

Abstract

MACINTYRE, CHARLES. Sustainability in Amazonian Development: Human Welfare and Environmental Quality in Colonization Settlements in the Brazilian Amazon. (Under the Direction of Erin O. Sills).

In the Brazilian Amazon, colonization settlements continue to play a dominant role in the historic process of development and deforestation. In order to better meet the agrarian reform demands as well as ecological conservation interests for the region, a sound understanding of the determinants of settler welfare is needed for sustainable social and environmental development. While much past research has focused on forest conversion and the actions of the agents driving this process, less attention has been given to the development of human welfare in these areas. Poorly understood patterns in development and deforestation in this region threaten to undermine the goals of both developers and conservationists. Low human welfare will perpetuate the cycle of frontier expansion and lead to increased environmental degradation. This paper sets out first, to identify the effect of settlement characteristics and deforestation patterns on human welfare and next, to identify the determinants the preservation of High Conservation Value forest, here represented by riparian forests. This study linked socio-economic and spatial data at the colonization settlement level to meet its objectives. First, nine measures of human welfare were analyzed against the age of the settlements, rates of deforestation within them and the biophysical, geographic and social factors which may impact these relationships. Next, the determinants of deforestation in riparian areas which in the face of high deforestation levels were, offer a realistic hope for preserving several key ecological functions of the land, were examined. Bivariate, multivariate and Principal Components Analysis statistical tests were utilized in this study.

Results indicate old age, low deforestation rates and high quality access to highways to be key determinants of high welfare. For riparian forests, access to highways, biophysical land characteristics, social organization and farmer origins were found to be key determinants. Analysis at the settlement level employed in this study will allow for policy creators to make good use of my results when aiming colonization and human welfare improvement efforts.

Sustainability in Amazonian Development: Human Welfare and Environmental Quality in
Colonization Settlement in the Brazilian Amazon.

by
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Dedication

To the farmers of Rio Negro, Honduras

Biography

Charles MacIntyre was born in San Francisco, California on June 25, 1980. In 1981 he moved to Durham, North Carolina with his family where his father was recruited to join the medical faculty of Duke University. He attended high school at Durham Academy and earned a Bachelors of Arts in History from the University of Colorado at Boulder in 2003. After college he travelled and worked in the Europe and served with the Peace Corps in Honduras in addition to working in education in Durham, North Carolina. In 2008, he joined the Masters program at North Carolina State University in the College of Natural Resources. During his time as a student here he spent two semesters abroad at the Universidade Federal de Viçosa in addition to several months in the Amazonian state of Rondônia, Brazil where he conducted the research for this paper on economic development and environmental conservation. While a graduate student he served as President of the International Society of Tropical Foresters, was awarded the 2010 Arthur W. Cooper Fellowship for Excellence in Social Sciences and earned memberships to the Xi Sigma Pi and Phi Kappa Phi honors societies.

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I. Introduction

The Amazon rainforest comprises 40% of the world's tropical forests and has key ecological functions ranging from carbon sequestration to biodiversity maintenance (Laurence et al. 2004). The majority of this forest is located within Brazil, which is one of the five 'megadiversity' countries in the world (Mittermeier 1998). As the Amazon region accounts 40% of Brazil's land area, it is to be expected that colonization and deforestation will continue, rooted in a need for agrarian land reform in the older developed regions of the country as well as the potential for economic gains to be had via exploration of the natural resources in the Amazon region.

However, concerns abound regarding the social and environmental sustainability of development in the Brazilian Amazon (Fearnside 2002, Rodrigues et al. 2009, Schneider 2000, Celentano and Veríssimo 2007). International, domestic and local interests are at odds in finding a balance for this region to provide global ecosystem services, national economic development and local economically viable livelihoods. In this context, it is crucial for all parties, that the development which will take place to be done in a manner as effective and sustainable as is possible, both socially and environmentally.

Understanding the evolution of human welfare over time is critical for optimal development. Much literature has evidenced a downward trend in human evolution over time (Barbier 2005, Rodrigues et al. 2009, Schneider 2000, Celentano and Verissimo 2007). Explained by Barbier 2005, the *frontier expansion hypothesis* posits that natural resource driven economies do not generate sufficient returns for sustainable human development and inevitably lead to a “boom bust pattern” in development. These studies have used both the time an area has been settled as well as deforestation rates to demonstrate a decline in human welfare over time. Such concerns warrant investigation by researchers and policy makers so as to avoid a lose–lose scenario, in which conservationists fail to see this unique region preserved and farmers who were seeking better livelihoods and economic gain find neither. However, these conclusions are often based upon municipal and regional data, which raises the questions of what a finer scaled analysis may be able to catch that these were unable to. In this light, analyses which have farm and settlement level data have evidenced an improvement in livelihoods; higher incomes, better access to health and education and an accumulation of wealth (Caviglia-Harris 2007). However, a potential confounder for these results would be that despite a relative variation in age and access in the farms and settlements analyzed in this study, all sample farms and settlements were located in or very close to the heart of development in the region and as such these patterns may not be applicable to other areas in the Amazon. Hence, it remains to be determined whether human welfare on the frontier of development in the Brazilian Amazon improves or worsens over time. My study has set out to add to this discussion and in making use of settlement level data with a wide geographic

dispersion, will distinguish itself from those discussed here and potentially have more explanatory power for other areas of development in the Amazon region.

In that light, an understanding of the history my study area is warranted, so as to be able to fully understand and place the results. As such, a detailed look at the history of the development in my study area as well as the agrarian reform movement will be given. My study area, the state of Rondônia located in the southwestern Brazilian Amazon is synonymous with large scale colonization and environmental exploration. Founded in a need for agrarian reform in other regions in Brazil as well as a chance for economic opportunity, Rondônia was the site of historic levels of immigration and deforestation starting in the 1970s which continue to this day. This effort has been orchestrated by the National Institute of Colonization and Agrarian Reform (INCRA), which has played an integral role in developing the infrastructure and financing needed for the large scale colonization which has taken place in the state. My study will consider 93 INCRA settlements, ranging in age, deforestation rates, location and size amongst many other variables.

In line with a growing trend to match socio-economic and spatial data (Druska and Horrace 2004; Pattanayak et al. 2007), my study will link three data sets; settlement level demographic interviews, municipal level welfare indicators and 25 years of classified Landsat imagery. This information includes nine measurements for human welfare; an asset score, literacy rates at settlement and municipal levels, education performance, public health

figures and Human Development Index scores. Using ArcGIS, deforestation rates, forest cover figures and access measurements were created. By using both these spatial statistics as well as the socio-economic information, I will be able to identify the effect of age and deforestation rates, as well as variables which confound these effects (e.g. access, land titling), on human welfare in the colonization settlements.

To further add to the understanding between welfare and environmental development, I will also examine the determinants of riparian forest cover, which in the context of high rates of deforestation, I consider to be High Conservation Value areas as they offer a realistic chance to salvage key ecosystem services such as ecological corridors and water cycling, despite high rates of deforestation around them. In accordance with environmental legislation, I have mapped out 30 meter buffers for streams and calculated forest coverage within them. Using the same data sets as in the welfare analysis section, I will identify determinants of forest cover in these ecologically fragile areas.

This paper is broken into four sections. First, a preliminary description of the study site as well as the data and GIS methods will be given. Next, the first chapter will explore the effect of settlement characteristics on human welfare, looking specifically at the age of the settlement, the rate of deforestation within it as well as other key physical and social characteristics. Next, the second chapter will examine the determinants of forest cover in riparian areas, giving special attention to both the drivers of tropical deforestation as well as

determinants of sustainable land use choices. I will finish with a single conclusion which will discuss both chapters jointly.

II. Study Site, Description of Data and GIS Methods

A. Study Site

The study area for my paper is 93 INCRA agrarian reform colonization settlements located within the Brazilian state of Rondônia.

The state of Rondônia lies within the legal Amazon and is located at 24° 0' 0" S, 51° 0' 0" W (WGS 1984) / 22K 500000 7345773 (UTM). The original land cover was principally lowland evergreen broadleaf rain forest and semi-evergreen moist broadleaf forest. In 2007, the state had 155 agrarian reform settlements established by INCRA, the Instituto Nacional de Colonização e Reforma Agrária or the National Institute of Colonization and Agrarian Reform. In this study, I consider 93 of these settlements that were officially established by INCRA between 40 and 4 years ago (1970 to 2002). This number was reduced from the greater number of settlements in the state due to satellite imagery in use here. The largest settlement in terms of area is 512,585 hectares, and the smallest is 430 hectares. In terms of lots, the largest settlement has 5,000 and the smallest has 30. Figure 1 shows the state of Rondônia and the INCRA settlements considered in my study.

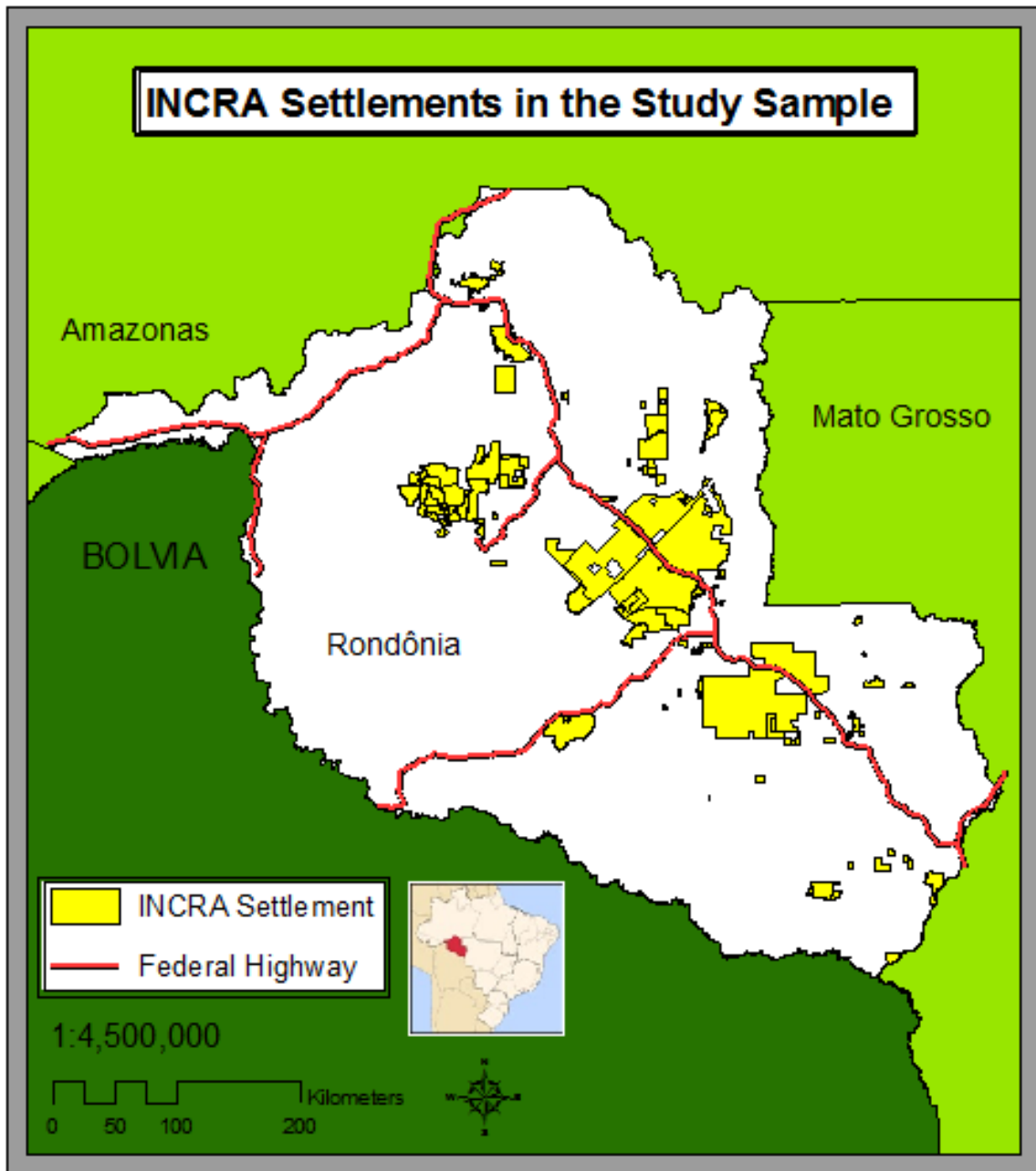


Figure 1 - *INCRA Settlements in the Study Sample*

B. Description of Data

The data used in this study were collected through personal interviews with government agencies located throughout the state of Rondônia. During the months of January, February, July and August in 2009, I met with governmental officials to collect secondary data on socio-economic indicators of residents within colonization settlements as well as historical data on the development of the state. In this section a description of the data collected and government agency it was collected from will be given.

The Instituto Nacional de Colonização e Reforma Agrária (INCRA) is a federal agency which operates agrarian reform and colonization settlements throughout Brazil. INCRA has a large presence in Rondônia with a headquarters in the state capital of Porto Velho and regional offices in the majority of urban centers. Through interviews with various officials, I collected basic information on all colonization settlements, which included information such as the age, size and capacity among other categories. Data on land tenure were collected as well. In addition, through interviews contextual information was gathered such as the history of the agency in the state and its policies on credit and land titling in addition to other topics. Critical to my study, through the Assessoria Técnica, Social e Ambiental division, interviews conducted in 40 settlements across the state which focused on socio-economic well being and land uses practices, were collected. These interviews, which were conducted in INCRA settlements, were carried out by the Empresa de Assistência Técnica e Extensão Rural or the

Enterprise for Technical Assistance and Rural Extension (EMATER). In addition to this socio-economic data spatial GIS data were collected which included shapefiles for outlines of all colonization settlements in the state and property boundaries within these settlements. Finally, the Plano de Desenvolvimento Sustentavel de Assentamento (PDSA) were collected for 50 settlements in the state. These documents are technical reports on the socio-economic and land use indicators of the settlement. Though they are intended to be create before the creation of a settlement, the vast majority of those collected were produced several years into the existence of a settlement and as such provided quality information on settlement functionality.

The Empresa de Assistência Técnica e Extensão Rural (EMATER) is a federal agency with the purpose of providing technical assistance in rural settings. With the large numbers of families practicing agricultural activities in Rondônia, EMATER has a very large presence and influence in the state with a critical role for promoting sustainable environmental development. Moreover, INCRA and EMATER have had several agreements over the course of their histories to provide technical assistance in colonization settlements. As mentioned above, as part of the agreement between the two agencies, EMATER conducted the socio-economic interviews for INCRA in the 80 settlements for which they provide technical assistance. As part of the agreement, local EMATER offices were to carry out interviews with all farmers in the settlements under their charge, synthesize the information into concise reports and centralize all interviews at the central EMATER office in Porto Velho. However,

due to a lack of funding, the synthesis and centralization aspect of this project were not completed in full. The original interviews were delivered to INCRA, however the concise reports were never completed in full and often remained at local EMATER offices around the state. As such, I dedicated a considerable amount of time to travelling to regional EMATER offices to procure the concise reports. In total, 40 concise reports were collected.

The Secretaria de Estado da Saúde de Rondônia (SESAU) is the state secretary of health. Municipal level information of tropical diseases was collected which include malaria, dengue, leishmaniasis, hepatitis, paracoccidioidomycosis, chagas, cromoblastomycose and water borne diarrhea. This information dates back to 1999.

The Secretaria de Estado da Educação de Rondônia (SEDUC) is the state secretary of education. Information on test scores, teacher qualification and quality of education indices was collected for all secondary schools in the state. It is important to note here that secondary schools are located in urban areas and not in rural settings. Rural students travel via bus to city centers once primary school has been completed. As such, data used from this organization is at the municipal level.

The Secretária de Desenvolvimento e Meio Ambiente do Estado de Rondônia (SEDAM) is the state secretary of development and the environment for the state. The function of this

agency is to ensure the sustainable development of natural resources in the state and has recently been made responsible for environmental licenses. This agency provided basic cartographic spatial information (shapefiles) such as roads, political boundaries and soil types among other information.

The Instituto Brasileiro de Geografia e Estatística (IBGE) is a federal institute with the purpose of maintaining statistical information on demography and society within Brazil. For my study, spatial information (shapefiles) was collected which was part of the Censo Agropecuário 2006. This included point files for houses interviewed, schools, health posts and livestock facilities. Municipal literacy rates from 2000 were also attained via their website.

Other state agencies which provided data that has been used to provide contextual information were the Companhia de Águas e Esgotos de Rondônia (CAERD), the Centrais Elétricas de Rondônia (CERON), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), the Fundação Nacional de Saúde (FUNASA), the Instituto Brasileiro do Meio Ambiente E Dos Recursos Naturais Renováveis (IBAMA), Secretaria de Estado do Planejamento e Coordenação Geral (SEPLAN), Secretaria de Estado da Agricultura, Produção e do Desenvolvimento Econômico e Social (SEAPES) and Serviço de Apoio às Pequenas e Médias Empresas de Rondônia (SEBRAE).

In addition to these governmental agencies, Landsat TM images processed for land use classification have been made available through collaboration with the University of California at Santa Barbara. These data cover the years 1984 to 2009.

Spatial data collected via governmental agencies in Brazil are in SAD UTM 1969 Zone 20S. The Landsat imagery is in WGS 1984. Conversions were made for data to match the Brazilian data as the vast majority of the data were originally created in this coordinate system. The extent of the analysis of this paper is limited to seven Landsat satellite images, which cover the majority of the state of Rondônia, though not all.

The spatial data collected from governmental agencies in Brazil were vector formats. The Landsat imagery is in a raster format. A cell size of 28.5 was chosen to match the Landsat imagery.

For topographical aspects of my study, an ASTER Digital Elevation Model was utilized. These data were downloaded from the NASA Jet Propulsion Laboratory website which makes this data publicly available with worldwide coverage. Several spatial analyses utilized this DEM in order to create new data (e.g. Slope layer, cost distance layers).

Finally, to add to my ability to explain Welfare outcomes, Human Development Index data from 2000 was collected from the United Nations Development Program website through the Atlas da Amazonia project.

Sample Size

As the data used in this study come from myriad sources, there are several sample sizes used in my analyses. The sample size breaks down as the following:

A. Sample of 93 Settlements

- Municipal indicators
- Year of Settlement Creation
- Area
- Lot size
- Lot occupation
- Land titles
- Phase of settlement
- HDI figures

B. Sample of 90 (+ A)

- Access to City
- Year of first cut
- Access to Federal Highway
- Steepness of terrain

C. Sample of 84 (+ A, B)

- Forest cover (general, primary and new), 1984 – 2009

D. Sample of 40 (+ A)

- Emater interview information

E. Sample of 31 (+ A, B, C, D)

- Riparian forest (general, primary and new)

Other information with unique sample size

- Year of Invasion
- Income
- Cattle
- Legal Reserve intact

C. GIS Methods

For my study, I have used ArcGIS to construct measurement for deforestation cover and rates, delimitate riparian areas, measure access to feature locations, determine the age for settlements as well as the topography within them.

Forest Cover

To calculate forest cover and deforestation rates, my study has utilized a robust time series dataset of Landsat Thematic Mapper 5/Enhanced Thematic Mapper (TM/ ETM+) images, made available through cooperation with the Geography Department at the University of California-Santa Barbara. This dataset ranges from 1984 to 2009 and has land use classified into 9 categories; primary forest, forest, pasture, green pasture, rock/savanna, water, burn, urban areas and clouds. These land classes were created using a multistage process described

in Roberts et al. 1998. I used this dataset to calculate both forest cover and deforestation rates.

Utilizing the Spatial Analyst toolbox in ArcGIS, I was able to calculate forest cover figures for the settlements which the Landsat imagery covered, which was 90 INCRA settlements. I classified forest cover to be both primary and regrowth forest. To calculate the percentage of forest cover in each settlement I simply divided the number of pixels classified for either primary forest or primary forest + regrowth forest, by the total number of pixels located within the boundaries of the settlement. Due to both the 30 meter resolution of Landsat imagery as well as variability in the month each year's imagery was calculated, I have chosen to base the majority of my analyses upon primary forest cover. Primary forest figures are more reliable for the following reason. Once a pixel in the dataset is changed from primary forest to any other land use, it can no longer be reclassified as primary forest. Hence, deforestation figures and rates based upon this category will not falsely evident regrowth or old pasture as forest. As a large part of my study examines forest in riparian areas, which are known for high levels of regrowth, this is an important consideration.

The method my paper has utilized to measure deforestation rates was to create a layer which represented the year in which each pixel in the raster layer was changed from primary forest to any other land use. These pixels were then reclassified into 3 classes; 'Pre-1990', '1990-1999' and '2000-2007'. Next, using zonal statistics within the ArcGIS Spatial Analyst

toolbox, I calculated the average cell count for each of these classes for all the settlements in my study sample for which this spatial data set covered.

In order to delimitate riparian areas and calculate forest cover within the, a vector shapefile for streams provided by the Secretary of the Environmental Development was used to define riparian areas. The scale of the stream network was 1:100,000 and as such was overly coarse for the purposes of delimiting riparian areas. Using unprocessed Landsat imagery as well as an imported Bing map in ArcGIS, the streams located in my sample of INCRA settlements were corrected by moving vertices in the layer to match its true position. Though time consuming, this method greatly improved the accuracy of the stream network and made possible the delimitation of riparian areas with confidence.

As this vector shapefile did not list width of the waterways and the spatial data for land use was at 30m resolution, this study created one 50m buffer on either side of the stream. Using this buffer and land use classified satellite images, old growth forest, new growth forest and general forest cover was calculated for each settlement from 1984 to 2009.

The following figure demonstrates buffered streams in one of my sampled settlements.

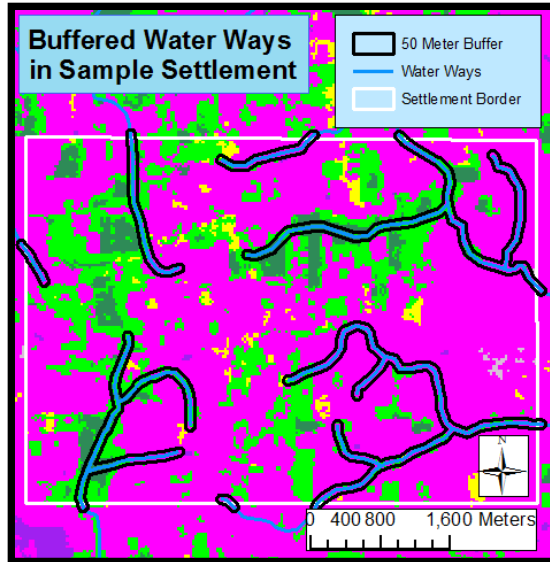


Figure 2- *Sample of buffered waterway (riparian area / HCV area)*

Access

ArcGIS was again utilized to create access measurements for my study. This included access to federal highways and cities.

Recent research has made use of spatial data and GIS tools for optimal measurement of access to feature locations (Verburg 2004, Black et al. 2004). Cost distance analysis was used in these studies to measure access to logging site and health care facilities and has been used in my study to create measurements of access to city centers and federal highways. The methodology in measuring access in a spatially based socio-economic analysis such as this

paper is critical. Using ArcGIS and my spatial data set, I measured access to cities and to federal highways as follows. A work script for this process is included in the appendix.

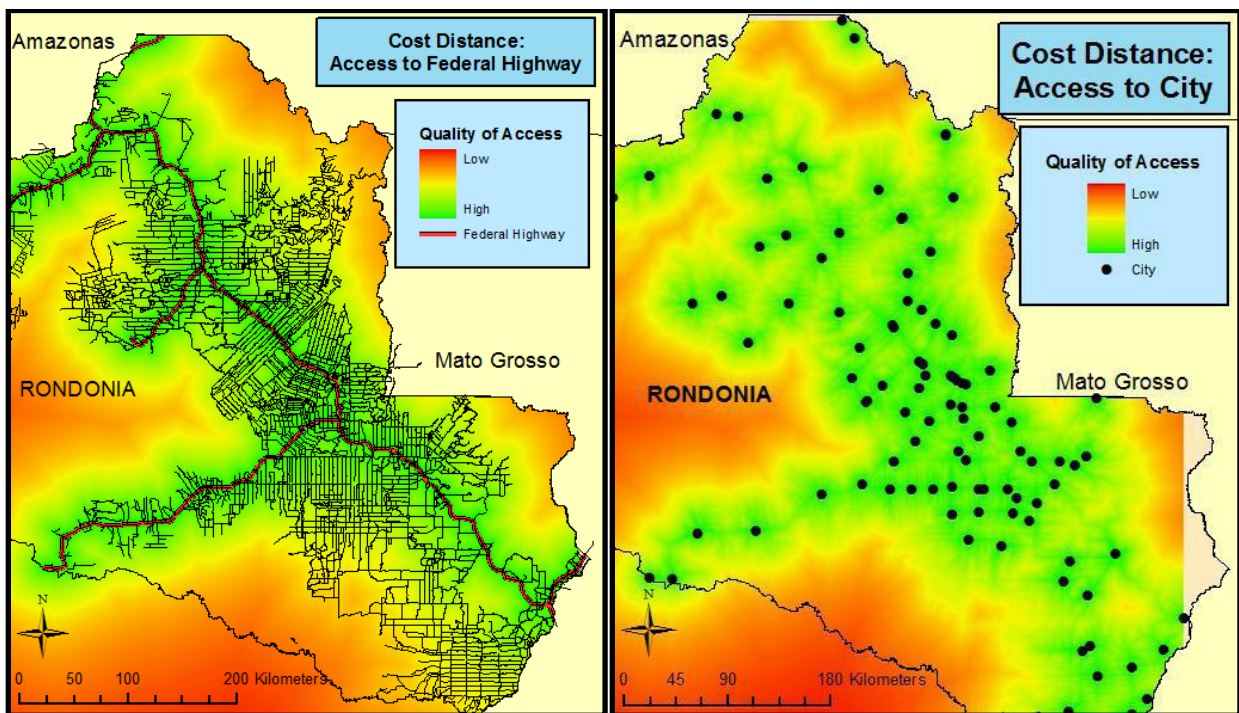
The first step this analysis was to create a slope layer. For this, the data were downloaded from the NASA Jet Propulsion Laboratory website which makes public available and free to download ASTER Digital Elevation Models (DEM) with worldwide coverage. Using an imaging processing software, ENVI, a slope layer was calculated from this DEM. Next, this slope layer was reclassified on a scale of 1 to 10, which 1 being the flattest areas and 10 being the areas with steeper slopes.

