human land-use preferences and influence ecological dynamics such as rates of deforestation and secondary succession (Miranda et al. 1997, Batistella et al. 2000, Batistella and Castro 2001). Based on these indications, three hypotheses were formulated for this study.

### **Hypothesis 1**

The fishbone settlement design of Anari leads to faster deforestation than Machadinho's architecture based on topographic features and including communal forest reserves.

### **Hypothesis 2**

Landscape fragmentation is higher in the fishbone settlement of Anari.

### **Hypothesis 3**

Institutional arrangements accounting for different social actors and allowing governance over natural resources to local actors in Machadinho produce positive environmental and social outcomes.

The study of LULC dynamics and landscape change in Machadinho and Anari represents a rare opportunity for a controlled comparison between types of settlement architectural and institutional designs in areas of relatively recent colonization in the Brazilian Amazon. Because Machadinho and Anari are adjacent to each other, the study area provides a quasi-experimental approach. As shown in the following chapters, the assessment of the colonization impact within these two distinct settlements produced accurate information about landscape structure and LULC change. If the hypotheses presented above are confirmed, the study will create the challenge for rethinking settlement implementation strategies in the Amazon. Producing the elements for such debate is the main goal of this dissertation.

Differences between occupation design and strategies in Machadinho and Anari suggest that institutional arrangements, human land-use preferences, and ecological dynamics are also distinct. This dissertation seeks to use methods for the quantification of landscape heterogeneity and change for the two settlements, searching for answers to the following questions:

1. How can the study of vegetation structure inform LULC classifications based on satellite imagery and field data? (Chapter 3)
2. What are the colonization trajectories and their impacts through time in terms of LULC dynamics? (Chapter 4)
3. What are the rates of deforestation, secondary succession, and farmland conversion? (Chapter 4)
4. How does landscape structure vary in each settlement across time? (Chapter 5)
5. How are the human dimensions of landscape transformation depicted across the spatial and temporal scales of analysis? (Chapter 6)

In order to answer these questions, satellite imagery and bibliographic, cartographic, and field data were integrated. Multi-temporal Landsat TM images were used for characterization and analysis of landscape change and LULC dynamics. The integrated methodological strategy combined image processing, vegetation structure data analysis, interviews with local people, GIS techniques, landscape metrics computation, and institutional analysis. The topics encompassed by each chapter are briefly described below.

### **1.3 - What to expect**

The itinerary followed by this dissertation reflects the multi-disciplinary character of the research. Each chapter is devoted to a topic supporting the comparative analysis between the two settlements in Rondônia. Every chapter contains a brief literature review on the topic, the methodological approach, results, and a discussion about the findings. Chapter 2 describes the environmental and cultural setting for the study. Machadinho and Anari are put in the context of the Amazon region colonization, and its heterogeneity and complexity. The reasons for the choice of these two settlements as an opportunity for a comparative study are also discussed. An extensive description of the study area and both settlements is included, using background data to describe the geographic locations, administrative boundaries, settlement architectures, climate, geology, geomorphology, hydrology, soils, vegetation, and fauna. Main rural production systems and calendars are also described to indicate people's activities, time allocation, and labor.

Chapter 3 addresses the vegetation structure of forest and secondary succession stands present in the area. Data collected in the field supported the creation of a database including vegetation variables such as number of individuals, height, diameter at breast height, density, basal area, and biomass. Trees, saplings, and herbaceous vegetation are described in terms of their importance in defining stages of regrowth, which are fundamental for the understanding of LULC dynamics within the landscapes. Moreover, spectral data referring to the same sites where vegetation data were collected were also integrated into the database. Statistical analysis indicated the potentials and limitations of using Landsat TM data to identify secondary succession stages. A discussion about the role of vegetation structure and spectral analysis for the study of LULC dynamics in

colonization areas of Amazônia is carried out. Recent trends regarding this research topic are also listed.

Chapters 4 and 5 include the core quantitative analysis of LULC dynamics and landscape change carried out in this dissertation. In Chapter 4, remote sensing and GIS techniques are used to evaluate the impact of colonization within the settlements on a multi-level and multi-temporal basis. After describing the general spatial trends in LULC, other specific questions are addressed. Transition matrices between the LULC classifications produced results about distinct agroecological processes, such as deforestation, production, and secondary succession. In Machadinho, analyses including and excluding the communal reserves are carried out to evaluate their importance within the landscape. The investigation of LULC processes within buffers along roads in both settlements provides other elements for discussion regarding the spatial patterns of colonization. Property-based analysis completes the investigation about LULC in Machadinho and Anari. A discussion about the colonization impact includes methodological and operational issues, main findings and their meanings, and the trajectories of LULC within the study area.

Chapter 5 takes advantage of the LULC classifications produced in Chapter 4 to analyze the study area from another perspective. Landscape structure rather than LULC is the focus of this chapter. Selected metrics measuring structure of landscapes, classes, and patches are used for this purpose. Each settlement is considered as one ‘landscape.’ Classes were recoded from the LULC categories and include forest, secondary succession, and production lands. Patches are individual areas (polygons) composing the landscape. Metrics concerning area, patch density, size and variability, edge, shape, core



area, diversity, interspersion, and juxtaposition were calculated and discussed. Besides focusing on the meaning of results for each settlement, the chapter also addresses unresolved problems in landscape spatial data analysis.

In Chapter 6, an institutional-based approach is taken to analyze the human dimensions of landscape change in Rondônia. A historic ecological perspective is used to discuss the structure of rules and incentives affecting land-use decision making in Machadinho and Anari. The underlying processes of landscape change are also analyzed for the settlements' implementation and consolidation phases.

In the last chapter, concluding remarks are addressed. Questions and hypotheses are discussed based on the main findings of the dissertation. Further studies are also suggested in search of better interactions among actors and the environment in the Amazon.