Next, the 2009 land use classified Landsat imagery was reclassified on a scale of 1 to 10, to represent ease of travel. For this scaling, federal highways were assigned a value of 1, highways a value of 2, local roads a value of 3 and all other categories, including pasture and forest, were classified as 10.

Next, these two reclassified layers, slope and land use, were combined using the Plus tool in order to create a Total Cost layer. Then using, the two inputs noted above, city centers and federal highways, Cost Distance analyses were run producing two new layers for which access to each input are measured. Each raster cell in these two new layers had a value measuring access. Using Zonal Statistics, the mean for the raster cells located within the boundaries of an INCRA settlement were found. This mean was then divided by the

maximum mean found in all INCRA settlements, so as to produce a rationale distribution of this measurement of access among the my sample of settlements. It is important to note here that this percentage of the maximum score for access had the same significance levels as the raw measurement (mean) produced by ArcGIS.

The following figures demonstrate the spatial patterns for each cost distance layer created.



Figures 3 and 4 – GIS based cost distance: access to federal highway (3) and access to city

(4)

Age of Agrarian Reform Settlements

Several methods exist for determining the age of an INCRA agrarian reform project in my study area.

A first option would be to measure the age of a settlement by the year it was created by INCRA. The advantage here is that there will be no measurement error and an age will be easily available for all settlements. However, due to the complex nature of land development in Rondônia, using this measurement may be hiding significant factors. First, as mentioned before the invasive forest mobility theory demonstrates how there are progressive waves of human occupation and development. For instance, an area may be partially explored by a logging company and in the skid trails they leave behind a group of landless peasants may occupy the land, be it private or public. A long term occupation may ensue which may or may not lead to INCRA to step in and recognize this occupation as an agrarian settlement. Before INCRA does incorporate such an occupation of land, which is the dominant paradigm, several years usually pass. In my study, I found an average of wait time of approximately 5 years between the time an area is occupied and developed and the time INCRA. As such in order to best understand the relationship between welfare, age and deforestation rates, this measurement of age is not ideal.

A second option is to use the year an area was occupied by a landless peasant group. There are two downsides to this method for my study. First, the source of this information for my study came from the PDSAs of which I only have 40. Hence, 53 settlements in my study were eliminated when testing using this measurement of age. Second, in several cases, though an area was reported to have been settled in the PDSA, when examining the spatial land use record there at times were gaps between this year of occupation and the time the land was actually cut into. I assume here that when an area of land is occupied by a landless peasant group, the tendency will be to deforest. A lack of deforestation I assume may mean that there are hidden details behind the year of occupation, perhaps a very small number of occupiers which grew the next year to a number more significant in terms of development patterns. As such, this method was not ideal either.

A third option for measuring age and the one adopted for the majority of analyses in my study was using the year the forest first demonstrated signs of human occupation. As the fishbone pattern of development is the dominant pattern of deforestation in the state and in agrarian reform settlements, the first year this pattern emerged was taken as the true birth date of human occupation in the area. For my study, on average, the cut date happened 8 months prior to the occupation date reported in the PDSA documents. It should be noted that in some settlements in my study area, significant deforestation had occurred before human occupation. In many cases the patterns of deforestation point to the land previously having been part of an extensive cattle ranch. Though as the primary purpose of my paper is to

determine the relationship between welfare, the age of settlement and deforestation rates, the date a group of colonists effectively settled a region is the most meaningful.

Topography: Steepness of Slopes

Past studies which have considered topography and land use studies have used reclassified slope layers to facilitate easier statistical analyses (Konig 2007). Simplifying this, I utilized ASTER 10 meter resolution data to generate a slope layer and then calculated a mean slope value for the raster cells within each of the settlements in my study sample.

Chapter 1: Sustainable Development in the Amazon: Relating Human Welfare to Age of Settlements and Recent Deforestation Rates

A. Introduction and Literature

Large scale economic development in the Brazilian Amazon was borne from a need for agrarian land reform and secure possession of the region. Government led colonization settlements and accompanying infrastructure projects laid the ground work for what quickly became an historic event of immigration with environmental degradation. The processes of economic development which took generations in other parts of the world are in the Brazilian Amazon today unfolding at rapid pace across time and space. Over the past 40 years governmental investiture and policy has created transportation, colonization and welfare infrastructure in the region. In this section, a brief review of agrarian reform in the country as well as relevant policies, programs and agencies and the role the state Rondônia has taken in the process will be given, before this paper moves to analyzing the patterns in human welfare across time and space.

1. Agrarian Reform in Brazil and the Amazon

Brazil has long been known as a country with a poor distribution of land. The Gini index of land ownership in Brazil since 1940 has hovered around .80, meaning that nearly 80% of the

land is owned by large scale owners while the smallest farmers had access to around 20% (OAS 2006).

Brazil possesses an area of 850 million hectares, 418 of which are under the domain with INCRA (Hackbart 2009). Of these registered properties, 86% are less than 100 hectares in size and total just 20% of the total area. On the other hand, properties larger than 1000 hectares in size comprise 2% of those registered and total 47% of the total area. In addition, a study released by INCRA in 2003 revealed that nearly 60,000 properties which totaled 134 million hectares were classified as unproductive (Hackbart 2009).

Similar numbers are found in Rondônia. According to the Censo Agropecuário from 1996, 85% of the properties in the state were less than 100 hectares in size, 97% were less than 500 hectares and 98% were less than 1,000 hectares (Wanane 2010). The properties less than 1000 hectares in size accounted for 52% of the total area and the properties over 1000 hectares, which account for only 1.2% of holdings, covered 48% of the states territory.

Principally through Article 16 of the Land Statute of 1964 which states that “land reform aims to establish a systematic relationship between humans, property and rural land use, capable of promoting social justice, progress and welfare of rural workers and economic development of the country, with gradual extinction of very small farms and large estates”, a legal basis for agrarian reform (i.e. governmental takeover of private land) is established in

Brazil. Though not be discussed in full detail here ¹, it is important to know that the military government of the 1960s played a large role in creating state agencies which were given powers to administer land reform and lead colonization efforts to alleviate some of these pressures.

Rondônia: History

The Amazonian state of Rondônia was created in 1981 via Lei Complementar N°. 41 de 22 of December 1981, being know previously as the Federal Territory of Rondônia and the Federal Territory of Guaporé before that (PRRA 2005). Until 1977 there existed only 2 municipalities though this number has grown to 53 today, demonstrating the rapid pace of development in the area. In 1970 the population of the territory was just over 100,000 inhabitants, comprised chiefly of indigenous groups, rubber tappers and extractivists. Today this population has risen to approximately 1.5 million and with 5.8 inhabitants/square kilometers, has the highest density of any state in the Amazon region.

The colonization and development of Rondônia is tied hand in hand with INCRA. The influence of this agency on the makeup of the state today is so strong that 90% of its municipalities originated as part of an agrarian settlement created between 1970 and 1975 (O Brasil e o Mundo).

¹ Full detail discussion of legal basis of agrarian land reform and history of INCRA is given in appendix

The story of the development of Rondônia begins with the creation of the Projeto Integrado de Colonização de Ouro Preto. Driven by the agrarian reform pressures from the southern parts of Brazil as discussed above, a team of agronomists, sociologists, engineers, economists were sent to what is today Rondônia in order to select the site for large scale colonization projects. Due to favorable soils and access to the urban centers of Coiaba and Porto Velho, the area then known as Seringal Ouro Preto was chosen to be the seed of development in the region. (O Brasil eo Mundo). Located on the rural highway BR-29, today the federal highway BR-364, planners carved roads into the jungle every five kilometers and demarcated 100 hectare plots. This road would play a key role in the development of the state. With an initial goal of settling 1,000 families in 3 years, authorities were soon overwhelmed when this goal was achieved within 1 year. By the end of the 3 year period planners had envisioned originally over 25,000 families had arrived. From all over Brazil, families were coming to Rondônia in droves, arriving in overcrowded flat bed trucks nicknamed “Pao de Arrara” attracted to what was being advertised as the land where honey milk flowed. By the end of 1979 INCRA had settled 20,000 families in their settlements with at least 30,000 more in the state waiting to be attended to (Wanatabe 2010). INCRA in short time was becoming overwhelmed by the arrival of families in the natal state. In 1976 alone, roughly 900 families per month were arriving in search of land and opportunity (Ianni 1986). Eventually INCRA had to back off its original stance of attending all families who arrived and in time these families took it upon themselves to secure land and a livelihood by invading land, both public

and private. In time the vast the majority of these squatters were settled by INCRA and received support. It is worth noting that in order to secure land title at that time it was necessary to make productive the land given to you in two years time, or in other words deforest and initiate agricultural and livestock activities (Watanabe 2010).

Large Scale Development Programs in Rondônia

Interlaced with the role INCRA has played in the development of Rondônia have been the Polonoroeste and Planoflora programs. These two programs have aimed to structuralize the environmental and economic development of the state.

Polonoroeste

Running from 1982 until 1992, the Programa Integrado de Desenvolvimento do Noroeste do Brasil (Polonoroeste), was a federal government program aimed at opening part of Mato Grosso and all of Rondônia to for development and population (Watanabe 2010). The goals of this program were to construct new highways to remote parts of the state, recuperate old highways, provide technical assistance, give the state control of health and education, construct agricultural storage facilities that were less bureaucratic and promote agricultural activities (Watanabe 2010). In total, the budget for this massive program was \$1.55 billion with \$400 million coming from the World Bank (Theodoro 2005). With these funds the

technical and agricultural extension agencies EMATER and Comissao Executiva do Piano da Lavmya Cacaueira (CEPLAC) Were started, in addition to the construction of hospitals, health posts as well as research activities and local office openings by EMBRAPA, among other activities (Watanabe 2010). As this program achieved its goals of creating infrastructure to attend the growing throngs of people migrating to the state and putting Rondônia in a position to become an agricultural power house, a commensurate amount of international concern grew as swaths of forest fell at the hand of the farmers this program was assisting.

Planoflora

To address calls for a more sustainable development plan in an area of immense ecosystem services, in 1992 the Plano Agropecuário e Florestal de Rondônia (PLANAFLOORO) was created, again partially financed by the World Bank (Watanabe 2010). The stated goals of this program were to improve the functionality of government agencies, ensure the conservation of biodiversity, protect Indian reserves, develop integrated agricultural and forest systems and prioritize socioeconomic infrastructure. This was to be done by promote sustainable forest use through extractivism and agroforestry system, create environmental education programs, increase environmental law enforcement and most importantly create a Ecological-Economic Zoning (ZEE - Zoneamento Ecológico-Econômico (Theodoro 2005). As part of this Z.E.E., areas were demarcated in a categorized system which classified what

type of land use was permitted. This system continues to be in effect to this day. The focus upon road construction seen in the Polonoeste was diminished, replaced by more sustainable goals.

INCRA in the Amazon

The National Institute of Colonization and Agrarian reform has the stated mission of implementing the policies of agrarian reform and giving order to the national land tenure regime. Via expropriation, purchase and donation among other means, this agency acquires land and settles families from across Brazil in colonization settlements to achieve its agrarian reform agenda.

History

In the context of the environmental and economic development of the Amazon region, INCRA has played a critical role. During the military government rule of the 1960s, the population and exploration of the region became priority. Large scale colonization and development plans attracted people from Brazil over with such phrases as “*integrar para não entregar*” (integrate so as not to hand over), describing the region as “*a land without people for a people without land*” (*O Brasil e o Mundo*). Development and population of the region was in response to several concerns. First, by populating this vast region the government was

securing de facto control of this land, which though politically fell into their jurisdiction, was in reality far from governmental control they feared.. Second, the development of the Amazon region helped to alleviate the growing demand for land in the increasingly mechanized south and south east of Brazil.

INCRA has played an integral role in the development of the region and continues to do so to this day. Today in the Amazon region, colonist farmers make up 83% of the rural population (Pacheco 2005). In terms of deforestation, in a recent list of the top 100 deforesters in the Amazon released by the Ministry of the Environment, INCRA colonization settlements claimed 6 of the top 10 spots (MMA). Over the past 40 years INCRA has had a tremendous role in the development and population of the region and though it has evolved greatly in its function and scope it continues to this day to be a leading force in the shape of economic and environmental development.

An Evolving INCRA

INCRA settlements in Rondônia have greatly changed in structure over the course of its 40 years in the state, responding to social, environmental and economic considerations. The original five settlements in Rondônia were the Projetos Integrados de Colonização (PIC). PIC Ouro Preto was founded in 1970, PIC Sydney Grão in 1971, PIC Gy-Parana in 1972, PIC Paulo de A. Ribeiro in 1973 and finally PIC Pe. Adolpho Rohl in 1975. Lot sizes in these

settlements ranged from 100 to 110 hectares. These PIC style settlements were designed to attend to all needs of settled families including health, education, social and infrastructure needs. Each of these settlements had a N.U.A.R. (Nucleo Urbano de Apoio Rural), which were centralized facilities which include agricultural storage units, schools, electricity, health posts and in some cases a small plot of land to have an urban residence (Theodoro 2005). To attract settlers with more money to invest and with more experience in agriculture and livestock management, INCRA instituted a new style of settlement called Projeto de Assentamento Dirigido (PAD) with larger lot size ranging from 250 to 1000 hectares. As discussed above, INCRA was unable to effectively settle the incredibly high number of families who were arriving in the state in search of land. However, in the interest of regularizing the land tenure situation the agency created what were referred to as Projetos de Assentamento Rapido (PAD). However, these settlements did not receive the support the previous two settlement types did (roads, schools, health posts, etc), simply land tenure security. Over 12,000 families were settled in this fashion on 100 hectare sized lots. In 1981, the first Projeto de Assentamento (PA) was created in PA Urupa, which became the dominant settlement type for the better part of 20 years. In these PAs, lot sizes range from 30 to 50 hectares and in a few instances INCRA attempted to create radial styled settlements to facilitate a sense of community at the center of the lots, though these were unpopular among families (Alves 2009). In the last decade, INCRA has made a concerted effort for improved sustainability of natural resources in their settlements by introducing new styled settlements. Examples include the settlements of Extractivist Settlements (PAE), the Settlements of

Forestry (PAF) and the Settlements of Sustainable Development (PD). Between 2003 and 2005, 250 of these new project types, totaling 6.7 million hectares for the benefit of 59.4 thousand families were created (Hackbart 2009).

As mentioned before, over time INCRA has devolved its responsibilities to state and municipal authorities. After the PIC settlements, INCRA no longer was the sole organization which attended to transportation, health and education need, ceding these duties to the state Secretaries of transportation, education and health (Watanabe 2010). State government agencies were growing up with their state and started to assume their proper duties. However, it is important to note here that at the advent of a settlement, even today, there is initial financial support surge aimed to help organizations create education, health and transportation infrastructure.

INCRA Today

Despite the agency having devolved some of its functions (education, health, transportation), it continues to have a leading role in the economic and environmental development of the region.

In 2005 alone, over 10.3 million hectares of public land in the legal Amazon were regularized and earmarked for future agrarian settlements for families (Hackbart 2009).

The total expenditures of INCRA rose from R\$993 million in 2003 to R\$2.7 billion in 2006. Over R\$500 million in credit was dispensed for settled families. 90 million houses were either improved or constructed in this time frame in addition to 10 thousand kilometers of roads being constructed for access to these new settlements². 32.7 million hectares were incorporated into INCRA 45% of which were expropriated. Over 7 million hectares of public lands with illegal tenure documentation (griladas) are being returned to the government by legal processes, 1.3 million of which from the state of Amazonas alone (Hackbart 2009)

In 2009 in Brazil, there were over seven thousand colonization settlements, 2,343 of which having been created over the past for years. Over its history, INCRA has settled over 1 million families, 381, 419 of which having been settled over the past four years (Hackbart 2009). The average of 95,355 families settled per year in this four year period is the highest rate in the history of the agency.

Further evidence of the growing clout of INCRA in the development of the region is provided by its growing budget. The budget in 2006 was R\$3.7 billion up from R\$1.5 billion in 2003. In the Amazon alone the number of INCRA settlements has risen dramatically over the past 15 years. In 1995 there were 167 settlements on 1,779 hectares of land and by 2005

² Not adjusted for inflation

these numbers had risen to 2,329 settlements in the region on 36,170 hectares of land (Imazon)

In addition, the 691,000 families INCRA had settled in the Amazon region by 2005 comprised over 60% of all the families the agency had settled in the entire country, further demonstrating the influential role it has had in the development and population of the region (Imazon). While INCRA has played a dominant role in Rondônia, their efforts have not been limited to or exceptional in this state. Of the 691,000 families that INCRA settled in the region by 2005, 29% were in Para, 17% in Mato Grosso, 16% in Maranhão and only 12% in Rondônia. Figure 19 breaks down the numbers for all Amazonian states.

2. Frontier Thesis, Forest Expansion Theory and the Boom Bust Pattern of Development

As my study aims to understand the relationship between age, deforestation rates and human welfare in the Brazilian Amazon, an understanding of the frontier thesis, the forest expansion theory and the boom bust theoretical pattern of development is crucial.

The Frontier Thesis was first put forward by Frederick Jackson Turner who in 1893 to an address to the American Historical Association argued that “the existence of an area of free land, its continuous recession, and the advance of American settlement westward, explain American development ... Clearly, the immigrant was attracted by the cheap lands of the

frontier, and even the native farmer felt their influence strongly. Year by year the farmers who lived on soil whose returns were diminished by unrotated crops were offered the virgin soils of the frontier at nominal prices. Their growing families demanded more lands, and these were dear. The competition of the unexhausted, cheap, and easily toured prairie lands compelled the farmer either to go west and continue the exhaustion of the soil on a new frontier, or to adopt intensive culture” (Barbier 2003).

Jackson Frontier Thesis was built upon by Walter Prescott in 1964 when he postulated that the exploitation of the worlds “Great Frontier”, which he defined as the Americas, Australia, New Zealand, and South Africa, wthe reason for the economic boom felt in Europe which ended in the 1800s with the closing of these frontiers (Barbier 2003). The historical work of these two men is a fine place to start when considering a study examining welfare along the frontier of the Brazilian Amazon.

Building on these theories, Barbier introduced the “frontier expansion theory” in which a developing economy will choose to exploit its natural resources at the maximum rate possible, creating a boom of economic activity, though only to be short lived once the natural resources have been exhausted and the frontier closes.

In the literature on the evolution of economic welfare in the Amazon during the course of its population, exploration and development, this boom and bust theory is prevalent (Schneider 2000 et al, Rodrigues et al. 2009, Celentano and Veríssimo 2007).

Schneider 2000 in his book *Sustainable Amazon: limitations and opportunities for rural development* first introduced this theory of the initial boom followed eventually by a bust in Amazonian development. In this work, Schneider simulated the natural resource exploration and economic income of a 10,000 km² area of untouched forest in the humid zone of the Amazon region. Schneider defined the humid zone as areas which receive more than 2,200 mm of rain per year, which accounts for 45% of the region. The simulated area had a highway and two secondary roads.

Schneider in his model assumes that if market forces are free, land use will be based largely upon predatory logging³ and extensive ranching. He predicts that the first 8 years of exploration and development will be marked by increasing profitability and the creation of jobs. To support this, he notes that 15% of the GDP in the states of Rondônia, Para and Mato Grosso is accounted for by the logging industry and that over 500,000 direct and indirect jobs are generated by the industry in the Amazon region. After this 8 year period of high grading,

³ Predatory logging can be described as short term, profit driven logging efforts, separate from colonization schemes, which target relatively undeveloped areas and high value timber species, harvest and move on to new areas

or harvesting the most profitable hard wood species, the logging industry in the study area would turn to harvesting lower value species. This period would last until the 20 year mark when the economic crisis starts and the bust sets in. He estimates that in year 8 the profits from both logging and the subsequent pasture management would reach \$US 100 million though by year 23 the profits would be down to \$US 5 million. However, a more sustainable forest management scheme which he advocates as a better practice than what he models, would generate \$US 70 million in year 8. Schneider moves on to describe the old frontier regions, Paragominas in Para, Sinop in Mato Grosso and Vilhena, Ji-Parana and Ariquemes in Rondônia. For intermediate logging areas in terms of age he chooses the north of Mato Grosso, Tailandia and Maraba in Para as examples. Finally, for new frontier areas he selected Novo Progresso in Para, Novo Aripuana and Apui in Amazonas and Senador Jose Porfirio in Para. He estimated that the older frontier regions have roughly 5 more years before the bust sets in, 10 to 20 more years for the intermediate areas and 30 to 40 years for the newest areas. Loggers in Rondônia have moved onto Bolivia and Amazonas according to the author. Evidence of a vanishing logging industry is provided with the closing of 50 saw mills and a 30% reduction in volume of wood processed in the Paragominas region of Para.

Celentano and Veríssimo 2007 built upon Schneider's boom bust model by comparing development indicators in areas at stratified states of development and population. Using municipal level data these authors split the Amazon region into 4 zones of human occupation status. The first category was the Non-forested which is characterized by a cerrado landscape

and located principally in the southern parts of Mato Grosso and Tocantins. This non-forested area covers 24% of the region. The second category was the deforested area, which is defined as municipalities which have had over 70% of their forest torn down. These areas are situated along the “arc of deforestation and runs from Acre, through Rondônia and northern Mato Grosso and over into southern Para and northern Maranhão. This area makes for 10% of the region. The third categories were areas which were under pressure from population and development, comprising roughly 14% of the region. The principal land uses in this category are predatory logging and extensive pasture creation. The fourth and final category is made up of areas covered in forest, which is defined as having no more than 5% deforested. This category covers 52% of the region.

To test for the boom bust model of development, the investigators examined 11 human development indicators in each the 4 categories of occupation. These indicators measured the violence, economic activity and Human Development Index (HDI) levels in the municipalities.

Looking at the violence levels in the 4 zones of occupation, the authors found that 43% of the rural murders committed in Amazonian between 2003 and 2006 happened within the 3rd category, areas under pressure of human occupation. In this same category, the highest murder rate at 62 per 100 thousand inhabitants was found in 2004, which compared with the regional average of 21 and the national average of 27 is strikingly high. In addition, in this

zone under the pressure of human occupation the highest indices of land tenure conflicts as well as slave labor were found between 2003 and 2006.

Regarding the GDP of an area, again the municipalities in the 3rd zone under pressure of occupation had the highest average annual GDP at US\$ 93.6 million in total and \$US 6.3 thousand per capita, far higher than the averages found in the other 3 zones. In addition, the highest increase between 2000 and 2004 was in this 3rd zone as well. Also, the highest rate of formal jobs was found in this zone. This study also showed evidence that the municipalities that were the most deforested had an average GDP lower than that of the region. In fact the 43 municipalities more than 90% deforested had an average GDP of \$23 million, 60% less than the average in the Amazon region.

When examining the Human Development Indicators, again this 3rd zone under threat of human occupation had the highest levels of all HDI indices. For overall this zone had a score of .731, for education a score of .76, for life expectancy a score of .735 and for income a score of .645. Again, the 43 municipalities with over 90% of its area deforested showed a lower average than regional figures with a HDI score of .674 compared with that of the region of .705. The percentage of deforestation in the municipalities showed a quadratic relationship with the HDI scores starting low in the forested areas, spiking in the under pressure category and falling during the deforested category. This increase in HDI can be attributed the authors state due to the arrival of immigrants with higher education levels and

more capital than people in the area before as well as the high level of economic activity, primarily predatory logging.

The authors conclude by stating there are short and long term costs and benefits to deforestation in the Amazon region. In the short term, GDP and HDI scores improve along the frontier of development with a surge of economic activity and migrants with higher levels of education and more capital, though in addition to higher levels of violence. In the long term, the socio-economic indicators dip back down to levels shown by forested areas. With the costs of a loss of ecosystem services and the 70% of CO₂ Brazilian emissions contributed to by deforestation in the region, development in the Amazon comes at too high of a price and does not justify the 8% of the Brazilian GDP it generates.

Finally, Rodrigues et al. 2009 built upon the previous efforts to further evidence this boom bust model of welfare along the course of development in the region. To measure welfare, this study drew upon HDI figures for 286 municipalities within the Brazilian Amazon collected in 2000. Then it took the deforestation figures for this same year within these municipalities and grouped them into 7 classes, according to both deforestation activity and deforestation extent. When the HDI figures were plotted against the deforestation extent figures, a boom and bust pattern was revealed. This pattern held true for the sub-indices of the HDI measure; standard of living, literacy and life expectancy. As this study development patterns across space rather than time, their conclusions do not necessarily imply that

absolute HDI in municipalities increase and then decline as deforestation progresses, but rather that HDI indicators in areas with early stages of deforestation improve more quickly than the national average. Likewise, the HDI indicators in areas in late stages of deforestation improve at rates lower than the national average. The authors of this study postulate that these trends can be attributed to newly a capitalization on newly available natural resources (land, timber, and minerals) and improved accessibility to market with the construction of new roads.

An Improving Welfare?

In addition to this literature which posits a decline in human welfare over time, there do exist studies which have evidenced just the opposite (Caviglia-Harris et al. 2009). In this three-round spatial panel study of households in Rondônia, Brazil the authors have demonstrated an improvement in several welfare outcomes over time (1996-2005). Regarding education levels, the average years of schooling raised from 2.5 to 2.89 years, due to a turnover in generations of heads of households. Regarding assets, cattle ownership was found to increase over 70%, rising from 72 to 125 heads of cattle per household. To add to this, income and vehicle ownership were also found to increase 90 and 118% respectively. During this same period these increases in human welfare were recorded, forest cover shrunk 50%.

3. Determinants of Welfare

Two recent studies, Marquette 2006 and Sparovek 2003, have examined the determinants of human welfare in agricultural settlements in Latin America. These include farm characteristics such as location / access, topography and parcel size time in existence as well as farmer characteristics such as social organization. These authors also consider the ramifications of government policy such as land titling, access to credit and government cash transfer programs in determining the welfare of farmers in settlements.

Farm Characteristics

The location of a settlement, the characteristics of the land on which a settlement lies and the structure of the settlement itself can be crucial in determining the welfare of its population. Access is a crucial component in determining the welfare of an area. That is, the ability to reach developed markets for farm goods, transportation infrastructure and goods and services only found in urban areas can greatly affect the welfare of a population. Access to urban areas can mean the ability to receive emergency medicine, attend secondary schools, receive attention from governmental and non-governmental extension agencies and gain access to established, competitive markets for agricultural goods (Marquette 2006). To expand on this last point, in Rondônia, where cattle ranching and milk production are the dominant land uses, the ability to receive fair market prices for these goods is crucial. In the context of my

study, where the time needed to reach an urban area ranges from under 10 minutes to over 3 hours, this ability to receive fair market prices for these goods varies greatly. In a settlement located close to a major highway, as many as 10 companies may compete to purchase dairy products, whereas a settlement located very far from an urban area, may have no pickup service at all. As the BR-364 is the main artery of transportation upon which lies the largest urban areas in the state, from which one can easily reach any city, be it the state capital of Porto Velho or southern cities such as Coiaba, I chose to measure the access to this federal highway as the method to determine access, to markets and urban areas.

Another key characteristic of a settlement which can determine the welfare of those living with it is the topography of the land. In the INCRA settlements in my study income generation primarily comes from ranching, milk production and agricultural production. As such, land with more the more favorable condition of flat land, upon which cattle can graze and crops can be planted can be expected to positively affect human welfare. In addition to the difficulty in developing these steeper sloped areas, there are also guidelines within the Brazilian Forest Code of 1965 which prohibit the development of such areas, prohibiting farmers from using this area for cattle grazing.

The structure of a settlement also is a key factor in welfare levels. Each settlement in my study has a unique design and size for each lot. Hence, I believe it is worth including this information in examining human welfare, as larger lot sizes could be surmised to allow for

higher income levels and in turn high levels of human welfare. As lot size in my study sample ranged from approximately 30 hectares to 110, this variation should allow for a true understanding of this variable.

The age of a settlement is a crucial component in determining the welfare of the population within it. Several studies have documented the 'house-hold life cycle', or the series of demographic and economic changes that households pass through over time with the birth of children and loss and gain of household members through death or migration (Marquette 2006, Walker et. Al 2002). In rural areas such as Rondônia, these household demographic changes have direct implications for levels of production as well as consumption. Settlements with households further along this life cycle pattern are less vulnerable to failure brought on by limited labor and high dependency burdens. In addition, settlements with households with several years of experience will have gained a knowledge of the land and productions patterns which will afford it a higher level of welfare than that of a younger settlement where start costs in terms of investment in equipment as well as know how will hinder human welfare, at least initially.

Farmer Characteristics

Another characteristics of a settlement which can affect the welfare of it residents is the social organization within it. This characteristic is often closely related to the age of the

settlement is the social organization with in it, as it has been found that younger settlements have lower levels of social cohesion (e.g. participation in cooperatives or syndicates) (Marquette 2006). In agricultural settings, where strong political and social organization can allow for stronger negotiation with buyers as well as purchasing of heavy equipment otherwise to expensive for a single farmer (e.g. a tractor), weak social organization does not allow for a maximization of human welfare in the settlement. Hence, in settlements with greater social organization and higher participation in groups, one can expect a higher level of human welfare brought about by the advantages had by participation.

Policy

Land titling in the Brazilian Amazon is an increasingly polemic matter. Poorly administered and enforced land titling processes have created a nebulous situation with one study estimating that in the Brazilian Amazon today there are 5 times the amount of land titles that there is land that is accounted for by these titles (Imazon). An increasingly important consideration in this discussion is the role of *Sem Terra* and other landless peasant movements, which despite noble intentions some of them may have, have been criticized for promoting “an industry of occupation”, in which farmers invade a piece of land, squat until they are recognized by INCRA and given at least an initially land title and proceed to sell the land and join another land invasion, by which inflating lot turnover in the region (Fearnside 2001). In this model, the goals of INCRA, of settling families in order to improve the land

tenure situation in Brazil in general, as well as the sustainable model of development in the area in general are undermined, with settlements conglomerating in the hands of the elite few who have the ability to purchase up the land. With the power given to the farmer with a definitive land title (the ability to sell the land or leverage it to gain access to credit, it is a key consideration when determining human welfare in these settlements. Hence, titling and credit are closely related and key considerations for human welfare.

Another policy consideration which can affect human welfare in settlements are government cash transfer programs which can give families extra cash which can be used to invest in agricultural equipment or simply provide the ability to adequately feed themselves. In Brazil *Bolsa Familia* is a social welfare program by which the government gives families in need cash transfers twice a month and has been considered as a determinant of welfare in my study as it could be surmised that those receiving these payments have been able to achieve higher levels of welfare for themselves.

B. Research Questions, Conceptual Framework and Statistical Methods

With the continued importance of colonization settlements and amidst varying theories of the evolution of human welfare of farmers along the frontier of development, a better understanding of the welfare of the colonist famers is merited. As such I seek to answer the following questions.

Research Questions

1. How does welfare evolve over time, controlling for multiple factors?
2. How is welfare affected by deforestation rates, controlling for multiple factors?

Conceptual Framework and Statistical Steps

In order to answer these questions and assess the effect of several variables on the outcome of human welfare within settlements, I created a conceptual framework which examines the relationship between age / rate of deforestation and several welfare outcomes, while accounting for highly correlated confounder variables as well as casual chain variables which also may affect welfare levels within each settlement.

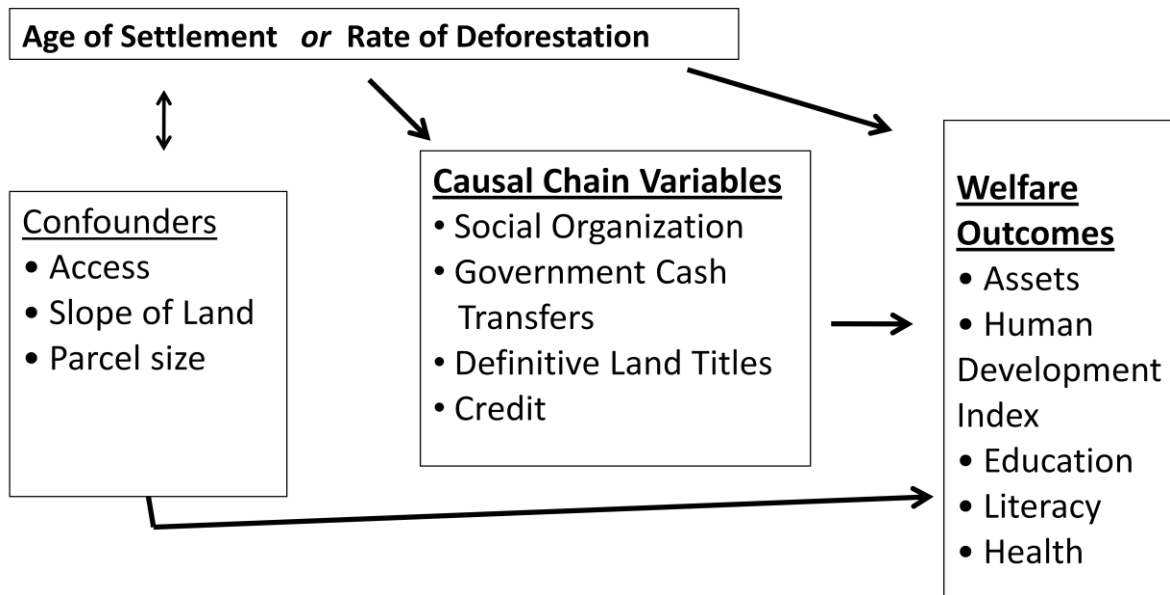


Figure 1.1- Chapter 1 conceptual framework

The first step was to run several stages of bivariate correlations. The first stage of bivariate correlations was for both welfare and age of the settlement as well as for welfare and rates of deforestation. Next, I ran correlations for age of the settlement and rate of deforestation with highly correlated variables (access, parcel size, slope), which I deem confounders. These 3 variables for distinct reasons are closely related to both age and rates of deforestation for historical reasons. For access, older settlements tend to have better access to the federal highway BR-364 as the original settlements in 1970s were built in conjunction with this highway. Likewise, as these settlements are older, their current rates of deforestation are lower. For slope, the lands along the BR-364, with the older settlements, were chosen due to their favorable agricultural conditions which can be theorized to mean flatter lands. Hence, flatter lands in my study sample I predict will have a tendency to be flatter and have lower

current rates of deforestation because of the age of development there. For parcel size, older settlements in my study sample tend to have larger average parcel sizes as this INCRA policy has shifted over time, from over 100 hectare lots to as small as 30 hectare lot sizes presently being given out.

Next, for the welfare measurements taken in 2007 (asset score, IDEB, literacy rate in settlement), I was further able to expand my initial bivariate correlation analysis, by adding in with several socio-demographic variables, I have dubbed causal chain variables, including participation in social groups, definitive land titles and access to credit.

Next, I ran OLS Multivariate Regressions for All Welfare Measurements, where;

<p>Welfare = Age <i>or</i> Deforestation Rate + 3 Confounders - Run for all 9 measurements</p>
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Figure 1.2 – *Chapter 1 conceptual model*

Finally, I ran full OLS Multivariate Regression for welfare measurements taken in 2007: Asset Score, IDEB and Literacy: Settlement, where;

Welfare = Age *or* Deforestation Rate + 3 Confounders + Significant Causal Chain

Variables

-Causal Chain Variables Significant at .20 confidence level were entered into model due to low sample sizes

C. Measures of Welfare and Methods

In this section, I will discuss the multiple measurements I used in my study for human welfare.

Asset Based Approach to Measuring Welfare

For a myriad political and scientific endeavors there is need to assess welfare, though this can be a challenge in rural under developed areas. Governments, international aid organizations and academic institutions among have a need for a rationale metric for socio-economic well being for sound policy creation. The need for an effective as well as efficient method is particularly felt in poor counties which do not have the financial or human resources to generate intricate household survey data in order to design policies and evaluate program

effectiveness (Sahn and Stifel 2003). Several methods have been developed ranging in ease, reliability and practicality.

In this section, first, I will discuss a popular method for measuring welfare, income and consumption analysis and explain why this was not employed in my study. Next, I will explain how the data found in the INCRA-EMATER interviews I collected justified constructing an asset score to measure welfare. This will include a discussion of choosing a weighting method which is inherent with an asset based score. Next, I will discuss the well known United Nations Human Development Index (HDI) and explain how utilizing this municipal level data even for my settlement level analysis was beneficial. Next, I will introduce the measure I have used for educational quality as this is a key consideration when examining human welfare. Related to this I will discuss the literacy information I have in my study and finally I will present what data on public health I have been able to use to measure welfare. In total for my study, I have nine measurements of human welfare; an asset score, four HDI components, settlement and municipal level literacy rates, education scores and public health information.

Income and Consumption Modeling

A popular yardstick for measuring welfare is a model based upon household income and consumption (Duclos et al. 2006). This methodology has the advantage of being easily

understood to policy makers though has several drawbacks as noted by Sahn and Stifel 2003. First, they point out surveys focused upon measuring income and consumption can be overly complex in their methodology and as such are more expensive and arduous to administer. Due to these difficulties this methodology is often beyond the means of smaller organizations or research efforts and can lead to the application of these surveys to be intermittent. A second downside to income and consumption based models is that they rely upon recall data which can lead to measurement errors. Pradhan 2000 found that for the more the number of items on the survey to recall consumption for, there was a higher error incidence. In addition, Scott and Amenuvegbe 1990 found that the longer the recall period was, the smaller the consumption reported was. A third drawback is that when constructing consumption aggregates, there is a need to determine the value of the goods being consumed. As such, there is a need for data on the price of goods, interest rates as well as depreciation rates for semi-durable and durable goods. The fourth and fifth weakness Sahn and Stifel point out deals with the choice of deflators and the inconsistency of consumer price indices as well as exchange rate distortions and the error associated with purchasing power parity figures.

To address the many dimensions of welfare and poverty, the asset index approach has gained increasing popularity in recent years (Fimer and Pritchett 1998, Sahn and Stifel 2000; World Bank 2000). Examples include Adato et al. 2006, Barrett et al. 2006, Booyesen et al 2005, Duclos et al. 2006. This approach has notably been used in Demographic and Health Surveys (DHS) (Booyesen et al. 2006). In addition, the World Health Survey conducted by the World

Health Organization collects information on asset⁴ ownership rather than income and consumption so as to get a comparable measure of permanent income across countries (Fimer and Pritchett 1996). In addition, both the Mexican Migration Project (MMP) and the subsequent Latin American Migration Project (LAMP), collect information on asset indicators and not income or consumption (Sahn and Stifel 2000).

Assets and durable goods used in previous studies, notably in DHS, include but are not limited to access to clean water, availability of water, time to water source, toilet facilities, flushing toilet, non-dirt floors, electricity, radios, televisions, refrigerators, bicycles, motorcycles, cars and housing materials (Montgomery 2001, Perz 2005). Though some of these goods may be provided for my governmental agencies in certain parts of the world, such as water and sanitation infrastructure, in my study area these goods are not provided for by the state. For instance, the percentage of households in my sample of settlement with access to running water ranges between 0% and 95%, septic tanks ownership between 0% and 88% and ownership of a house between 60% and 100%. Durable goods such as these taken for granted in other parts of the world are in Rondônia, Brazil indicators of welfare. A full breakdown of these goods is given in the appendix.

For my study, all household asset possession ascertained by the collected INCRA-EMATER surveys were employed in my welfare model. These included housing material, drinking

⁴ For my study, I will define an asset as a durable good or infrastructure components of a household, indicative of higher welfare

water source and water infrastructure, sanitation infrastructure and transportation equipment possession. Electricity, though present in my surveys, was not used in my asset score. In INCRA agrarian reform settlements electricity by and large is provided for by governmental programs (*Luz No Campo, Luz Para Todos*) and unlike the other components in use from my survey, is not a welfare output but rather an input. Likewise, access to education and health posts, though certainly correlated with household welfare again are not incorporated into my measure of welfare as they are beyond the influence of the households which were surveyed.

For housing material, respondents in for the survey were asked if they had a house and if so what it was made of. Answer choices included brick, wood and tent. In addition, I considered plainly whether or not they had a house.

For sources of water for the household, answer choices included stream, river, Amazonian well, semi-artesian well and other. For water infrastructure, household were asked whether or not they had running water. For sanitation infrastructure, households were given answer choices of having a septic tank, a black tank or an open air pit.

For transportation, households were asked if they had a mechanically wheeled device, an animal or nothing.

Weighting Methods

This section briefly reviews alternative methodologies for combining assets into a single welfare index.

One method is simply to add up all assets, essentially giving each asset or each category of assets equal weight. Despite being fairly common in literature (Montgomery et al. 2000), this method has significant weaknesses. First, it is difficult to rationalize equal weights; for example owning a television and owning a car are hardly equally indicative of wealth (Montgomery 2001). In addition, it is difficult to incorporate the quality of assets when there is information available on this.

Another popular approach is to use the financial value of each asset as its weight. This method can potentially incorporate current value, purchase date, depreciation rate, rate of interest and purchase price (Montgomery 2001). However, some large datasets, such as DHS and NFHS, do not include this information on current value, purchase price or age of assets (Howe 2008). In addition, pricing assets such as a dirt floor can be difficult. Moreover, this method of price indexing the assets of a household is both financially and time demanding and often outside the means of an academic group or smaller governmental organization.

A potentially simpler and slightly more straight-forward method of creating weights is using the inverse proportion of households that own each asset as its weight (Howe 2008). Originally developed by Townsend (1978), this method is based on the assumption that assets owned by a smaller proportion of households are more indicative of higher household welfare and as such should be given a higher weight. However, this logic does not hold true for all assets such as a motorcycle which may increase initially with wealth, though decline once a certain level of wealth is attained and a car is purchased to replace the motorcycle. (Howe 2008). Due to this flaw as well as the fact that this methodology is best for binary data sets (e.g., household level data), it was not utilized in my study.

Another method, which was employed by Sparovek et al. 2003, is to use weights at the discretion of the research team. While this method makes the best use of the research team's sense of field conditions, it is difficult to verify and to compare across settings and studies.⁵

Principal Components Analysis (PCA) has gained popularity as a method for determining weights for assets. A study by Filmer and Pritchett in 2001 has greatly influenced the adoption of PCA for determining weights in demographic based studies. In this study, the relationship between household wealth and children's school enrollment was estimated using

⁵ Multiple Correspondence Analysis (MCA) is similar to PCA and has been employed in weight creation, but it is intended for use with discrete data sets.

a linear index as a proxy for wealth, based upon asset ownership using PCA to derive weights (Filmer and Pritchett 2001). In this paper, the authors point out that while their study chose educational enrollment as an outcome other outcomes present in the DHS data, such as mortality, morbidity, use of health facilities, fertility and use of contraceptives could be analyzed as was done by Bonwella- Chacin and Hammer 1999, Gwatkin et al. 2000, Bommier and Boerma 1999. It is important to note that in PCA the Welfare index produced is a relative measure which for my study is beneficial as I am comparing the 93 settlements in my study sample with each other.

As the my data set does not include information on prices, though does contain several indicators of asset ownership, Principal Components Analysis was most appropriate for determining weights for the various components of my asset score. Furthermore, this method is designed for continuous data sets with normal distribution which well suits my study as my data set is composed primarily of continuous variables ranging from 0 to 100%.

Principal Components Analysis: Weights for Welfare Components	
Asset Category	Weight
House	
Brick House	0.15129
Wood House	0.18253
Tent	-0.3023
Not Homeless	0.29384
Water	
Source: River	0.18534
Source: Stream	-0.2222
Source: Well	0.32677
Source: Spring	-0.2054
Running Water	0.24953
Sanitation	
Septic Tank	0.31003
Black Tank	0.03508
Open Air Pit	-0.4066
Household Transportation	
Tractor	0.30006
Animal	0.07697
None	-0.3359

Chart 1.1- *Principle Components Analysis Weights for Welfare Components*

Human Development Index (HDI)

The United Nations in response to a need for an effective methodology to measure human welfare around the globe first introduced in the 1990 *Human Development Report*, the now well known Human Development Index. This metric is a summary composite index which measures the development aspects of health, knowledge and standard of living (UNDP). Health is measured by life expectancy at birth, the knowledge component is measured by a

combination of the literacy rate and combined primary, secondary and tertiary gross enrollment ratio and the standard of living is measured by the GDP per capita (PPP US\$) (UNDP). These scores are often reported together, at regional and state levels, though recently disaggregation of both the categories as well as scales of analysis has grown popular among researchers and policy makers to better understand trends in development within a country, region or state. For instance, in Bolivia it was found that the richest 20% of the country's population had an HDI rank 97 positions higher than the poorest 20%. In countries such as Brazil with a great disparity in wealth and well being across vast geographic regions, both spatial and categorical disaggregation is essential.

In the context of human development in the Brazilian Amazon, Rodrigues et al. 2009 employed this disaggregated HDI measurement for municipalities in the region to demonstrate changes in socio-economic well being across time and space to suggest a temporally driven economic boom and bust pattern.

For my study, HDI figures taken at the municipal scale will be applied to my sample of settlements. In doing so I will be able to first, have several welfare outcomes for the year 2000 as opposed to other data I have which was collected in 2007. Second, by using this HDI data I will increase my ability to understand the relationship between welfare, age and deforestation rates as using disaggregated HDI figures gives me four more welfare outcomes.

IDEB: Índice de Desenvolvimento de Educação Básico (Index of Basic Education Development)

Education is a basic component of human welfare and in recognition of this the Brazilian government created in 2007 an *Education Development Plan* aimed at improving the quality of education in the country (Côrtes 2009). As part of this plan the IDEB: Índice de Desenvolvimento de Educação Básico was created, which is a measure built upon school performance on standardized tests (Prova Brasil). IDEB scores are generated for every school in Brazil. As I did not have information on which settlements in my study sample were serviced by which school, I took the mean IDEB score for the municipality in which the settlement was located as its score.

Literacy Rates

Literacy rates also are a popular measure for human welfare as evidenced by their incorporation in the United Nations HDI formula. The Instituto Brasileiro de Geografia e Estatística (IBGE), or the Brazilian Institute of Geography and Statistics, makes publicly available literacy rates at the municipal level. To add another welfare outcome to my study, I downloaded literacy rates for the municipalities in Rondônia and as with the IDEB and HDI figures, applied these numbers to the settlements in my sample for the municipality in which they were located. In addition, the INCRA-EMATER interviews I collected and used as the

basis for my asset score, contained literacy rates. As such, I have 2 measurements of literacy rates which makes more robust my analysis of this measure for welfare.

Public Health

Along with wealth and education, public health is a key consideration for a discussion on human welfare. As the theatre for my examination of human welfare is the anthropogenic developed areas of the Brazilian Amazon, using tropical disease figures as a proxy public health well being is logical. As discussed in my literature review, malaria, paracoccidioidomycosis, cromoblastomycosis and leishmaniasis are linked with land use change in tropical environments and were the four diseases for which I collected reliable information. As such, I have constructed a composite index for the indigence of these diseases for the years 2003-2006. Once more, as this information was recorded at the municipal level, I applied this information to the settlements for the municipality in which they were located. In a comprehensive global study on the effects of deforestation on infectious disease rates the authors found in the majority of cases a correlation of this land change and an increase in disease rates (Walsh 1993).

Malaria in particular stand out in literature as linked with tropical deforestation (Wash 1993, Pattanayak et al. 2006, Yasauko and Levin 1997, Taylor 1997). In Amazonia, Walsh 1993

found rates of malaria in particular to increase with deforestation as large number of migrants have cleared land and created a suitable habitat for disease carrying insects.

Other tropical diseases as well, including paracoccidioidomycosis, cromblastomycose and leishmaniasis are linked with land use change in tropical environments.

Paracoccidioidomycosis is a fungal tropical disease which can cause painful lesions, pulmonary complications and internal disorders and is more commonly known as *South American blastomycosis*. A paper on the disease focusing on mortality on Brazil from 1980 to 1995 found that agricultural frontier regions with high rates of deforestation can show be hyperendemic areas, with young adults primarily being affected (Coutinho 2002, Fonesca et al. 1999). He goes on to write “The Central west and North represent new agricultural frontiers and have undergone accelerated transformations in their original environment in recent decades, with intense social mobility, implementation of large-scale agricultural and cattle-raising settlements, occupation of new farming areas by small and medium farmers, systematic deforestation of native areas, extensive seasonal slashing and burning, etc. In an initial approach, all these factors could facilitate greater exposure to the ecotypes in which the fungus is found in nature, thereby allowing for human contamination” (Fonseca et al., 1999).

Leishmaniasis is a parasitic disease caused by bites from sand flies and symptoms include skin lesions and damage to internal organs. Cromoblastomycosis is a long term fungal infection found in rural areas in the tropics.

Aside from the health implications of these tropical diseases there is a cost associated with them. Sachs and Malaney 2002 list out these social and economic costs including quality of life, fertility, population growth, savings and investment, labor productivity, premature mortality, and medical costs (Sachs and Malaney 2002). Pattanayak et al. 2006 report on the direct and indirect costs of malaria at the household level which include loss of work efficiency and time and work reallocation within the household. The authors here estimate that malaria can decrease per capita GNP by 0.25 to 1.30% in tropical countries. Furthermore, the long term costs of child development and a compromised immunity are unknown though in need of consideration (Hutubessy et al. 2001).

D. Results

Variable	N	Mean	Std Dev	Minimum	Maximum
Asset Score	40	70.6453	33.2163	-3.5274	125.1157
Literacy: Settlement	39	90.3159	6.0657	76	100
IDEB	93	3.8205	0.2705	3	4.3
Disease Incidence	93	0.0969	0.0862	0.0087	0.4387
Literacy: Municipality	93	81.8384	3.3660	75.8324	90.9784

HDI	93	0.7024	0.0286	0.661	0.763
HDI: Income	93	0.6442	0.0487	0.561	0.728
HDI: Life Expectancy	93	0.6825	0.0229	0.635	0.752
HDI: Education	93	0.7808	0.0425	0.723	0.898
Year of Settlement Creation	93	1995	6.6789	1972	2006
Years Since First Cutover (Age)	93	20.1505	7.1139	8	40
Forest Cover: 2007	84	0.3859	0.1472	0.1108	0.8006
Primary Forest Cover: 2007	84	0.1959	0.1169	0.0353	0.6360
Forest Cover: 2000	84	0.6052	0.1753	0.1102	0.9161
Primary Forest Cover: 2000	84	0.4267	0.1854	0.0672	0.7974
% Change From Primary Forest: Pre 1990	84	0.2166	0.1991	0.0043	0.8066
Rate of Deforestation: 2000-2007	84	0.4672	0.1391	0.1728	0.7460
Rate of Deforestation: 1990-1999	84	0.3162	0.1717	0.0142	0.7390
Years to Deforest Half of Forest	57	10.0175	3.6523	3	20
Forest Cover at Year of First Cut	66	0.8910	0.0886	0.5891	0.9884
Access to Federal Highway	90	78.0149	14.9866	25.7061	98.6690
Steepness of Slopes	90	4.7913	1.5949	2.4921	8.9467
Parcel Size	93	42.5161	19.7905	3	110
Definitive Land Title	93	38.8123	76.0007	0	593.9
Credit	40	93.7133	38.5710	0	168
Participation in Social Group	40	71.0863	22.5895	25	100
Government Cash Transfers	40	27.1310	18.4459	3.92	75
Origin of Colonist Farmer: North	40	11.3002	8.8971	0	44
Origin of Colonist Farmer: East	40	13.4892	8.3387	2.94	37
Origin of Colonist Farmer: Centralwest	40	11.4133	5.8108	1	28

Origin of Colonist Farmer: South	40	20.4726	10.2142	1.67	54.8
Origin of Colonist Farmer: Southeast	40	43.6609	14.6678	10	74

Chart 1.2- *Chapter 1 descriptive statistics*

CHART 1.3									
Bivariate Correlations, P-Value, and Sample Size									
	Asset Score	Literacy Rate: Settlement	IDEB	Disease Incidence	Literacy Rate: Munic.	HDI	HDI Inc.	HDI-Health	HDI-Ed.
Years Since First Cut	0.3293	-0.2453	0.1910	-.26325	0.3012	0.2545	0.0729	0.1339	0.3578
	0.038	0.1324	0.0665	.0108	0.0033	0.0138	0.4868	0.2006	0.0004
	40	39	93	93	93	93	93	93	93

Chart 1.3- *Conceptual Framework: Step 1a – Bivariate Correlations of Age of Settlement OR Rate of Deforestation and Welfare Measurements*

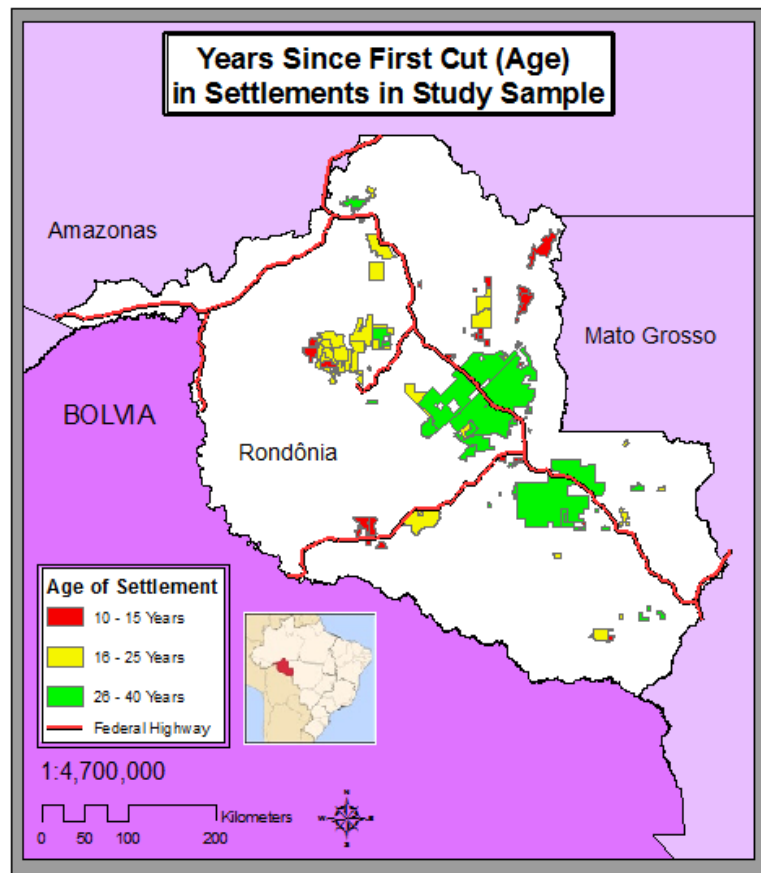


Figure 1.3- *Years since first cut (age) in settlement in study sample*

CHART 1.4: Welfare Measurements and Rates of Deforestation				
Bivariate Correlations, P-Value, and Sample Size				
Deforestation Rates	Asset Score	Literacy Rate: Settlement	IDEA	Disease Incidence
Rate of Deforestation: Prior Period	0.03159	0.4316	-0.283	.2351
	0.866	0.0172	0.0091	.0313
	31	30	84	84

Chart 1.4- *Conceptual Framework: Step 1b – Bivariate Correlations of Rate of Deforestation and Welfare Measurements; 2000-2007*

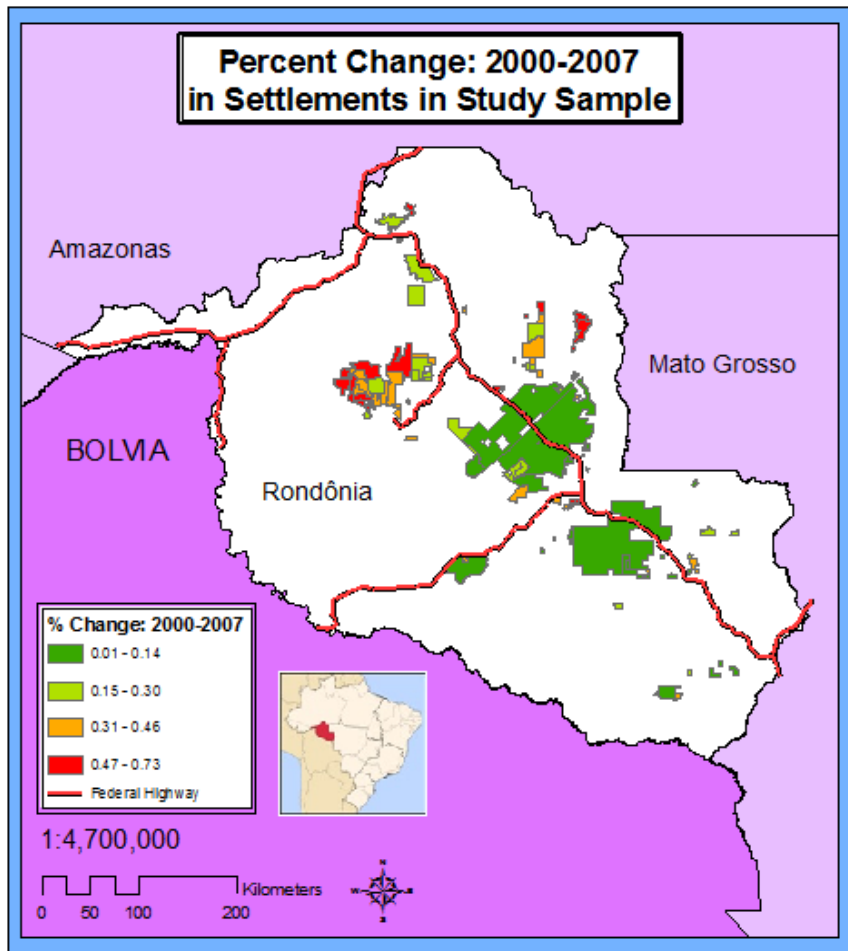


Figure 1.4- *Percent change: 2000-2007 in settlements in study sample*

CHART 1.5: Welfare Measurements and Rates of Deforestation					
Bivariate Correlations, P-Value, and Sample Size					
Deforestation Rates	Literacy Rate: Municipality	HDI	HDI- Income	HDI- Health	HDI- Education
Rate of Deforestation: Prior Period	-0.0994	-0.1729	-0.0971	-0.0413	-0.2166
	0.3682	0.1159	0.3794	0.709	0.0478
	84	84	84	84	84

Chart 1.5- Conceptual Framework: Step 1b – Bivariate Correlations of Rate of Deforestation and Welfare Measurements; 1990-1999

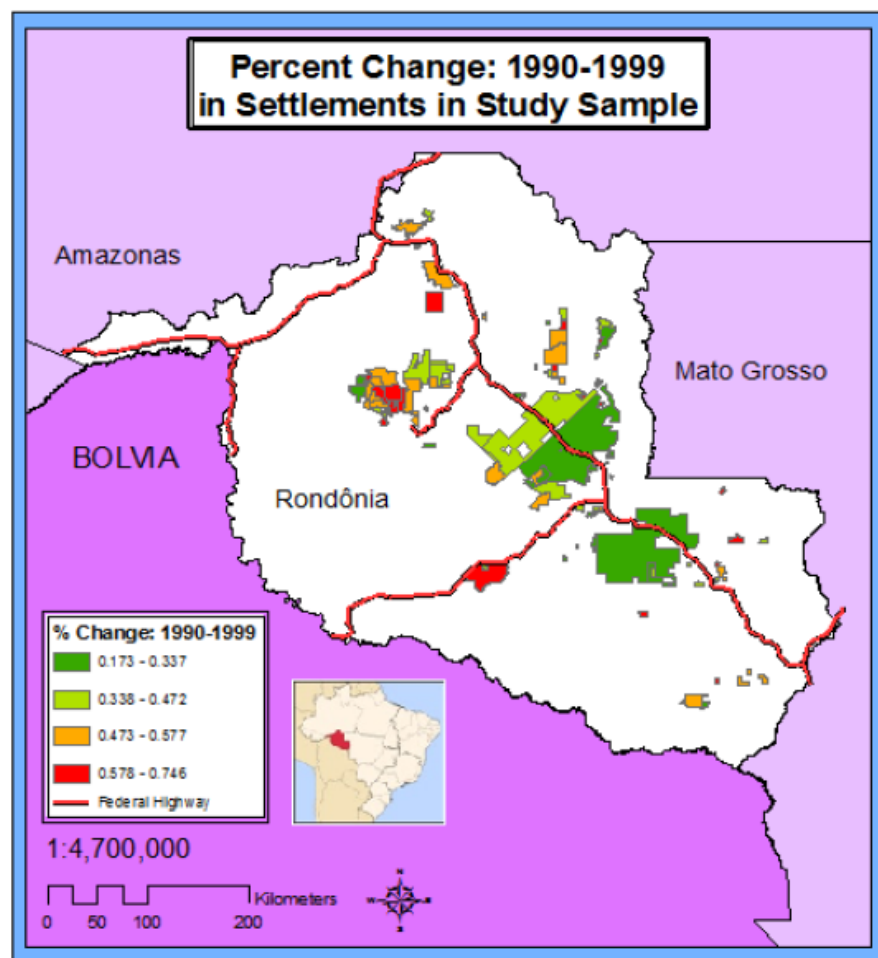


Figure 1.5- Percent Change: 1990-1999 in Settlements in Study Sample

Chart 1.6: Age of Settlement and Rate of Deforestation and Confounder: Access to Federal Highway			
	Access to Federal Highway		Access to Federal Highway
Years Since First Cut (Age)	0.27623 0.0084 90	Rate of Deforestation	-0.3646 0.0006 84

Chat 1.6- *Conceptual Framework: Step 2 – Bivariate Correlations of Welfare Measurements and Confounders; Access*

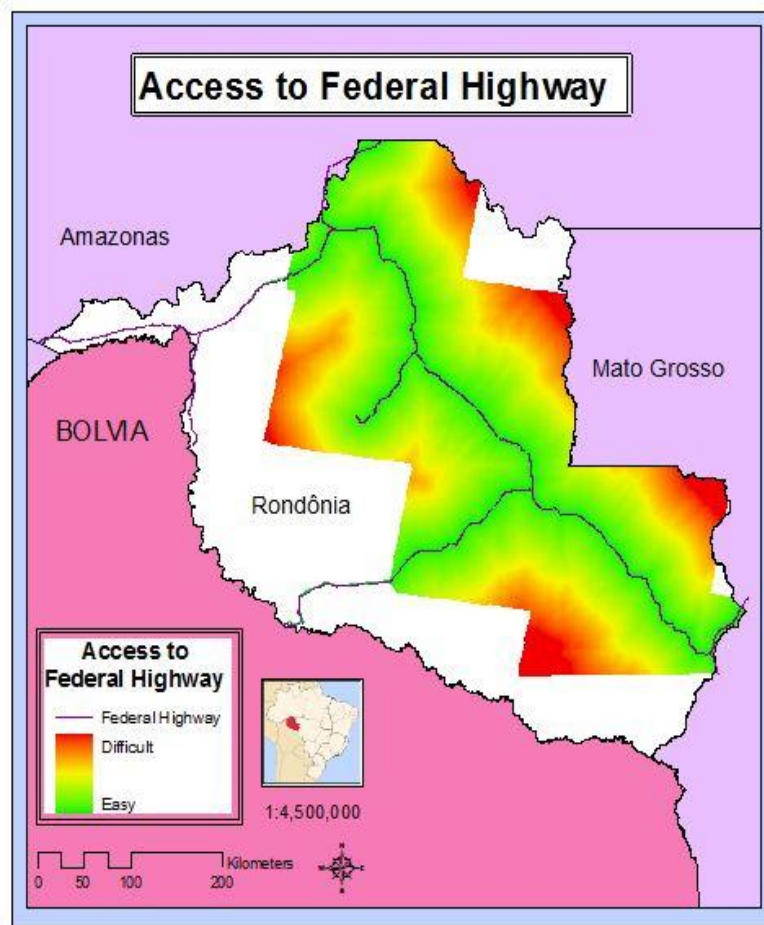


Figure 1.6- *Access to Federal Highway*

Chart 1.7: Age of Settlement and Rate of Deforestation and Confounder: Steepness of Slopes			
	Steepness of Slopes		Steepness of Slopes
Years Since First Cut (Age)	0.17255	Rate of Deforestation	0.00274
	0.1039		0.9803
	90		84

Chart 1.7-Conceptual Framework: Step 2 – Bivariate Correlations of Welfare Measurements and Confounders; Steepness of Slopes

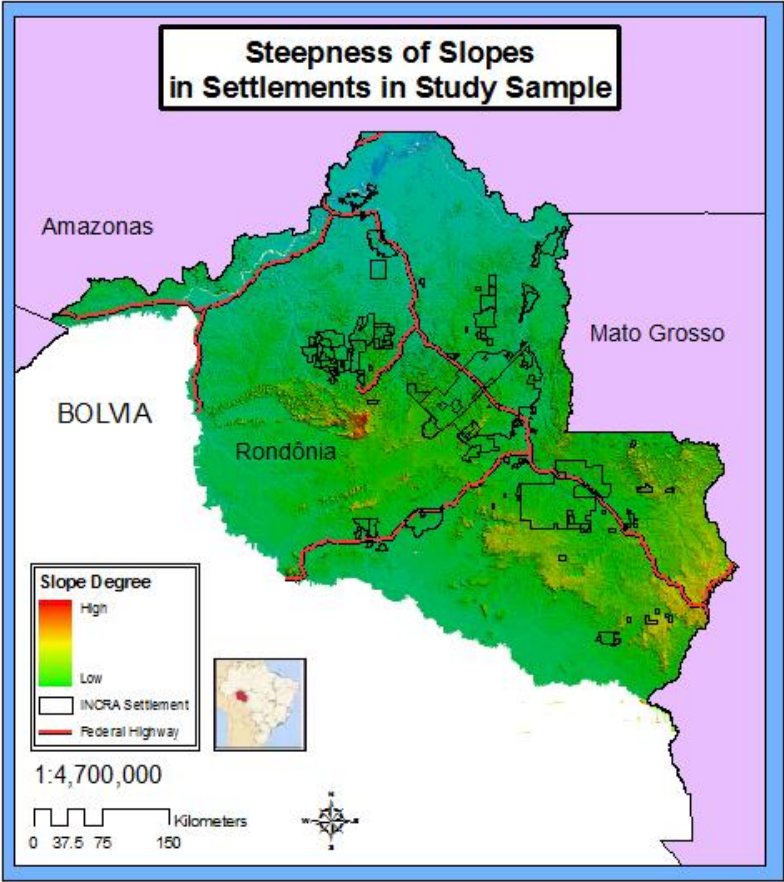


Figure 1.7- Steepness of Slopes in Settlements in Study Sample

Chart 1.8: Age of Settlement and Rate of Deforestation and Confounder: Parcel Size			
	Parcel Size		Parcel Size
Years Since First Cut (Age)	0.3375 0.0009 93	Rate of Deforestation	-0.0246 0.824 84

Chart 1.8- *Conceptual Framework: Step 2 – Bivariate Correlations of Welfare Measurements and Confounders: Parcel Size*

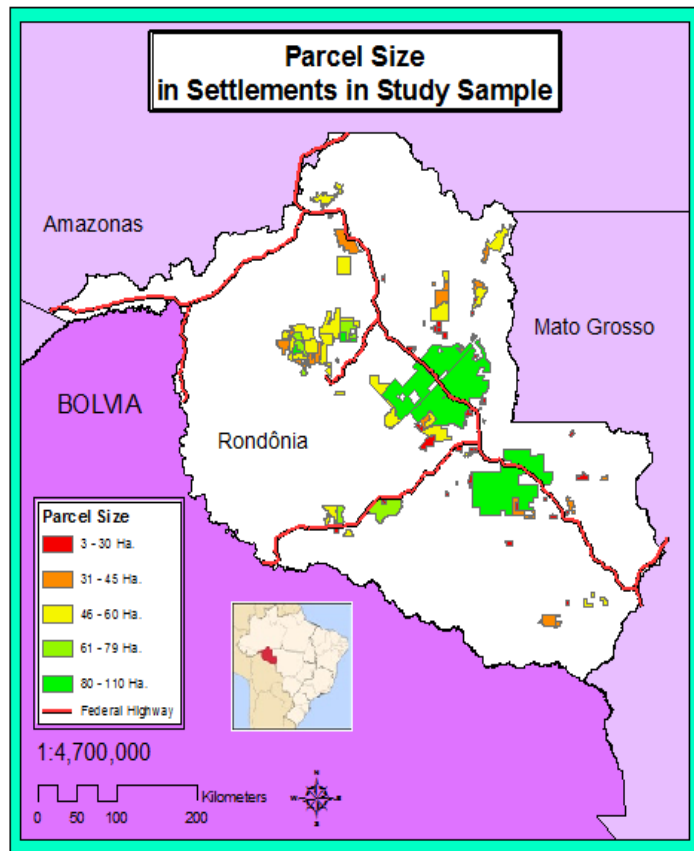


Figure 1.8- *Parcel Size in Settlements in Study Sample*

		Participation in Social Group	Govt. Cash Transfers	Definitive Land Title	Creidt
Age	<i>Coefficient</i>	0.0831	0.3332	0.4873	0.1018
	<i>P-Value</i>	0.6102	0.0356	<.0001	0.5316
	<i>N</i>	40	40	93	40
Rate of Deforestation	<i>Coefficient</i>	-0.1683	-0.3262	-0.4744	0.1927
	<i>P-Value</i>	0.3652	0.0732	<.0001	0.2989
	<i>N</i>	31	31	84	31

Chart 1.9- Conceptual Framework: Step 3a – Bivariate Correlations of Causal Chain Variables, Age of Settlement and Rate of Deforestation

		Participation in Social Group	Govt. Cash Transfers	Definitive Land Title	Creidt
Asset Score	<i>Coefficient</i>	0.2075	0.3876	0.2458	0.3207
	<i>P-Value</i>	0.1988	0.0135	0.1262	0.0436
	<i>N</i>	40	40	40	40
IDEB	<i>Coefficient</i>	-0.051	0.1434	0.0068	-0.1605
	<i>P-Value</i>	0.7542	0.3771	0.9484	0.3225
	<i>N</i>	40	40	93	40
Literacy-Settlement	<i>Coefficient</i>	-0.2898	-0.4203	-0.3282	-0.0407
	<i>P-Value</i>	0.0735	0.0077	0.0414	0.8056
	<i>N</i>	39	39	39	39

Chart 1.10- Conceptual Framework: Step 3b – Bivariate Correlations of Causal Chain Variables and Welfare Measurements

Multivariate Regression: Asset Score (AGE)			
P-Value	R-Square		
0.1063	0.2065		
Variable	Coefficient	P-Value	N
Age	0.73259	0.3784	37
Access to Federal Highway	0.63275	0.0487	37
Slope	-4.43169	0.1966	37
Parcel Size	0.02134	0.9412	37

Multivariate Regression: Asset Score (RATE)			
P-Value	R-Square		
0.0898	0.2581		
Variable	Coefficient	P-Value	N
Change: 2000-2007	7.70611	0.8334	31
Access to Federal Highway	-0.28078	0.4612	31
Slope	-8.84717	0.0059	31
Parcel Size	0.09249	0.7295	31

Chart 1.11- *Conceptual Framework: Step 4 – OLS Multivariate Regressions: Asset Score*

Multivariate Regression: IDEB (AGE)			
P-Value	R-Square		
0.0184	0.1289		
Variable	Coefficient	P-Value	N
Age	0.01024	0.0266	90
Access to Federal Highway	0.00112	0.5732	90
Slope	-0.04052	0.0257	90
Parcel Size	-0.00184	0.2242	90

Multivariate Regression: IDEB (RATE)			
P-Value	R-Square		
0.0095	0.1542		
Variable	Coefficient	P-Value	N
Change: 2000-2007	-0.42597	0.0212	84
Access to Federal Highway	0.0012	0.6094	84
Slope	-0.04272	0.0244	84
Parcel Size	-0.0005664	0.7009	84

Chart 1.12- *Conceptual Framework: Step 4 – OLS Multivariate Regressions: IDEB*

Multivariate Regression: Literacy-Settlement (AGE)			
P-Value	R-Square		
0.7159	0.0638		
Variable	Coefficient	P-Value	N
Age	-0.14838	0.437	36
Access to Federal Highway	-0.03917	0.5778	36
Slope	-0.2744	0.7247	36
Parcel Size	0.04216	0.5188	36

Multivariate Regression: Literacy-Settlement (RATE)			
P-Value	R-Square		
0.172	0.2181		
Variable	Coefficient	P-Value	N
Change: 2000-2007	21.68895	0.0382	30
Access to Federal Highway	0.0612	0.5553	30
Slope	-0.49396	0.5472	30
Parcel Size	0.03684	0.6125	30

Chart 1.13- *Conceptual Framework: Step 4 – OLS Multivariate Regressions: Literacy Rate-Settlement*

Multivariate Regression: Disease Incidence (AGE)			
P-Value	R-Square		
0.0066	0.1524		
Variable	Coefficient	P-Value	N
Age	-0.00338	0.0213	90
Access to Federal Highway	-0.00102	0.1061	90
Slope	0.01037	0.0706	90
Parcel Size	0.00000388	0.9935	90

Multivariate Regression: Disease Incidence (RATE)			
P-Value	R-Square		
0.1251	0.0862		
Variable	Coefficient	P-Value	N
Change: 1990-1999	0.10136	0.1559	84
Access to Federal Highway	-0.0008623	0.23	84
Slope	0.00788	0.2093	84
Parcel Size	-0.0002761	0.5699	84

Chart 1.14- *Conceptual Framework: Step 4 – OLS Multivariate Regressions: Disease*

Incidence

Multivariate Regression: HDI (AGE)			
P-Value	R-Square		
0.0427	0.1084		
Variable	Coefficient	P-Value	N
Age	0.00028495	0.5522	90
Access to Federal Highway	0.00048564	0.022	90
Slope	0.0025	0.1868	90
Parcel Size	0.0001266	0.4259	90

Multivariate Regression: HDI (RATE)			
P-Value	R-Square		
0.0243	0.1308		
Variable	Coefficient	P-Value	N
Change: 1990-1999	-0.03768	0.1041	84
Access to Federal Highway	0.00051384	0.0289	84
Slope	0.00407	0.0472	84
Parcel Size	0.00009091	0.5635	84

Chart 1.15- *Conceptual Framework: Step 4 – OLS Multivariate Regressions: HDI*

Multivariate Regression: HDI-Income (AGE)			
P-Value	R-Square		
0.0118	0.1393		
Variable	Coefficient	P-Value	N
Age	-0.00134	0.0933	90
Access to Federal Highway	0.00050534	0.1443	90
Slope	0.00753	0.0172	90
Parcel Size	0.00063028	0.0178	90

Multivariate Regression: HDI-Income (RATE)			
P-Value	R-Square		
0.0184	0.1378		
Variable	Coefficient	P-Value	N
Change: 1990-1999	-0.05069	0.1848	84
Access to Federal Highway	0.00001559	0.9675	84
Slope	0.0089	0.0092	84
Parcel Size	0.00035083	0.1795	84

Chart 1.16- *Conceptual Framework: Step 4 – OLS Multivariate Regressions: HDI-Income*

Multivariate Regression: HDI-Life Expectancy (AGE)			
P-Value	R-Square		
0.2625	0.0592		
Variable	Coefficient	P-Value	N
Age	0.00008618	0.8311	90
Access to Federal Highway	0.00030017	0.091	90
Slope	0.00071932	0.6511	90
Parcel Size	0.00015972	0.2349	90

Multivariate Regression: HDI-Life Expectancy (RATE)			
P-Value	R-Square		
0.3498	0.054		
Variable	Coefficient	P-Value	N
Change: 1990-1999	-0.00771	0.6733	84
Access to Federal Highway	0.00022632	0.221	84
Slope	0.0228	0.1586	84
Parcel Size	0.00009593	0.4434	84

Chart 1.17- *Conceptual Framework: Step 4 – OLS Multivariate Regressions: HDI-Life*

Expectancy

Multivariate Regression: HDI-Education (AGE)			
P-Value	R-Square		
0.0003	0.2183		
Variable	Coefficient	P-Value	N
Age	0.00208	0.0028	90
Access to Federal Highway	0.00067191	0.0253	90
Slope	-0.0006853	0.7976	90
Parcel Size	-0.0004081	0.0724	90

Multivariate Regression: HDI-Education (RATE)			
P-Value	R-Square		
0.0005	0.2218		
Variable	Coefficient	P-Value	N
Change: 1990-1999	-0.05454	0.0988	84
Access to Federal Highway	0.00132	0.0001	84
Slope	0.00103	0.7199	84
Parcel Size	-0.0001736	0.4392	84

Chart 1.18- *Conceptual Framework: Step 4 – OLS Multivariate Regressions: HDI-Education*

Multivariate Regression: Literacy-Munic. (AGE)			
P-Value	R-Square		
0.0463	0.1064		
Variable	Coefficient	P-Value	N
Age	0.02184	0.6939	90
Access to Federal Highway	0.05303	0.0306	90
Slope	0.17102	0.4342	90
Parcel Size	0.03031	0.102	90

Multivariate Regression: Literacy-Munic. (RATE)			
P-Value	R-Square		
0.0761	0.1004		
Variable	Coefficient	P-Value	N
Change: 1990-1999	-1.65861	0.5423	84
Access to Federal Highway	0.05738	0.0388	84
Slope	0.21298	0.3746	84
Parcel Size	0.03167	0.0914	84

Chart 1.19 -*Conceptual Framework: Step 4 – OLS Multivariate Regressions: Literacy-*

Municipality

Multivariate Regression: Asset Score (AGE)			
P-Value		R-Square	
0.122		0.3381	
Variable	Coefficient	P-Value	N
Age	0.2163	0.8125	37
Access to Federal Highway	0.6565	0.0659	37
Slope	-6.0111	0.0986	37
Parcel Size	0.2613	0.3963	37
Definitive Land Title	0.1228	0.3778	37
Participation in Social Group	0.1773	0.4568	37
Govt. Cash Transfers	0.3942	0.2087	37
Credit	0.0151	0.9272	37

Chart 1.20 *Conceptual Framework: Step 5 – OLS Multivariate Regression: Asset Score*

Multivariate Regression: Literacy-Settlement			
P-Value		R-Square	
0.4298		0.2055	
Variable	Coefficient	P-Value	N
Age	0.00294	0.9886	36
Access to Federal Highway	-0.04681	0.496	36
Slope	-0.06778	0.9318	36
Parcel Size	-0.01201	0.8595	36
Definitive Land Title	-0.02651	0.3975	36
Participation in Social Group	-0.02627	0.6322	36
Govt. Cash Transfers	-0.09898	0.1555	36

Chart 1.21- *Conceptual Framework: Step 5 – OLS Multivariate Regression: Literacy-Settlement*

E. Discussion

This chapter has the objective of understanding welfare outcomes in agrarian reform settlements in the Brazilian Amazon, specifically how these are related to the age of the settlement as well as deforestation rates within them. With the continued dominant role INCRA has in the development of the Amazon, understanding the well being of the colonist farmers is crucial for meeting both the goals of agrarian reform as well as ecological conservation. Whereas much past research has focused on farmers, pixels or census units, my study chose to examine outcomes at the level of the settlement, the level at which much governmental and nongovernmental extension efforts are determined, and as such is relevant for policy makers.

In this discussion section, first I will discuss how human welfare has evolved over time in the agrarian reform settlements in my study sample as well as how this welfare has been affected by deforestation rates, while controlling for multiple factors. Next, I will discuss the confounding variables in these relationships, access, topography and parcel sizes, and explain their relationships with human welfare. Finally, I will discuss the causal chain variables which add to these above relationships; definitive land titles, social group organization and government cash transfers.

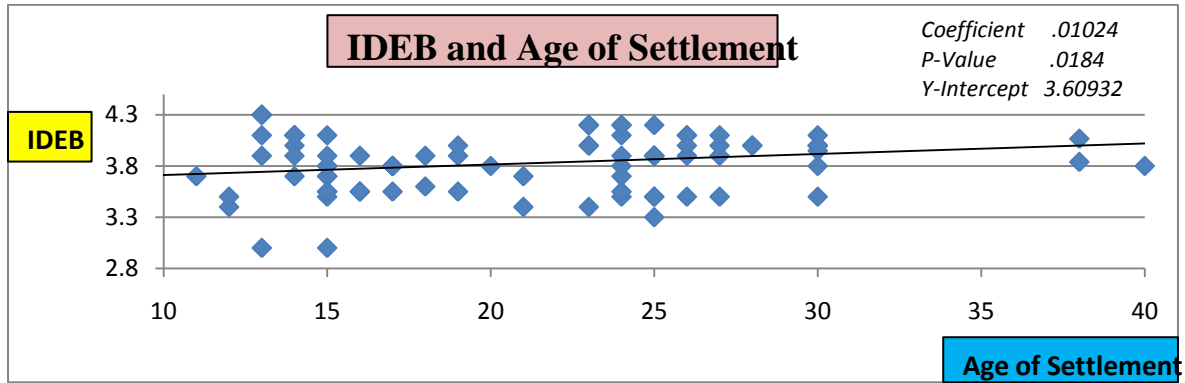
Age of Settlement

In 8 of the 9 human welfare measurements my study examined there was a significant correlation with the age of the settlement. The asset score, IDEB, municipal literacy rate, HDI, HDI-Life Expectancy and HDI-Education all correlated positively with age, as is demonstrated in Chart 3. That is to say that the older settlements in my study sample all demonstrated higher levels of these human welfare measurements than did the younger settlements. The settlement level literacy rate as well as the disease incidence measurement both correlated negatively, which is to say that older settlements in my study sample demonstrated lower levels of these welfare measurements.

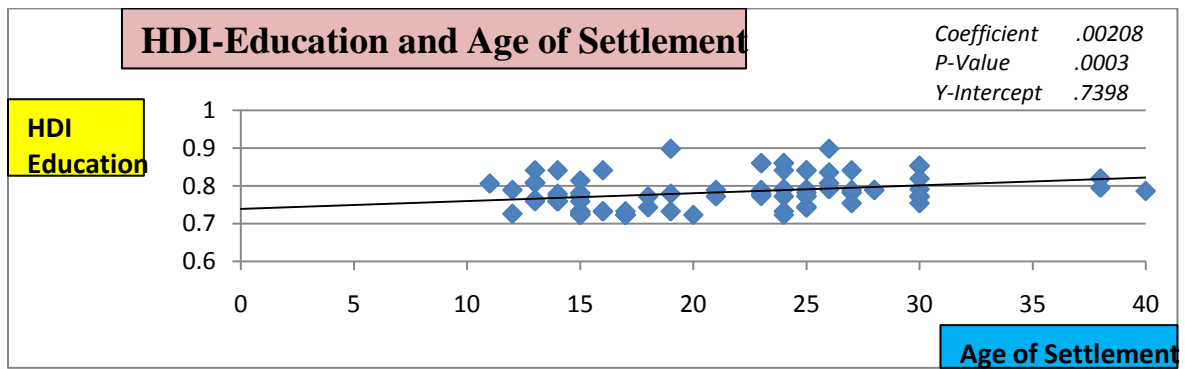
In the multivariate regressions for welfare, age remained significant in 3 instances; IDEB score, HDI Income, HDI Education and Disease Incidence.

In the multivariate regressions, both IDEB and HDI Education are positively correlated with age. Charts 1.12 and 1.18 above as well as Graphs 1.1 and 1.2 below demonstrate these results. These findings give strong evidence of a positive evolution of welfare in terms of education in the region. Contrary to the low HDI Education scores reported by Celentano and Veríssimo 2007 in the municipalities they examined, my study has found on the contrary,

that older areas are where higher educational quality is found, which is promising for the future of human welfare in the region.



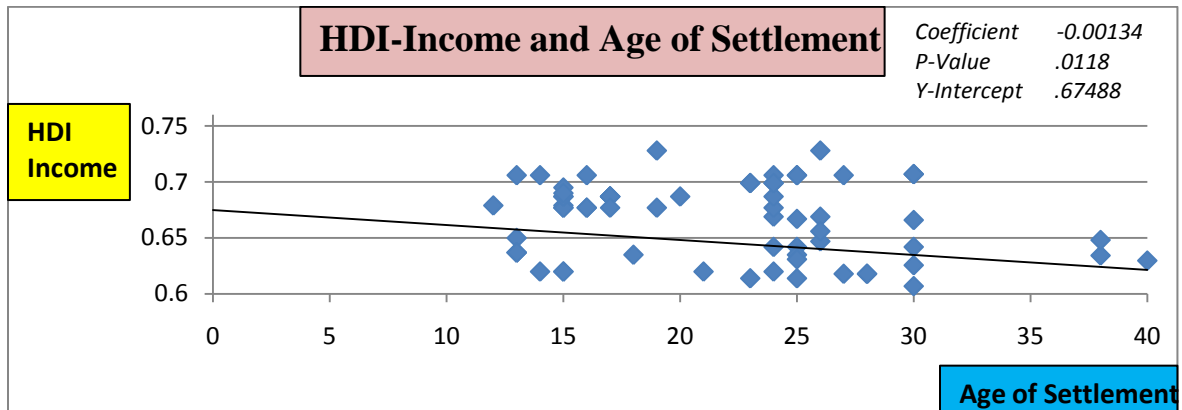
Graph 1.1- IDEB and Age of Settlement



Graph 1.2- HDI-Education and Age of Settlement

Age also correlated negatively with HDI Income, which could be in line with the literature reviewed for this study, which suggest that there is an initial economic burst brought on by a rapid exploitation of natural resources on the property as well as an influx of money from

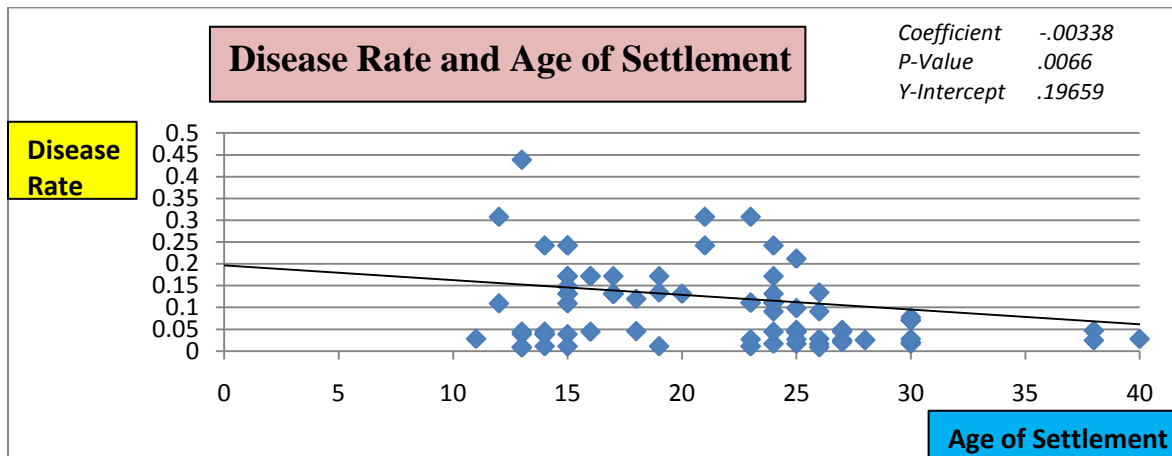
new forestry related jobs (Rodrigues et al. 2009, Schneider 2000, Celentano and Veríssimo 2007). Graph 1.3 below demonstrates.



Graph 1.3- *HDI-Income and Age of Settlement*

The Disease Incidence in the settlements in my study sample also remained negatively correlated with age in the multivariate analyses, which is to say that older settlements have lower levels of the tropical disease I examined that did the younger settlements. Chart 1.14 above and Graph 1.4 below demonstrate. Given that the vectors for these diseases includes deforestation, standing water and exposed soils, this finding is in line with expectations. When considering the social and economic costs of these debilitating tropical diseases (quality of life, fertility, population growth, savings and investment, labor productivity, premature mortality, and medical costs) these lower incidence rates are of considerable advantage to older settlements (Sachs and Malaney 2002). Adding to this, Pattanyak et al. 2006 estimation of GNP per capita decreasing by 0.25% to 1.3% in tropical countries due to

malaria as well as the long term costs in relation to child development and a compromised immune system reported by Hutubessy et al. 2001, low rates of diseases as an positive influence on human welfare cannot be overstated.



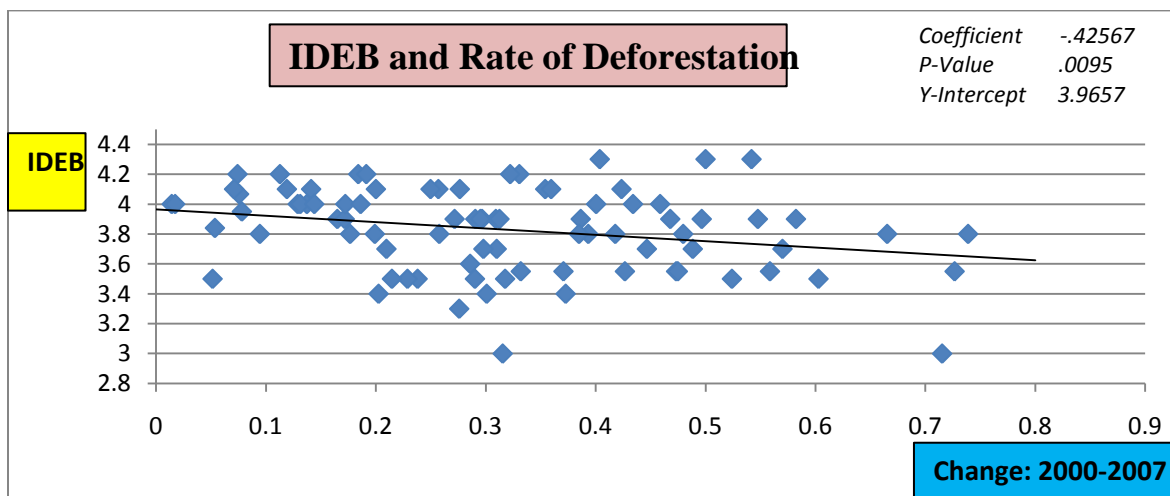
Graph 1.4- *Disease Rate of Age of Settlement*

Rate of Deforestation

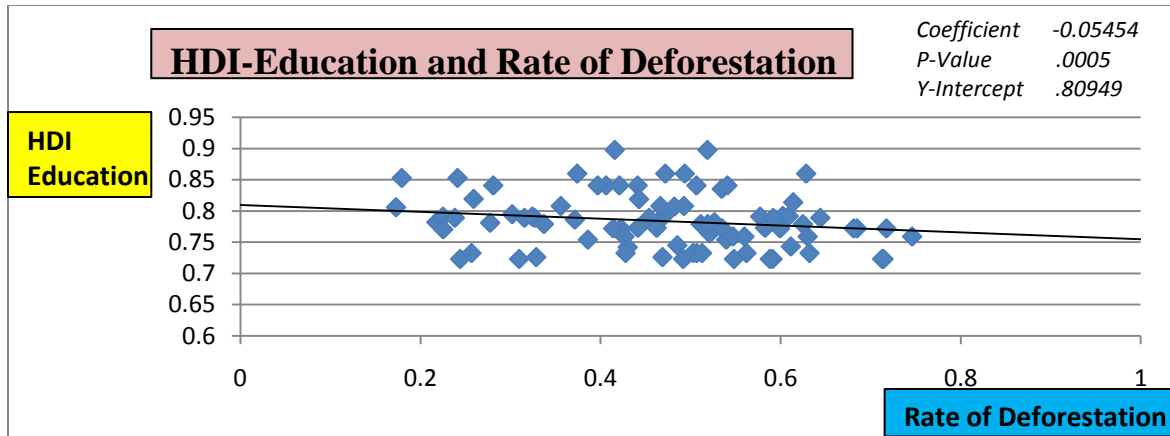
Deforestation rates in the period prior to the welfare measurement correlated with five of the nine human welfare measurements. IDEB scores, HDI and HDI Education scores as well as disease indices correlated negatively with higher rates of deforestation, where as settlement level literacy rates as well as my Disease Incidence measurement correlated positively.

In the multivariate analyses, the IDEB, settlement level literacy rate, HDI and HDI-Income remained significantly correlated with the rate of deforestation.

This results for the IDEB and HDI-Education, demonstrated in Charts 1.12 and 1.18 above and Graphs 1.5 and 1.6 below, are in line with previous results discussed; newly developed with higher current rate of deforestation areas do not match the educational performances of those found in older areas, where deforestation rates are currently lower.

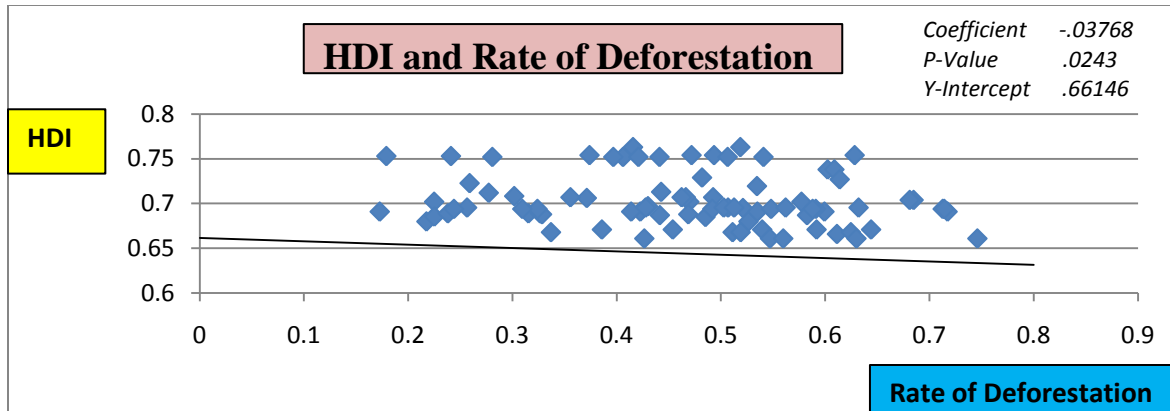


Graph 1.5 - IDEB and Rate of Deforestation



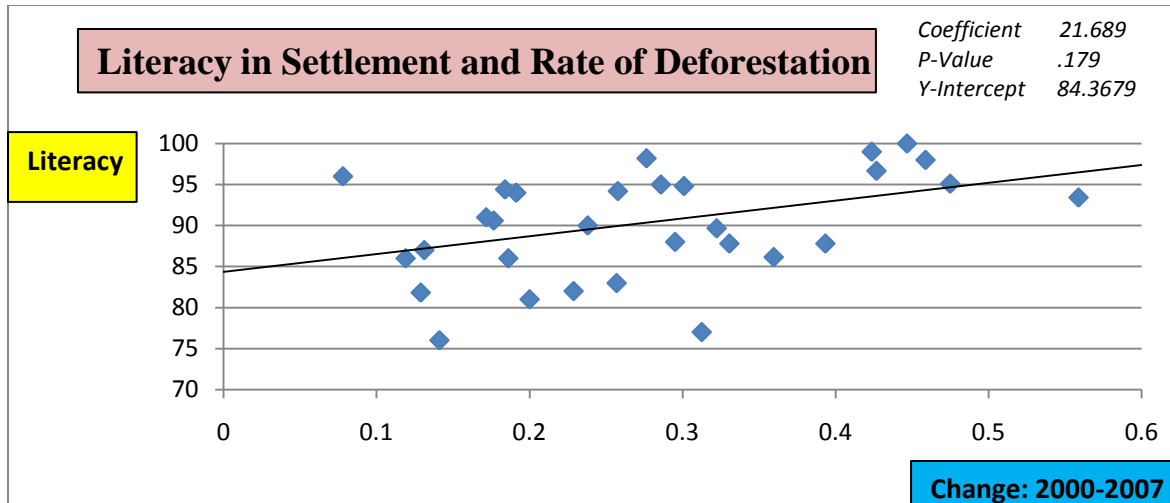
Graph 1.6 - *HDI-Education and Rate of Deforestation*

For the HDI score, the result of lower levels being found in areas with higher rates of deforestation is logical and in line with other findings in this paper which suggest that human welfare evolves over time towards an improvement in conditions. This runs contrary to the findings of other papers which have evidenced higher rates of HDI along the active frontier of development, which oppose to my study, were conducted at the municipal level (Celentano and Veríssimo 2007). Chart 1.12 above and Graph 1.7 demonstrate my findings.



Graph 1.7 - *HDI and Rate of Deforestation*

Settlement level literacy rates remained positively correlated in the multivariate analysis, as shown in Chart 1.13 above and Graph 1.8 below. This finding may at first seem to run against my findings on education levels as it is the areas with higher rates of deforestation that have higher literacy rates, whereas education levels fall behind here. However, in the light of previous research which posits that literacy levels will be high here due to an influx of educational results from other parts of Brazil from where the immigrants hail, which often have higher educational standards and institutions than those that are found in newly developed parts of Rondônia, my finding can be understood.



Graph 1.8 - *Literacy in Settlement and Rate of Deforestation*

Confounding Variables: Access, Parcel Size and Slope

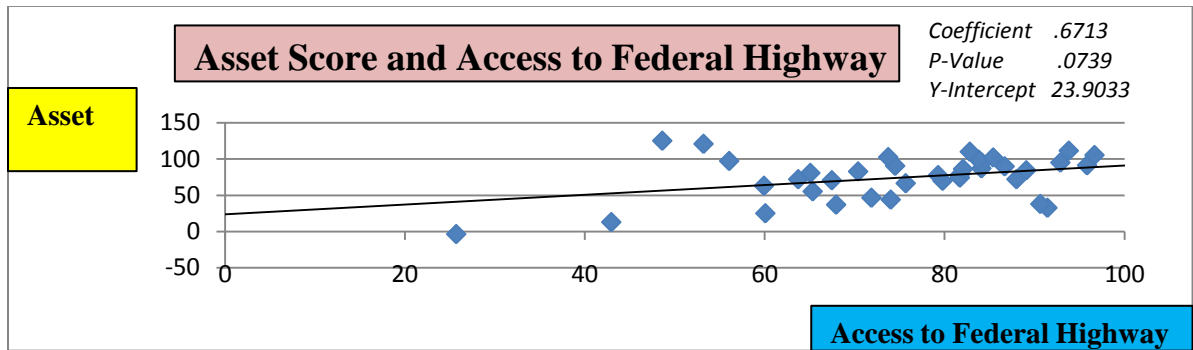
As explained during the introduction of the conceptual model of my analysis for this chapter, there are several confounding variables which I addressed when examining the relationship between age of the settlements and their rates of deforestation with human welfare levels. These included access, the steepness of slopes and parcel sizes, each of which having a strong correlation with both the age of the settlement and rate of deforestation, making necessary their consideration for a true of understanding of the evolution of human welfare in Rondônia.

Access

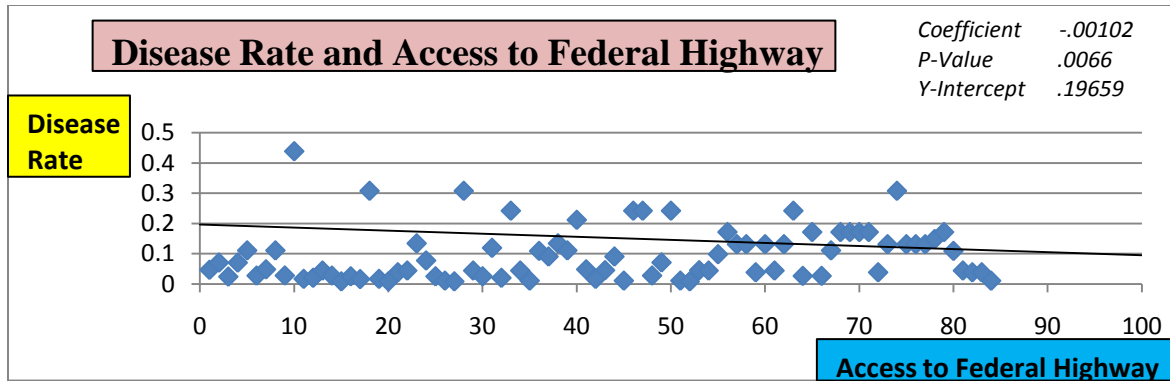
Chart 1.6 and Figure 1.6 demonstrate that access to a federal highway is correlated with both the age of the settlement as well as the rate of deforestation within it. Access to federal highways has decreased over time, with older settlements having better access than newer settlements. As explained in my literature review on the history of Rondônia, the construction of the BR 364 federal highway in the 1970s was integral in the development of the state. The 5 original INCRA settlements were established along this north-south highway. Over time, INCRA settlements, be it through peasant land invasions or INCRA led efforts, were created increasingly further away from this federal highway as the more desirable land near the highway became more scarce (*O Brasil e O Mundo*). Thus, older settlements generally have better access to federal highways. Access to roads is also a well known driver of deforestation, as in the Von Thünen model. Thus, these same areas with easy access to federal highways display low levels of forest cover, as shown in Chart 1.5. Because they are already so highly deforested, their rate of deforestation in the most recent period before the welfare measures (2000-2007 or 1990-1999) tends to be very low

Regarding the relationship between access and human welfare, I have found access to be a key determinant as it had a statistically significant relationship with 6 of my 9 welfare measurements, including the asset score (Chart 1.11 above and Graph 1.9 below), disease

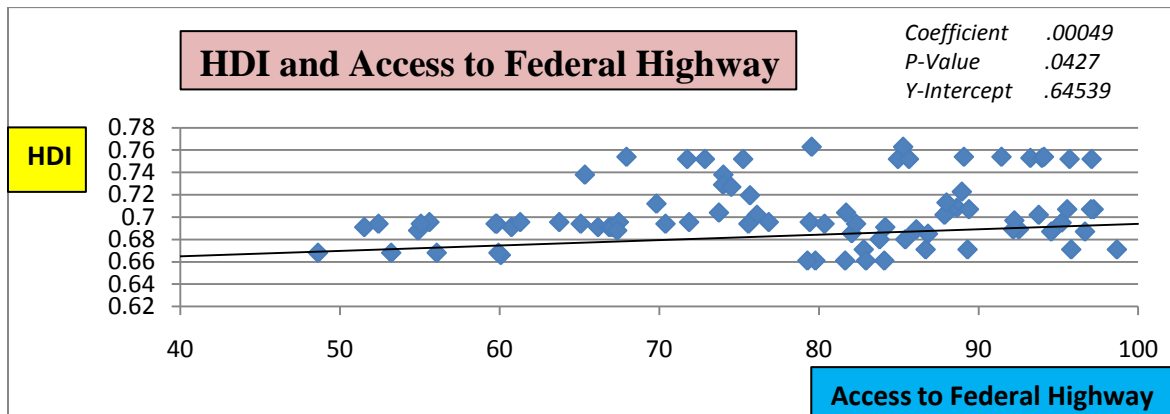
incidence (Chart 1.14 above and Graph 1.10 below), HDI (Chart 1.15 above and Graph 1.11 below), HDI-Life Expectancy (Chart 1.17 and Graph 1.12), HDI-Education (Chart 1.18 above and Graphs 1.13 below) and municipal literacy rate (Chart 1.19 above and Graph 1.13 below). This trend of higher human welfare in settlements with better access may be attributed to receive emergency medicine, attend secondary schools, receive attention from governmental and non-governmental extension agencies and gain access to established, competitive markets for agricultural goods (Marquette 2006). Again, to elaborate on this last point, in Rondônia, where cattle ranching and milk production are the dominant land uses, the ability to receive fair market prices for these goods is crucial.



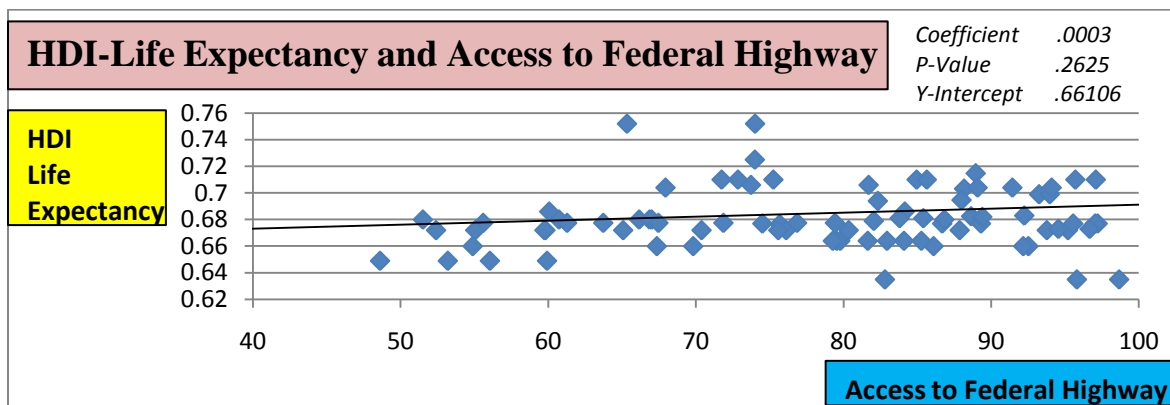
Graph 1.9 - Asset Score and Access to Federal Highway



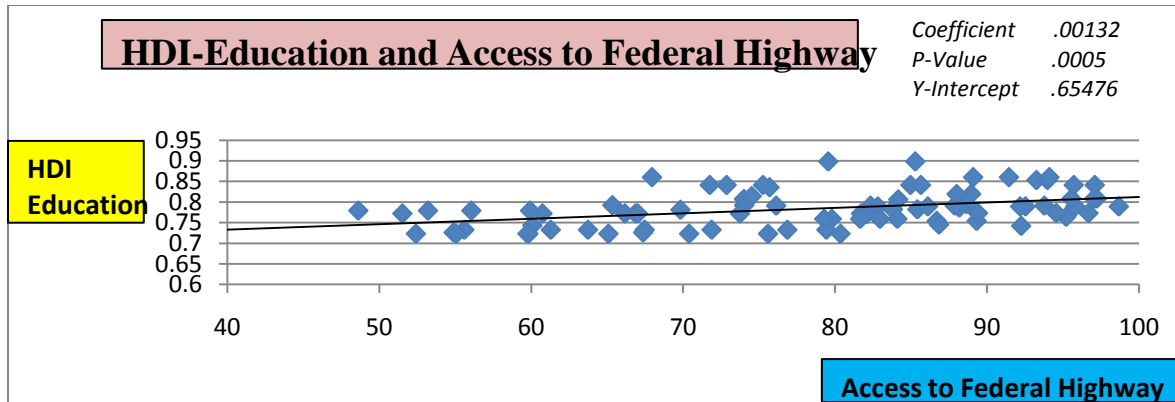
Graph 1.10-*Disease Rate and Access to Federal Highway*



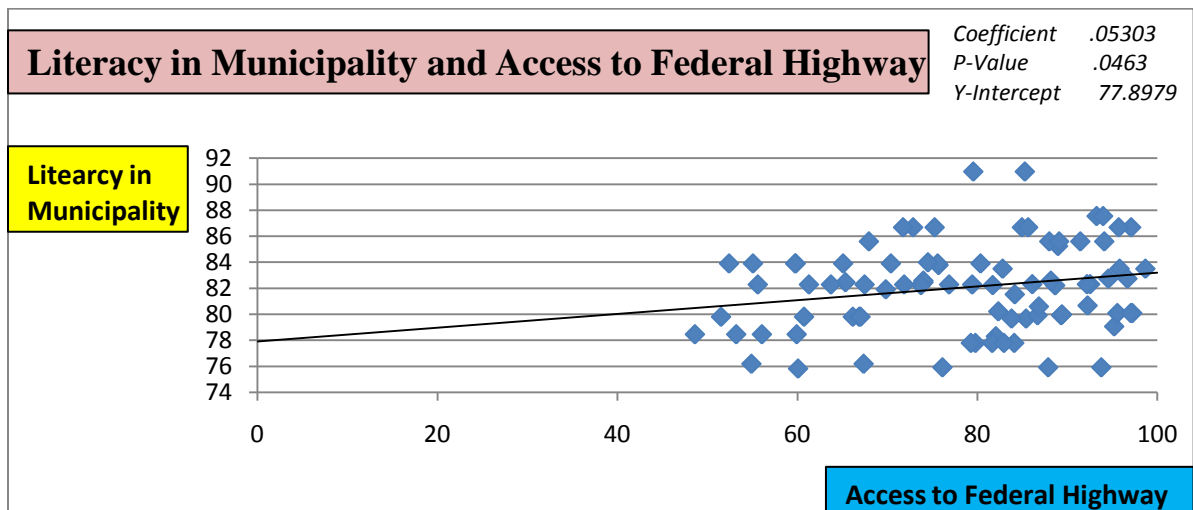
Graph 1.11 - *HDI and Access to Federal Highway*



Graph 1.12- *HDI-Life Expectancy and Access to Federal Highway*



Graph 1.13 – HDI -Education and Access to Federal Highway

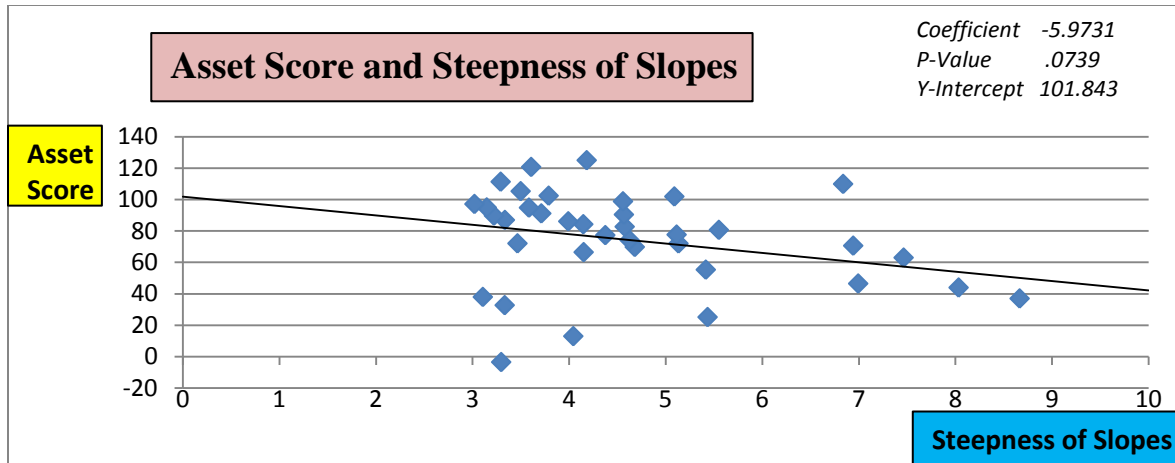


Graph 1.14- Literacy in Municipality and Access to Federal Highway

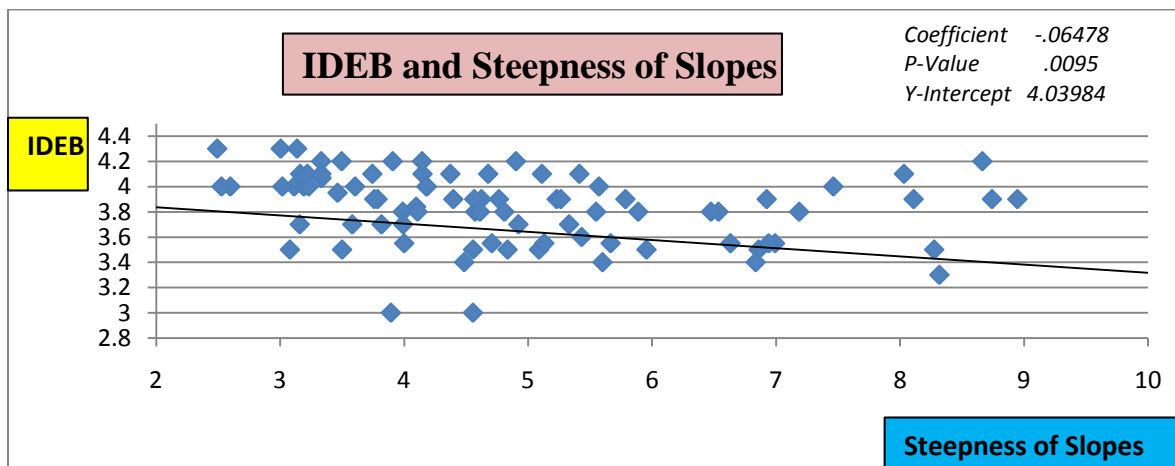
Though the steepness of slopes in the settlements in my study sample were not statistically correlated with the age of settlements nor the rate of deforestation within them at a significant level, I left them in the multivariate regressions due topography being a key determinant of farm production. In the multivariate regressions, steepness of slopes was

significantly correlated with 5 of my 9 human welfare measurements, including the asset score, IDEB, disease incidence, HDI and HDI-Income.

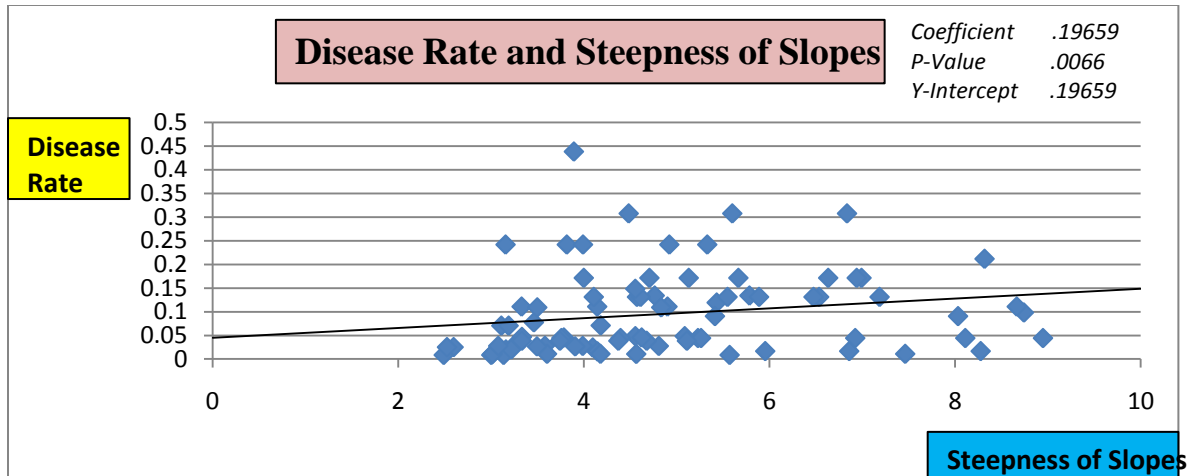
However, in terms of positive and negative effect upon human welfare, the results are mixed. For the asset score, in both the simple and full model regressions, steeper slopes were shown to have a negative influence on human welfare, as demonstrated in by Charts 1.11 and 1.20 above as well as Graph 1.14 below. This finding is in line with expectations, as settlements with poorer topography have lower asset scores indicating lower levels of human welfare, as I predicated before due to a loss of quality land for cattle grazing and agricultural production. In addition, steep slopes I also found to have a negative effect upon the education performance IDEB measurement, as shown in Chart 1.12 above and Graphs 1.15 below. This result perhaps can be attributed again to poor output capacity of the land and an aggregate low economic output of the settlement having a deleterious effect upon educational performance of the children who may either struggle to afford study materials or perhaps are required to dedicate more time to land which is harder to prepare and manage. Finally, steep slopes were also positive determinant of disease incidence, as shown in Chart 1.14 above and Graph 1.16. Here, it could be surmised that clearing forests in these areas is more difficult and the vectors for certain tropical diseases of water collection in disturbed areas for instance is not as quickly eradicated as it is in areas which are flatter and more open.



Graph 1.15 - *Asset Score and Steepness of Slopes*

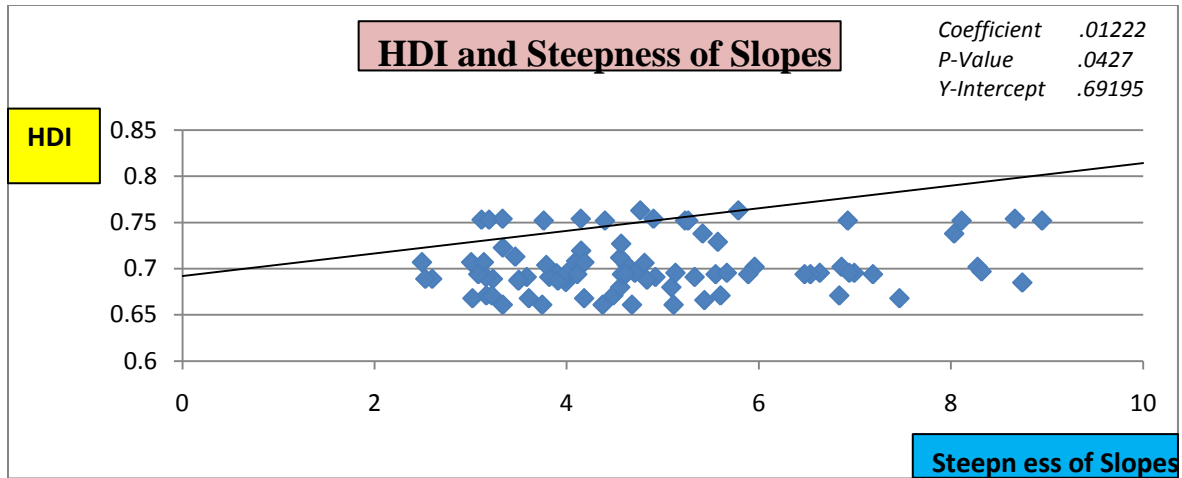


Graph 1.16- *IDEB and Steepness of Slopes*

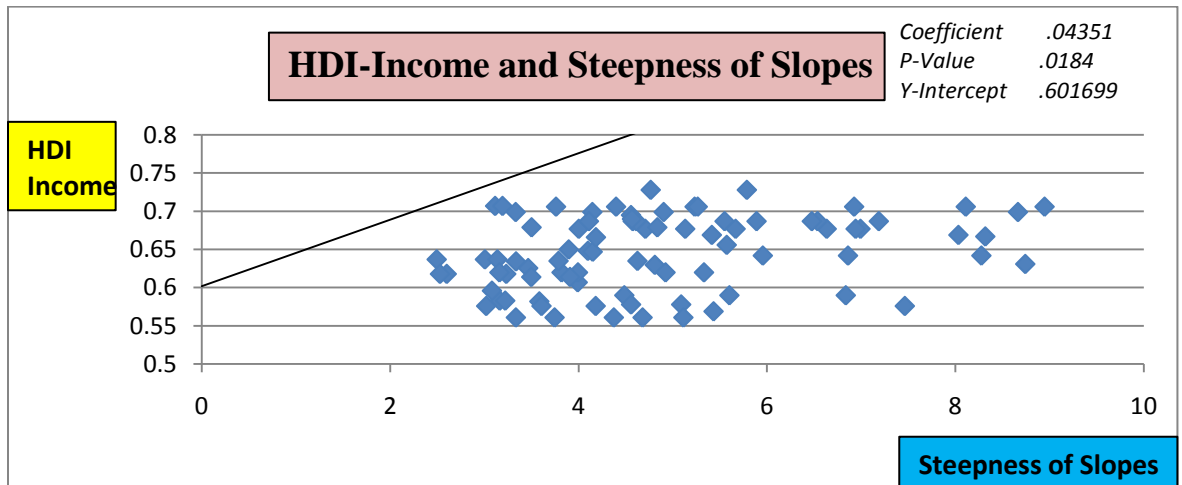


Graph 1.17- *Disease Rate and Steepness of Slopes*

For other welfare measurements, including HDI and HDI-Income I found steep slopes to have a positive influence, as shown in Charts 1.15 and 1.16 above as well as Graphs 1.17 and 1.18 below. Here, I posit that as these high HDI figures in areas with steeper slopes can be attributed that as these welfare measurements were taken in the year 2000, when the settlements presently with the steepest slopes were not in existence.



Graph 1.18 - *HDI and Steepness of Slopes*

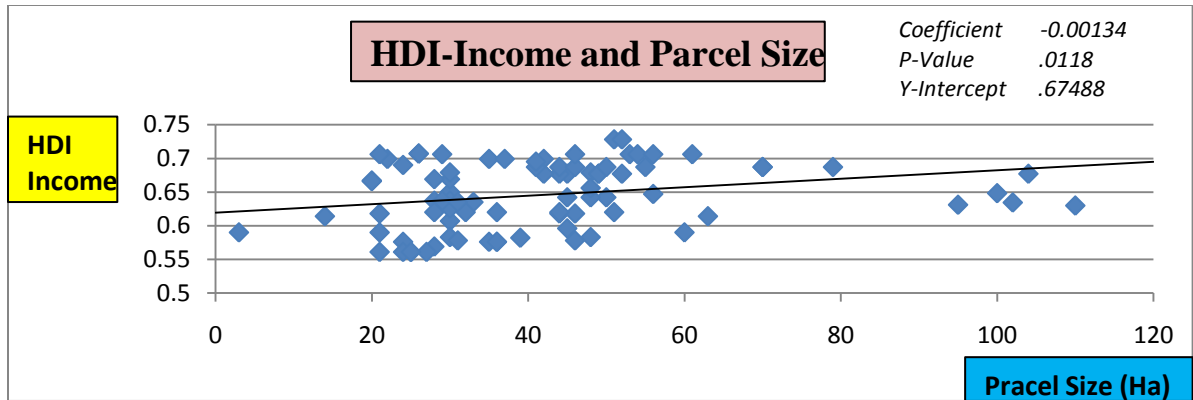


Graph 1.19 - *HDI-Income and Steepness of Slopes*

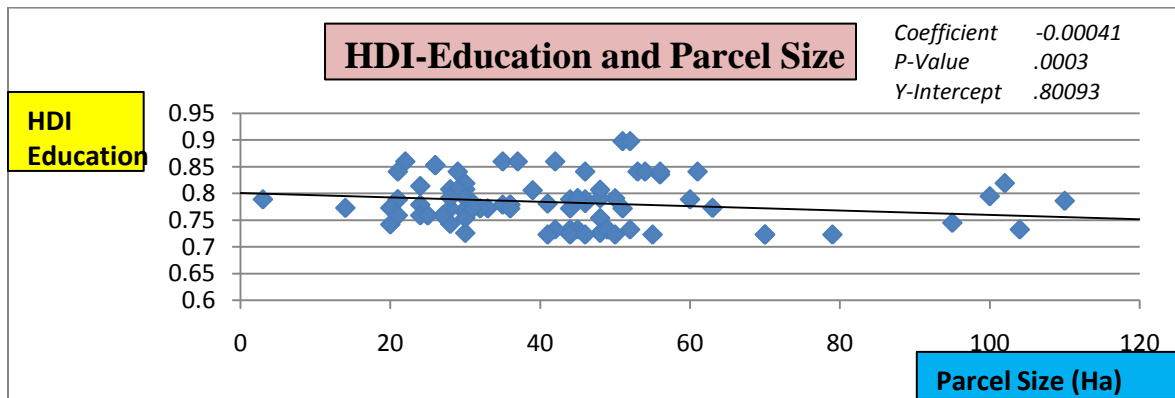
Parcel size as well is correlated with age and deforestation rates. Originally, INCRA settlements in Rondônia averaged around 100 hectares in size. For the 5 original settlements,

the state doled out large tracts of land to address the governmental aim of occupying the land in a timely manner. With the rapid influx of immigrants into the state during the 1980s, this need to assign overly large tracts of land to newly arrived colonist farmers diminished. As such, over time the average size of land parcels has shrunk with the majority of settlements created since the mid 1990s ranging between 30 and 50 hectares in size. Though current deforestation rates do not correlate with parcel size, the tendency for larger lots to have more primary forest intact today suggests a relationship does exist in some fashion.

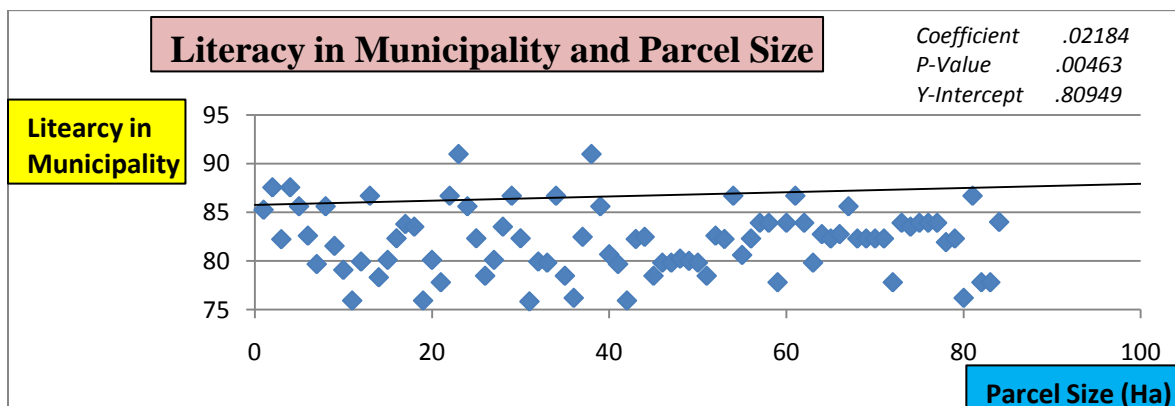
Regarding the human welfare, in the multivariate regressions, parcel size was shown to have a positive effect on 3 of the measurements including HDI-Income (Chart 1.16 above and Graph 1.19 below), HDI-Education (Chart 1.18 above and Graph 1.20 below) and municipal literacy rates (Chart 1.19 above and Graph 1.21 below). For HDI-Income, it is of little surprise that the settlements with larger parcel sizes have higher levels on income. For HDI-Education, it could be posited that larger parcel sizes require more time investment by family members for agricultural production which may cut into study time and hence educational performance. For the higher municipal literacy rates areas with larger parcel sizes, this could be the effect of adult education programs which may be located closer to urban areas where larger parcel sizes are generally found.



Graph 1.20 - *HDI-Income and Parcel Size*



Graph 1.21- *HDI-Education and Parcel Size*



Graph 1.22- *Literacy in Municipality and Parcel Size*

Casual Chain Variables

As explained in the introduction of conceptual model, for welfare measurements taken in 2007, I ran secondary multivariate regressions which included additional socio-demographic information from the INCRA-EMATER interviews which I have dubbed causal chain variables; definitive land titles, access to credit and government cash transfer programs. The causal chain variables are often closely related with the age of the settlement and rate of deforestation within them as well as the welfare measurements.

Land titles are closely correlated with the age of the settlement as well as the rate of deforestation within them, as shown in Charts 1.9 and 1.10, with older settlements and low rates of deforestation associated with higher levels of definitive land title possession. As INCRA has stringent guidelines on issuing land titles to the colonist farmers in their settlements, following a rigid protocol of settlement performance and steps to follow, it is not surprising that younger settlements have lower levels of land title possession.

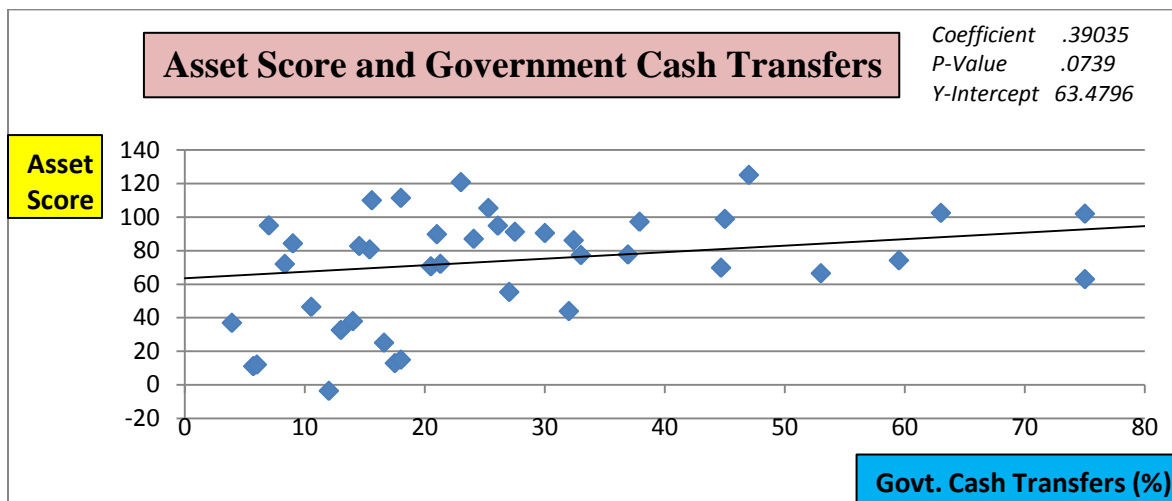
Regarding welfare, definitive land title correlated negatively with the literacy rate within the settlement. As discussed before, this is in line with expectations, as newer settlements, along with low levels of land titling, will have higher levels of literacy due to the influx of migrant

farmers from more developed parts of Brazil. In the multivariate regressions, land titles however were not found to be a determinant of asset possession nor the settlement level literacy rate. Access to credit as well, though correlated with asset scores initially positively, in the multivariate regression was not shown to be a key determinant.

Participation in social groups is not related to age of the settlement nor the rate of deforestation however, is correlated positively with asset scores and negatively with settlement level literacy rates, as shown in Charts 1.9 and 1.10. Both of these results are in line with expectations as organized social groups are associated with more affluent areas which are more established, often older and hence will have less immigration which would raise literacy rates. However, in the multivariate regression participation in social groups was not found to be a significant determinant of asset scores, demonstrated in Chart 1.20.

Finally, governmental cash transfer programs (*Bolsa Familia*) are correlated with both age and deforestation rates (Chart 1.9). Regarding welfare, higher asset scores are associated with high participation in this program and as expected. Graph 1.23 below demonstrates. For this study it is assumed that families receiving these cash payments in at the time of the EMATER interviews, were receiving them in years prior and as such I am comfortable in using this measure as a possible determining factor for welfare. For age, older settlements have higher levels of participation in this program. Whereas before analyzing results, I believed

participation in this program would be a sign of low welfare, seeing how participation in this program parallels other trends positively associated with welfare (land title, parcel, access, etc.), I posit that older settlements, located closer to cities are better connected with local governance and are better positioned for participation. For deforestation rates, high participation in this cash transfer program is correlated with low rates, again adding credence to the theory I have just laid forward. In the multivariate regression for asset scores, participation in this *Bolsa Familia* remained significant and was shown to be a positive determinant of human welfare.



Graph 1.23 - *Asset Score and Government Cash Transfers*

Chapter 2: High Conservation Value Forest: Determinants of Riparian Forest Cover

A. Introduction and Literature

1. Ecological and Legal Considerations

With high rates of deforestation in the Amazon region, riparian forests have key ecological functions and are of increasing importance in tropical forests qualifying them as High Conservation Value forests (Jennings 2003). Introduced by the Forest Stewardship Council for use in certification the concept of giving higher value to an areas with unique functions is growing in use among policy makers and researchers whom recognize the importance of their conservation.

Riparian forests provide several key ecosystem services. A healthy riparian area can maintain high water quality, moderate flooding, help recharge underground water supplies, prevent soil erosion and preserve wildlife habitat and biodiversity by providing ecological corridors (SEDAM). In addition, some riparian area can provide landowners with valuable biomass, timber and nut crops if managed properly (ISU 2007).

A fundamental ecosystem service provided by riparian forest is water quality maintenance and chemical runoff mitigation. As streams and rivers are a large source of water for the settlements in my study area, this service is a key consideration. Furthering the need for

healthy riparian forest is pasture and livestock grazing being the dominant landscape in the study area, which has been proven to cause harm to water quality due to animal excrement (Belsky et al. 1999)

Several studies have been done demonstrating the beneficial effect riparian forests have. Perry et al. 1999 conducted a GIS based study on the Little River Research Watershed of Georgia to show that nitrogen (N) and phosphorous (O) loadings at the watershed have the potential to increase over 16% and 9% respectively under a 50% deforested riparian area scenario. They found a potential decrease of N and P loadings of over 13% and 7% respectively under a 50% reforestation scenario. Likewise, Smith 1999 found similar results. In a Virginia base experiment, 15 feet wide vegetative filter strips were shown to remove 55% of nitrogen and 60% of phosphorous runoff into the water (Smith 1999). Though, sufficient amounts were found to enter the water stream to support proper levels of algae and plant growth.

Riparian forests are crucial for mitigating soil and sediment runoff. Annually, 75 billion tons of soils are eroded from terrestrial ecosystems primarily from agricultural lands (Zuazo 2008). As soil creation is a slow, gradual process, the rate of loss is approximately 13-40 times greater. Vegetation has a key role in riparian areas. Erosion caused by water removes first the fine organic particles which lie closer to the surface and diminishes the productivity of the land. Naylor et al. 2002 broke down the effects of vegetation on soil into two

categories; bioprotection and bioconstruction. Bioprotection involves guarding against erosion by reducing runoff and bioconstruction means increasing water filtration into the soil matrix (Naylor et al. 2002). Gysels et al. 2002 demonstrated positive effects plants have by fixing soils in place with root systems. Glade 2001 build upon this concept by demonstrating the protective effects vegetation systems can have against landslides. In addition, soil loss contributes to a failure for terrestrial systems to sequester carbon further exacerbating global climate change (Zuazo 2008).

With an increasingly fragmented forest landscape, intact riparian networks offer a realistic and multi-beneficial opportunity for ecological corridors and biodiversity maintenance. Riparian corridors possess an unusually diverse array of species and environmental processes (SEDAM). This "ecological" diversity is related to variable flood regimes, geomorphic channel processes, altitudinal climate shifts, and upland influences on the fluvial corridor. This dynamic environment results in a variety of life history strategies, and a diversity of biogeochemical cycles and rates, as organisms adapt to disturbance regimes over broad spatial—temporal scales. In sum, effective riparian management could ameliorate many of the negative environmental externalities of deforestation and subsequent land uses. Riparian corridors could play an essential role in water and landscape planning, in the restoration of aquatic systems, and in catalyzing institutional and societal cooperation for these efforts (Naiman 1999).

Legal

The Brazilian Forest Code 4771 of 1965 set forth standards in Article 2 for the protection of riparian forests. Areas of Permanent Preservation (APP) were created in this law which requires buffers around water ways so as to protect their ecological importance. The forests and natural vegetation in these protected areas are intended to remain untouched and should they be degraded, they are required to be recuperated (Lei 4771/65). The required width of the buffer is determined by the width of the water way in question and is measured from the highest level. For water ways under 10 meters in width a 30 meter buffer on either side of stream is required. For water ways between 10 and 50 meters in width a 50 meter buffer is required. For water ways between 100 and 200 meters in width, a 100 meter buffer is required. For water ways between 200 and 600 meters in width a 200 meter buffer is required. Finally, for water ways over 600 meters in width a 500 meter buffer is required. In addition, a 50 meter buffer is required around all water springs indeterminate of the width of the water way they feed.

To bolster the implementation of this law and allow for the realize the ecological function of these riparian forests, the Secretary of Environmental Development in Rondônia (SEDAM) launched in March of 2009 *A Programa Mata Ciliar* or *The Riparian Forest Program* through Decree N° 14133, of 18 of March of 2009 (Decree 14133). Through technical and financial

support this program will educate and assist land owners in recuperating degraded riparian forests throughout the state (SEDAM).

In addition, through the Instrucao Normativa of 9 September of 2009 of the Ministry of the Environment published in the Diario Oficial da Uniao N 172, a benefits program intended to transport and plant both native and exotic species in riparian areas was established (MMA 2009)

2. Determinants of Forest Cover and Sustainable Land Use Practices

Access (The Von Thünen model)

In his work “"Der Isolierte Staat in Beziehung der Landwirtschaft und Nationalökonomie”, Johann Heinrich von Thünen in studying the spatial economics of rent and access to a city center, laid the groundwork for many modern day theories which seek to explain the advance of the frontier of deforestation in the Brazilian Amazon (Katzman 1977, Walker 2004, Schmink and Wood 1984, Pfaff 1999 Nepstad et al . 2001, Soares-Filho et al . 2001, Munroe et al . 2002 Cropper et al . 2001, and Zeller 2002 and Stolle et al . 2003 for Asia, and Mertens and Lambin 1997).

Transportation infrastructure has been shown to open the access to forests for the agents of deforestation; poor farmers, ranchers, loggers and miners (Martine 1980; Moran 1981; Schmink and Wood 1984). Since the time of the introduction of railroads in the Brazilian Amazon this has been the story (Katzman 1977).

A large amount of empirical evidence exists which examines accessibility and distance to city centers and transportation networks in explaining the advance the deforestation frontier. In a 2001 study, Nepstad et al. modeled the increased access to forest in the Amazon region which would be brought on by the road 6,250 km worth of road construction and improvement plans part of the *Avança Brasil* program. It was predicted that 120,000 to 270,000 km² (Nepstad et al. 2001). Taking this further, Laurence et al 2001 evidenced how this implantation of this program would lead to a 28% to 42% loss of original Amazonian forest (Laurence et al. 2001).

Regarding current deforestation, a much cited study, Pfaff 1999, found a positive correlation between paved-road density (km/sq) and deforestation rates by looking at deforestation rates in the 1970s and 1980s on the municipal level. Building upon this work, Pfaff again found that deforestation increases in census tracts that lack roads but that are in the same county as and within 100 km of a census tract with a new paved or unpaved road (Pfaff 2007). In addition, Alves 2001 found that 2/3 of deforestation in the Amazon basin has occurred within 50 km of a major paved highway.

In addition to opening access to deforestation, proximity to urban areas can also be theorized to have a countering effect which could preserve forests. Areas which are easy to reach by land invaders and other agents of deforestation are also easily accessible by environmental law enforcement agencies (IBAMA) as well as environmental extension agencies (EMATER). Given the stringent environmental laws for forest cover and preservation of protected areas farmers living within the range of these groups may be influenced to leave more forest standing where otherwise they would clear it. Hence, close proximity to transportation infrastructure and urban areas can not only act as a negative determinant of forest cover but also as a sustainable land use practice determinant.

Property Size

Recent literature has drawn attention to property size acting as a determinant of forest cover, notably in riparian areas (HCV) in the Amazon (D'Antona et al. 2006 Pichon & Bilsborrow 1994; Pichon 1997). These studies have shown a smaller farm size to be positively correlated with increased rates of deforestation. This trend extends outside of Amazonia as well as Carr 2004 should this same trend in the Guatemalan Maya Biosphere and Turner and Geoghegan 2004 demonstrating this effect in Yucatan Mexico (Carr 2004, Turner and Geoghegan 2004).

As discussed above, the property sizes awarded by INCRA vary greatly across time and space. Property sizes in my sample of INCRA settlements in Rondônia vary from 3 hectares

to 110 hectares. The variation in property sizes is increasing with processes of land inheritance and investment, leading to both land fragmentation and land conglomeration.

Slope

Past studies have found that the slope of land influences its use. For example, Evans et al. (2001) and Evans and Moran (2002) found that lands with steeper slopes are more likely to be forested, while flatter lands are more likely to be in agriculture or pasture, in the United States of America.

In the context of land use in the tropical regions, several studies have demonstrated this same trend (Adan and Peterson 1998, Rudel 1993, Sader and Joyce 1988). Adan and Peterson 1998 note that steep slopes are often unfriendly for agricultural cultivation. They go on to speculate that in tropical regions, steep slopes may limit illegal deforestation as machinery cannot access trees located on steep slopes. Sader and Joyce 1988 demonstrated how in Costa Rica deforestation generally decreased as slope increased. From an environmental perspective, this correlation between steep slopes and forest is helpful, as forest vegetation on steep slopes can play the key ecological function of avoiding erosion.

Land Tenure

The tragedy of the commons theory posits that that one will be more inclined to take proper care of something for which legal ownership exists. Such is the line of thinking when discussing the role land tenure plays in land use choices and deforestation in HCV areas. Geist and Lambin 2002 in a review of 152 cases studies on poverty and land use found that 2/3 of the poverty driven deforestation cases examined were related to property rights, specifically insecure ownership, quasi-open access and low empowerment of local land users (Geist and Lambin 2002).

In addition to acting as a determinant of sustainable land use however, land titling in the study region can also be seen as a determinant of deforestation. When considering land tenure as related to deforestation it is important to note for my study area, that early on in the 1970s and 1980s, in order to receive a definitive land title for a property one had to “improve” it, or in other words deforest large sections of it to make it productive.

Poverty

The conventional wisdom on the link between poverty and environmental degradation is summed up well in the United Nations Human Development Report from 1990 which stated

poverty is one of the greatest threats to the environment” (United Nations 1990). This belief was buttressed by an International Monetary Fund article from 1993 stating “Poverty and the environment are linked in that the poor are more likely to resort to activities that can degrade the environment” (IMF 1993). To add to this, the now well known Bruntland Report from 1987 phrased it “Poverty reduces people’s capacity to use resources in a sustainable manner; it intensifies pressure on the environment” (World Commission on Environment 1987). Finally, the link between deforestation in HCV areas and poverty was explained in a World Bank Environment Department publication which explained how the poor “have a small margin for curbing or foregoing present consumption in order to avoid damaging or depleting the natural resources on which they depend for survival” (World Bank).

Rudel and Roper 1997 characterized frontier colonization in tropical areas as a process of poverty and capital driven deforestation (Rudel and Roper 1997). Poverty driven deforestation refers to expanding peasant populations who by economic necessity clear land for agriculture. They dub this process the immiserization theory. Capital driven deforestation refers to private or public investment to explore and develop forested areas on the edge of the frontier for political, economic or social reasons. This process they refer to as the frontier theory. They conclude that the frontier theory can be used to explain deforestation rates for larger scale analyses, with large tracts of forest (ie. Amazonia, Rondônia) and that the immiserization theory can be used to model deforestation at smaller scales with smaller sets of forests (ie. Settlement level deforestation).

Geist and Lambin 2002 conducted a meta-analysis on 152 case studies that examined the relationship between poverty and deforestation, identifying commonalities and concluded that the link between the two can be over generalized. Dimensions of poverty associated with higher rates of deforestation included resource-poor farming, survival economies, insufficient food production, chronic food deficit, displacement, limited land endowment, growing land scarcity, landlessness, land division, creation of poor land holdings, meta and holdings, low living standard, joblessness, extremely low income levels, social deprivation, marginalization, and low empowerment of local user groups (Geist and Lambin 2002).

Geist and Lambin (2002) present several results particularly relevant to Rondônia. First, in the 80% of cases in which poverty was related to deforestation, this relationship was mediated by human population dynamics, primarily population growth to due in-migration and natural increment. As discussed above, Rondônia has historically had very high rates of migration and population growth. Next, in about half of the cases reviewed, colonist shifting cultivation, permanent smallholder subsistence farming, cattle ranching and colonization settlements are related. Third, in nearly all cases reviewed, pro-deforestation policies, primarily focused on land and economic development, were in play. Without doubt, past policies in the state of Rondônia have contributed to the deforestation in HCV areas in the state, though in recent years policy cannot be said to feed too much into it, colonization project creation aside. The authors conclude that based upon their empirical evidence it is not

possible to confirm that deforestation is driven primarily by poverty, instead indicating the capital-driven process as the primary model. They note that these processes overlap in 42% of the cases, consistent with the historical development patterns in Rondônia.

Giving further depth to the understanding of the relationship between poverty and the environment is the literature which seeks to better define poverty itself. Though the environment side of this relationship is widely differentiated (biophysical characteristics, geography, etc), the notion of poverty is treated as one dimensional too often. Reardon 1995 posits a consideration of various types of assets can better define poverty and explain its relationship with the environment. This author considers the natural resource assets, human resource assets, on-farm physical and financial assets and off-farm physical and financial assets to define poverty (Reardon 1995).

In describing the Amazon region, Reardon states that poor farmers are rich in access to forest cover and biodiversity, though poor in market demand for them as well as in soil nutrients, labor supply, quality health care and secure income streams. Hence, the author declares, farmers are led to convert forests into agricultural plots and capitalize on their biophysical wealth, fleeting as it may be (Reardon 1995). He goes on however to clarify that much of the past deforestation in the region has little to do with poverty and instead was driven by public policy and large landholders.

Adding to the literature on poverty and deforestation in HCV areas, Broader 1995 points out in some cases impoverished groups have turned environmentalist. He gives Chico Mendes as an example, the well known rubber tapper from Acre, Brazil, who fought for forest conservation amidst an encroaching deforestation frontier brought on by colonization. This phenomenon of environmentalism among low income groups appears more likely where those groups traditionally depend upon forests and other natural ecosystems for their livelihoods, which is generally not true in the colonization settlements that I consider in this study.

The link between deforestation in HCV areas and poverty is not limited to deforestation. Soil erosion can be the result of irresponsible deforestation and compromise the ability of land to provide ecosystem services. As soils in the tropics have a high propensity for being shallow and fragile in structure, erosion is a serious concern (Anada 2003).

Related to the discussion on the relationship between poverty and land use is access to credit. It could be posited that farmers with access to credit are less hard pressed to explore areas which are environmentally sensitive (e.g. riparian forests) in order to provide for themselves financially. Likewise, it could also be foreseen that access to credit could facilitate forest clearing by providing the necessary financing for renting heavy machinery necessary for such work (e.g. chainsaws, yarders).

Social Organization

A hope amongst environmental conservationist is that participation in social organization (i.e. cooperative, associations, syndicates) will lead to environmentally considerate behavior in terms of land use. The ability to receive higher prices and afford expensive farming equipment, among other benefits, may allow farmers to realistically consider the adoption of more sustainable farming practices (eg. agro-forestry), which done alone can be less attractive. Caviglia and Kahn 2007 evidenced that social networks and information networks can greatly increase the probability of adoption of sustainable land use choices. The growing role of the state agency for rural technical assistance, EMATER, which supports social groups, has a large role in Rondônia. As noted before, EMATER has an agreement with INCRA to provide assistance to their settlements and as such the participation in social groups for my study will be a key consideration.

Household Life Cycle (Time)

Another determinant of deforestation and forest cover is the household life cycle or in other words time on the lot. Several studies have calculated the average rate of deforestation in areas similar to my study area around 1 hectare per year (Homma *et al.*, 1992 cited in Laurance *et al.*, 2001). Hence, settlements which are older in age can be expected to have less forest remaining today.

Origin of Farmers

Given that the settlements in my study sample attract farmers from all across Brazil, a key consideration of land use choices in terms of sustainability which is important to consider is the origin of the farmer. It has been posited that local knowledge of environment may lead to increased sustainability (Marquette 2006). I will determine the origin of the colonist farmer on the regional level, of which Brazil is broken into five; north, north east, central west, south and southeast. As Rondônia falls in the north region, I will deem farmers from the states that fall within this region to be local. It can be surmised that despite the variation within this vast region, that these peoples will have a local know how of the land and weather which could be advantageous in terms practicing sustainable land use choices.

B. Research Question, Conceptual Framework and Statistical Methods

Research Question

- What are the determinants of forest cover in riparian areas?

Conceptual Framework

To examine what determines forest cover in riparian areas, I turned to the determinants of tropical deforestation as well as the determinants of sustainable land use choices.

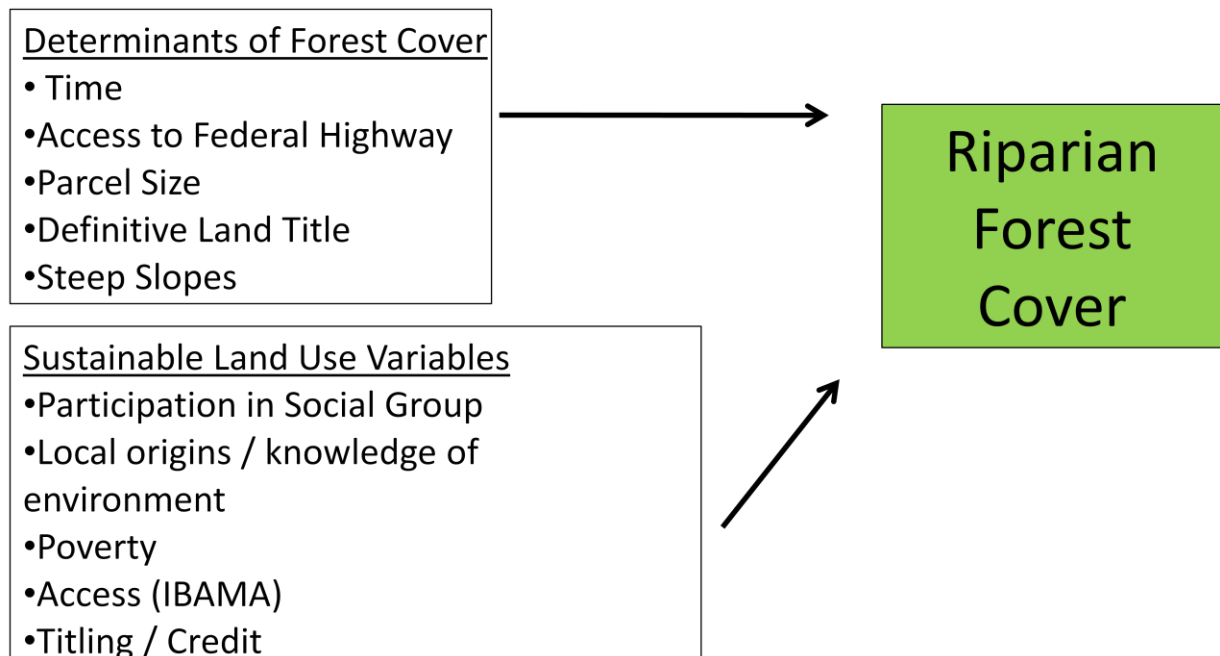


Figure 2.1- Chapter 2 conceptual Model

Statistical Methods

To test for the relationships between welfare, age, deforestation and their confounders I employed the following statistical steps:

1. Bivariate Correlations

- Riparian forest cover and determinants of (general) forest cover
- Riparian forest cover and determinants of sustainable land use

2. OLS Multivariate Regressions for Determinants of Forest Cover

$$\text{Riparian Forest Cover} = \text{Age of Settlement} + \text{Access to Federal Highway} + \text{Parcel Size} + \text{Topography} + \text{Definitive Land Title}$$

3. Full OLS Multivariate Regression: Determinants of Forest Cover and Determinants of Sustainable Land Use

$$\text{Riparian Forest Cover} = 5 \text{ Determinants of Forest Cover} + \text{Participation in Social Group} + \text{Origin of Farmers: North} + \text{HDI: Income} + \text{Credit}$$

-Determinants of Sustainable Land Use Significant at .20 confidence level were entered into model due to low sample sizes

C. Results

Variable	N	Mean	Std Dev	Minimum	Maximum
Primary Riparian Forest 2007	31	0.2327189	0.1329445	0.058427	0.497807
Primary Forest 2007	31	0.1589292	0.091616	0.0358622	0.4338309

Age of Settlement	31	20.612903	5.3458858	11	30
Access to Federal Highway	31	74.974691	11.940121	48.614406	96.670699
Steepness of Slopes in Riparian Areas	31	4.6620582	1.4038157	2.839853	7.876912
Parcel Size	31	37.709677	17.247596	14	104
Definitive Land Title	31	38.000792	43.810854	0	100
Participation in Social Group	31	73.820986	22.303058	33	100
HDI-Income	31	0.6232796	0.0515567	0.561	0.699
Origin of Colonist Farmer: North	31	9.0324566	6.8745728	0	35
Credit	31	95.826863	30.050211	25	155

Chart 2.1- Chapter 2 descriptive statistics

CHART 2.2										
Bivariate Correlations, P-Value, and Sample Size										
		Years Since First Cut (Age)	Access to Federal Highway	Steepness of Slope	Parcel Size	HDI: Income	Definitive Land Title	Participation in Social Group	Origin of Colonist Farmer: North	Credit
Riparian Forest Cover: 2007	Coefficient	0.02061	-0.2818	-0.28331	0.20168	-0.274	-0.1176	0.39966	0.21062	-0.23563
	P-Value	0.9124	0.1246	0.1225	0.2766	0.1362	0.5286	0.0259	0.2554	0.2019
	N	31	31	31	31	31	31	31	31	31
Primary Forest Cover 2007	Coefficient	0.27043	0.11794	-0.00574	0.40574	0.0348	-0.0837	0.17476	0.4204	0.03269
	P-Value	0.1412	0.5275	0.9755	0.0235	0.8525	0.6544	0.3471	0.0185	0.8614
	N	31	31	31	31	31	31	31	31	31

Chart 2.2 – Riparian Forest Cover and Overall Forest Cover and Potential Determinants

The chart above shows the correlations between the forest cover determinant as well as sustainable land use variables with primary riparian forest cover from 2007 as well as general primary forest cover from 2007. These variables included age, access, parcel size, definitive land titles, welfare measurements and social group participation. Adding to this list, I also included the origin of the colonist farmers in the settlements, as perhaps farmers from more economically developed areas or perhaps those with local knowledge of Amazonia might make different land use choices.

As the chart above shows, the correlations between primary forest cover in all of the settlement and primary forest cover in riparian areas are different. Whereas general forest cover correlated with just parcel size and the origin of colonist farmers, riparian forest cover demonstrated significant relationships with access to federal highways, steepness of slopes, HDI-Income figures, participation in social groups and credit.

Regressions

Following the next step in the conceptual model, I ran two multivariate regressions. The first model included core variables such as age, access to federal highways, steepness of slopes, definitive land titling and parcel size. Adding to this in the full model regressions, I entered the determinants of general forest cover variables and sustainable land use variables which were correlated with primary riparian forest cover, significant at the .20 level.

Multivariate Regression: Primary Riparian Forest Cover 2007			
P-Value	R-Square		
0.1097	0.2883		
Variable	Coefficient	P-Value	N
Age	0.00218	0.6508	31
Access to Federal Highway	-0.00457	0.0389	31
Riparian Slopes	-0.04214	0.0271	31
Parcel Size	0.00151	0.2889	31
Definitive Land Title	-0.000138	0.8163	31

Chart 2.3- *Conceptual Framework: Step 1a – Bivariate Correlations of Age of Settlement OR Rate of Deforestation and Welfare Measurements*

Multivariate Regression: Primary Riparian Forest Cover 2007			
P-Value	R-Square		
0.0084	0.6012		
Variable	Coefficient	P-Value	N
Age	0.00692	0.1093	31
Access to Federal Highway	-0.00586	0.0132	31
Riparian Slopes	-0.04171	0.0235	31
Parcel Size	-0.00063	0.7051	31
Definitive Land Title	-0.000549	0.2826	31
Participation in Social Group	0.00241	0.0278	31
HDI-Income	-0.14006	0.7982	31
Origin: North	0.01022	0.0172	31
Credit	-0.000562	0.4302	31

Chart 2.4- *Conceptual Framework: Step 1a – Bivariate Correlations of Age of Settlement OR Rate of Deforestation and Welfare Measurements*

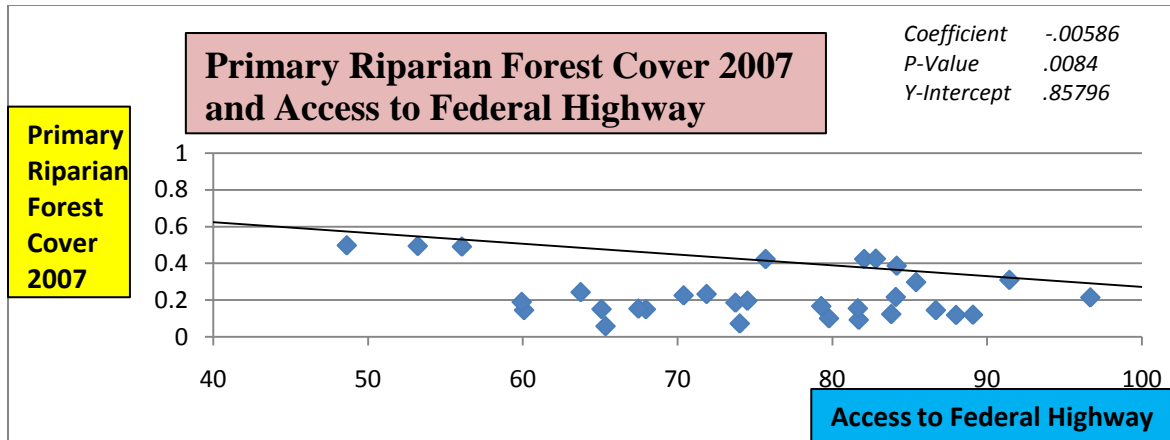
D. Discussion

In the midst of high rates of deforestation and compromised ecosystem services, the preservation of riparian forest offers a realistic chance to salvage key ecological functions otherwise forgone by unchecked development. As discussed in my literature review, these areas can act as ecological corridors to maintain biodiversity as well as filtration strips for sediment runoff (Evans 2002). Hence, understanding the determinants of their preservation merits investigation so as to promote sustainable policy. Programs such as *A Programa de Mata Ciliar* which aim to both rehabilitate and preserve forest in these areas clearly can benefit from this analysis.

In choosing possible determinants for deforestation in riparian areas, I turned to literature on drivers of deforestation in tropical areas in general as well as determinants of sustainable land use practices. For drivers of deforestation, this included the age of the settlement, access, property size, topography of the land and definitive land titles. For sustainable land use determinants, my variables included participation in social groups, human welfare levels, access to urban areas, the origins of the colonist farmers and definitive land titles with the associated access to credit. In this section I will discuss these variables together when they are both a driver of deforestation and a sustainable land use determinant and individually when necessary.

Access

Access, or the Von Thünen model of deforestation was a key consideration. A large amount of literature has evidenced the negative effect access can have upon forest cover (Katzman 1977, Walker 2004, Schmink and Wood 1984, Pfaff 1999 Nepstad et al . 2001, Soares-Filho et al . 2001, Munroe et al . 2002 Cropper et al . 2001, and Zeller 2002 and Stolle et al . 2003 for Asia, and Mertens and Lambin 1997.1). Charts 2.2, 2.3 and 2.4 above and Graph 2.1 below demonstrate my findings are in line with those from the literature reviewed for drivers of deforestation; better access to federal highways is negatively correlated with riparian forest. This result is not entirely surprising as access has been proven to be a key driver of deforestation, though in light of the increased vigilance of environmental law enforcement and environmental programs aimed at riparian forests, it is surprising that areas closer to highways and centers of development, where environmental enforcement offices are located, do not show higher levels of general forest cover, which would indicate regrowth.

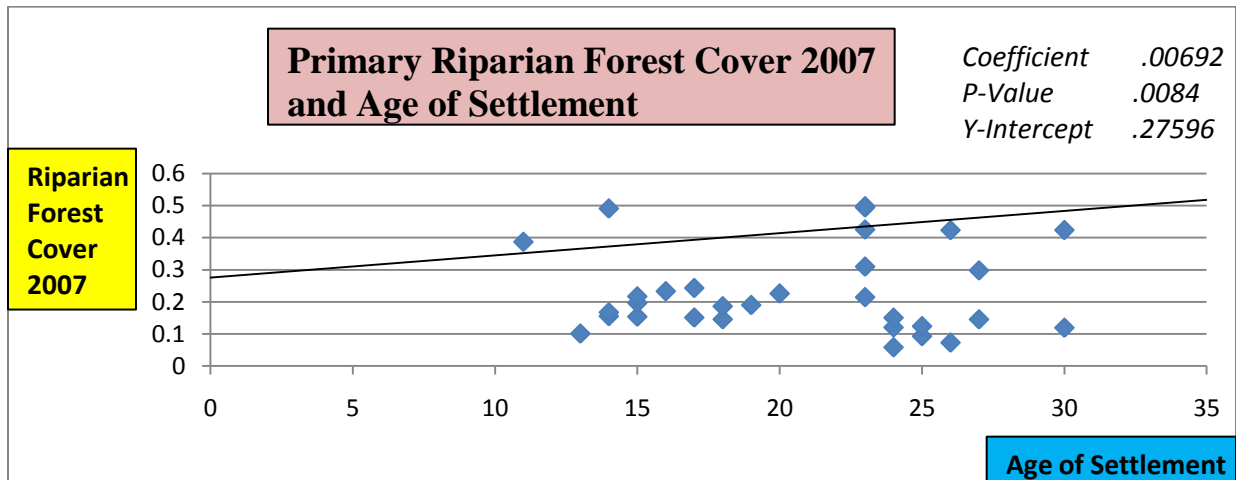


Graph 2.1 – Primary Riparian Forest Cover 2007 and Access to Federal Highway

Age of Settlement

I found that older settlements have higher levels of primary riparian forest which goes against the expectations. Chart 2.4 and Graph 2.2 show this trend of lower riparian forest cover in new settlements. Although newer settlements have less primary forest cover at the time of their founding, the increased rate of deforestation in settlements over time, from 3% a year to 5% as shown in Forest Figures Chart in the appendix, indicates that deforestation patterns are in fact changing in my sample of settlements. This result here that older settlements have maintained more primary riparian forests than younger settlements is concerning. In addition to promoting forest rehabilitation in riparian areas, programs such as *A Programa Mata*

Ciliar can take note of this finding and focus efforts as well on promoting riparian forests in new settlements.

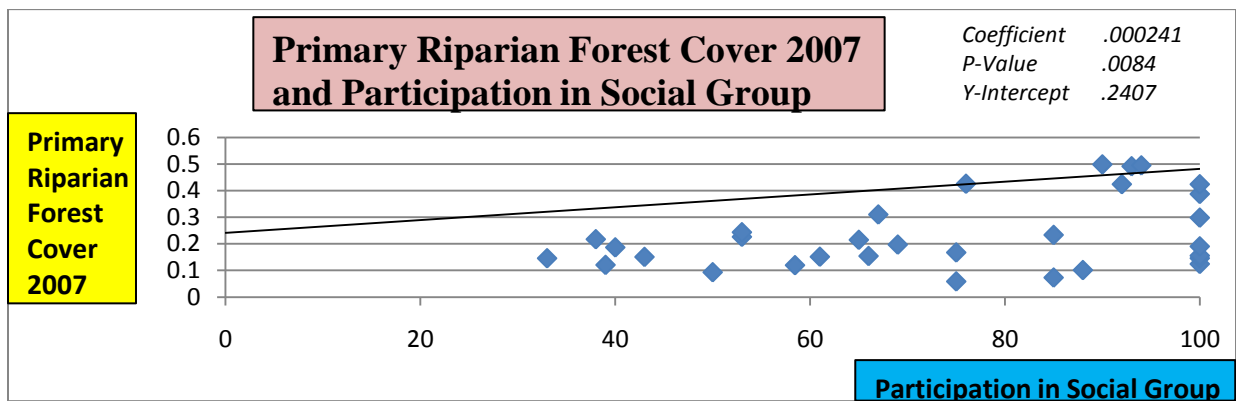


Graph 2.2 – Primary Riparian Forest Cover 2007 and Age of Settlement

Social Organization

Another variable I have chosen to include in my consideration for the determinants of riparian forest cover is participation in social groups; cooperatives, associations, syndicates. As maintenance of forest in these High Conservation Value areas can be considered to be sustainable land use behavior, I wanted to test if patterns found in previous studies (Caviglia and Kahn 2001) hold true for my study. Both my bivariate and multivariate regressions (Charts 2.2 and 2.4) demonstrate participation in social groups is positively correlated with high levels of forest cover in riparian areas. This result is furthered as shown in Graph 2.3

below. As participation in social groups is also associated with age, which is itself correlated with low forest cover in general, this finding is note worthy. I believe that this finding suggests that farmers who choose to participate in social groups are more sustainably minded and as such choose to preserve these High Conservation Value areas. As a means to promote riparian forest regrowth and maintenance, efforts by EMATER and other agencies could focus upon promoting social organization.

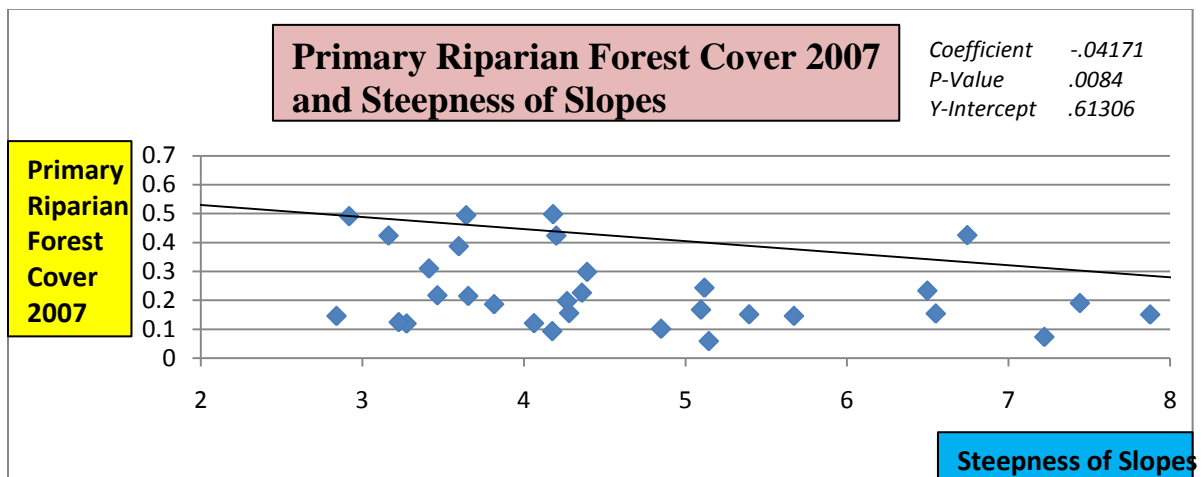


Graph 2.3 – Primary Riparian Forest Cover 2007 and Participation in Social Group

Topography

Drawing from past studies (Adan and Peterson 1998, Rudel 1993, Sader and Joyce 1988, Evans et al. 2001, Evans and Moran 2002), I chose to include slope in my analysis of the determinants for riparian forest cover as this literature has indicated a tendency for these areas to remain in forest, due to a both a recognition of their ecological importance as well as

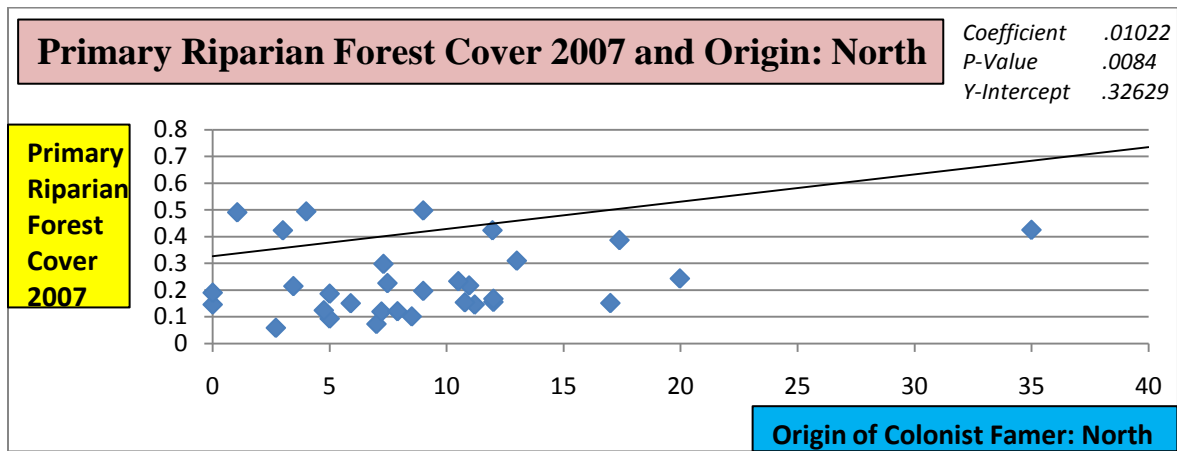
difficulty in accessing them. However, my bivariate and multivariate regressions (Charts 2.2, 2.3 and 2.4) have demonstrated steeper slopes to be negatively correlated with primary riparian forest cover. Graph 2.4 further demonstrates my finding. In my study area, steeper slopes are found in areas with poor access to cities and poor access to cities is associated with lower levels of asset possession. Hence, I argue that in these areas distant from city centers and environmental law enforcement agencies, with less wealth as indicated by low asset scores, there is a tendency to deforest in riparian zones either in order to increase land under production or perhaps a disregard for environmental law.



Graph 2.4 – Primary Riparian Forest Cover 2007 and Steepness of Slopes

Local Origins of Colonist Farmers

Another variable I chose to examine for affect upon riparian forest cover was the origin of the colonist farmers in the settlements in my study sample. In both my bivariate and multivariate regressions farmers from the north region of Brazil had higher levels of riparian forest cover. Chart 2.4 and Graph 2.5 demonstrate. This trend is interesting as despite this region having lower levels of economic development, the trend noted in literature such as the Bruntland report on poverty leading to deforestation, is not the case here. I believe that this trend of farmers from the north maintaining more of their riparian forest can be attributed to local knowledge of the importance of sustainable land use practices in the region.



Graph 2.5 – *Primary Riparian Forest Cover 2007 and Origin of Colonist Famer: North*

Human Welfare: Poverty

As a means to test theories relating to poverty and deforestation (United Nations 1990, Rudel and Roper 1997), I included HDI Income figures into my analyses. Though initially significant in my bivariate regressions, once age, access and other factors were considered, these welfare measurements became highly insignificant as shown Chart 2.4. The initial correlation between these two welfare measurements and low levels of riparian forest cover I argue would be due to high access to federal highways which is strongly related with low levels of riparian forest cover.

Property Size

Property size was another variable I tested for, again based upon the literature on the drivers of deforestation on tropical areas, which has noted larger property size tend to have higher levels of forest cover (D'Antona et al. 2006 Pichon & Bilsborrow 1994, Pichon 1997, Carr 2004, Turner and Geoghegan 2004). While my bivariate analysis in Chart 2.2 showed larger parcel sizes tend to have more primary forest cover than do smaller ones, this effect was not shared for riparian forest, as shown by the lack of correlation in Chart of 2.2 and a significant relationship in Charts 2.3 and 2.4.

Definitive Land Title

Land tenure as well was a variable I chose to consider in my examination of riparian forest cover. As noted in my literature review, the effect of land tenure on forest outcomes is theorized to both positively and negatively affect sustainable land uses decisions. The tragedy of the commons posits that poor land tenure will lead a farmer to treat a piece of land in a fashion that produces economic returns as quickly as possible, with little consideration for future production or the environmental sustainability. However, as I have shown in this paper, land title is also correlated with age and age is correlated with low levels of forest cover. Perhaps due to this ambiguous effect, none of the regressions were significant, meaning that I did not find definitive land titles to affect riparian forest cover.

V. Conclusion

This paper has the objectives of understanding the relationships between human welfare and settlement characteristics as well as the determinants of deforestation in riparian areas. My analysis found higher levels of human welfare in settlements which have longer been in existence, that have lower current rates of deforestation and better access to federal highways. Higher education levels, literacy rates, HDI scores and asset possession in addition to lower levels of tropical diseases all demonstrate high human welfare in these areas. In addition, I have found the determinants of High Conservation Value riparian forest to include the age of the settlement, its access to federal highways, the slopes of the riparian areas, participation in social groups and the origin of the colonist farmers.

In the context of high levels of tropical disease outbreaks, poor land tenure and the associated low levels of credit, poor access to federal highways and cities, poor social organization, less governmental cash transfers and an average wait time of 5 years between effective settlement of an area an official recognition by INCRA, I have found that the boom bust pattern of development in Rondônia found in municipal level analyses is not shared by analyses at the settlement level such as my study. Aside from a survival of the strongest style of development, it would be hard to argue how the above challenges would facilitate any sort of boom. In the context of development in the Amazon, critics speak of high rates of turnover. In the light of the findings of this paper, in addition to the biophysical and land productivity

basis this turnover is purported to be based upon, the poor social organization and health risk associated with newly developed areas must be considered in the discussion for an improvement for sustainable development.

Despite many critics, INCRA has improved many of its policies for the better over time. Since a horrible massacre in 1995 over a land invasion in the south of the Rondônia, the agency has been more vigilant in addressing landless invasions and quicker to respond to settling these peoples in the invaded land or in areas in other parts of the state deemed suitable. The agency has devolved several of its prior functions (i.e. road construction and education), to state and municipal authorities. If sustainable development is to be reached in the region, the full development of society must take place which includes self-autonomy and not a top down style of development, which though effective in the 1970s and 1980s, has been outgrown by the state.

For human welfare, a key finding from my study, which may have a beneficial effect upon welfare though deleterious one upon forests, is access. I have shown access to federal highways, and in turn cities and markets, to be a positive determinant of welfare. However, I have also shown access to be a key determinant of deforestation in High Conservation Value areas of riparian forests. Hence, improving access in order to improve livelihoods will only

beget more development in previously inaccessible areas and perpetuate the problem of distant communities having low levels of welfare.

The other key finding in this paper and of utmost importance to the ecological future of the region is the determinants of riparian forest cover. Faced with the reality of a continued aggressive style of development in the region, these riparian forests offer a real chance of salvaging crucial ecological services of biodiversity maintenance and water cycling. Rondônia took a large step in preserving its natural resources with the Planofloro program in 1992 which partitioned off swathes of forest, deemed out of bounds for development. However, the next step it must take so as to preserve the quality of the land it has developed or will soon, is a vigilant protection of riparian areas. The key finding from my study to offer this movement for protecting riparian areas is the positive effect social groups can have and the fact that newer settlements have a tendency to tear down more of the primary forests in these areas, indicating efforts of programs such as *A Programa de Mata Ciliar* can be focused here. Furthermore, the state agency for technical assistance which has the state purpose of supporting social groups, EMATER, must continue to support the people of Rondônia and mend what is said to be a fractured relationship with INCRA. These two agencies must work hand in hand as each has the power to both better and worsen the affairs of the other.

It is recommend that future research examine policies which can bring the benefits of access to more remote areas, without increasing road networks themselves. This may be through improved public transportation or perhaps governmental support of the milk and beef industry that remote areas currently have little access to. It is also recommended that future research aim its efforts at identifying what types of social networks display higher levels of riparian forest and assess the possibility of ecosystem service payments for these relatively small, though increasingly important areas.

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VII. Appendix

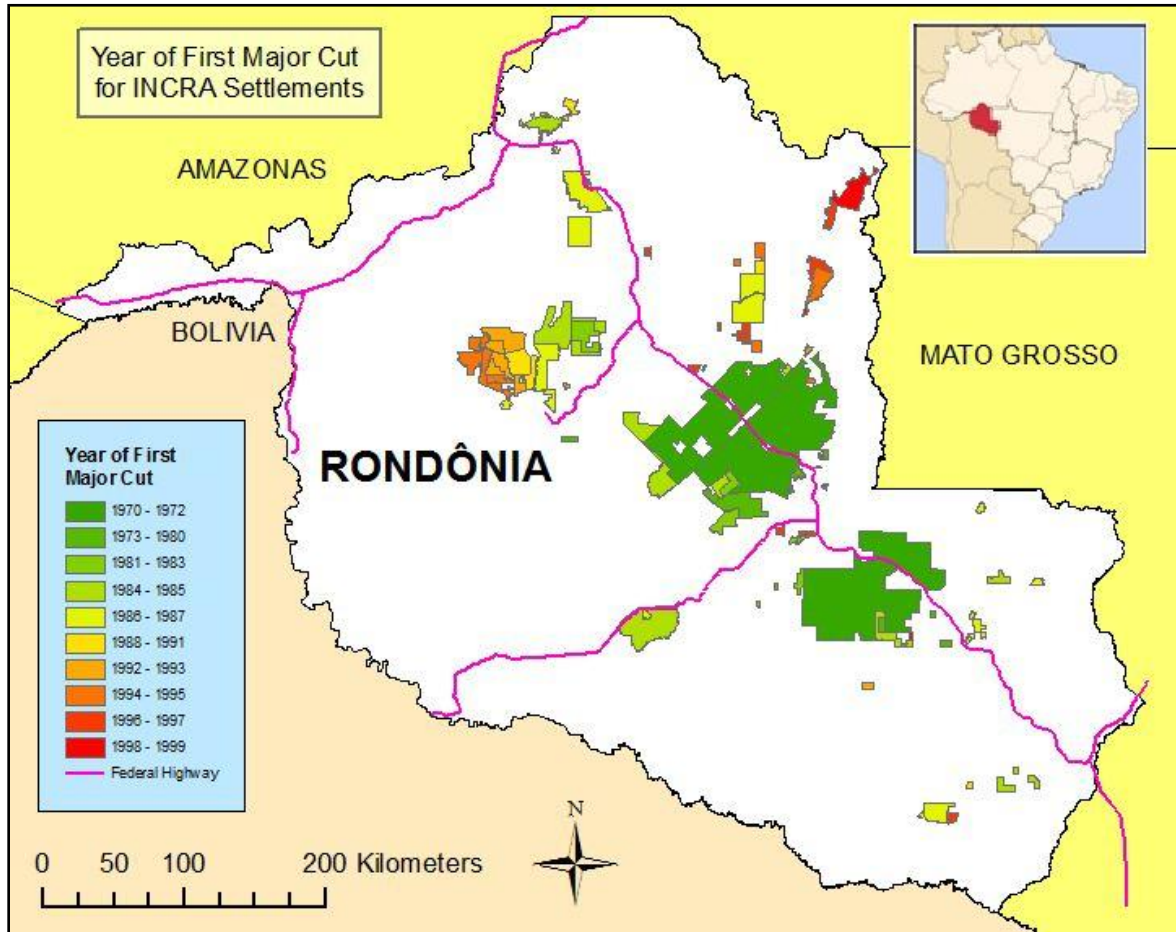
1. Description of Variables

Variable	
Assets	Asset based, PCA based welfare score
Literacy Settlement	Literacy Rate For Head of Household
IDEB	Quality of Education measurement, based upon test scores
HDI	Municipal Human Development Index-2000
HDI Income	Municipal Human Development Index for Income-2000
HDI Life Expectancy	Municipal Human Development Index for Life Expectancy-2000
HDI Education	Municipal Human Development Index for Education-2000
Literacy Municipality	Municipal Literacy rate– 2000
Disease Incidence	Aggregate disease incidence of tropical disease, 2003-2006 – Municipal
Year of First Cut (Age)	Year in which first major cut occurred in settlement / Effective settlement date
Year of Creation	Year in which INCRA founded settlement

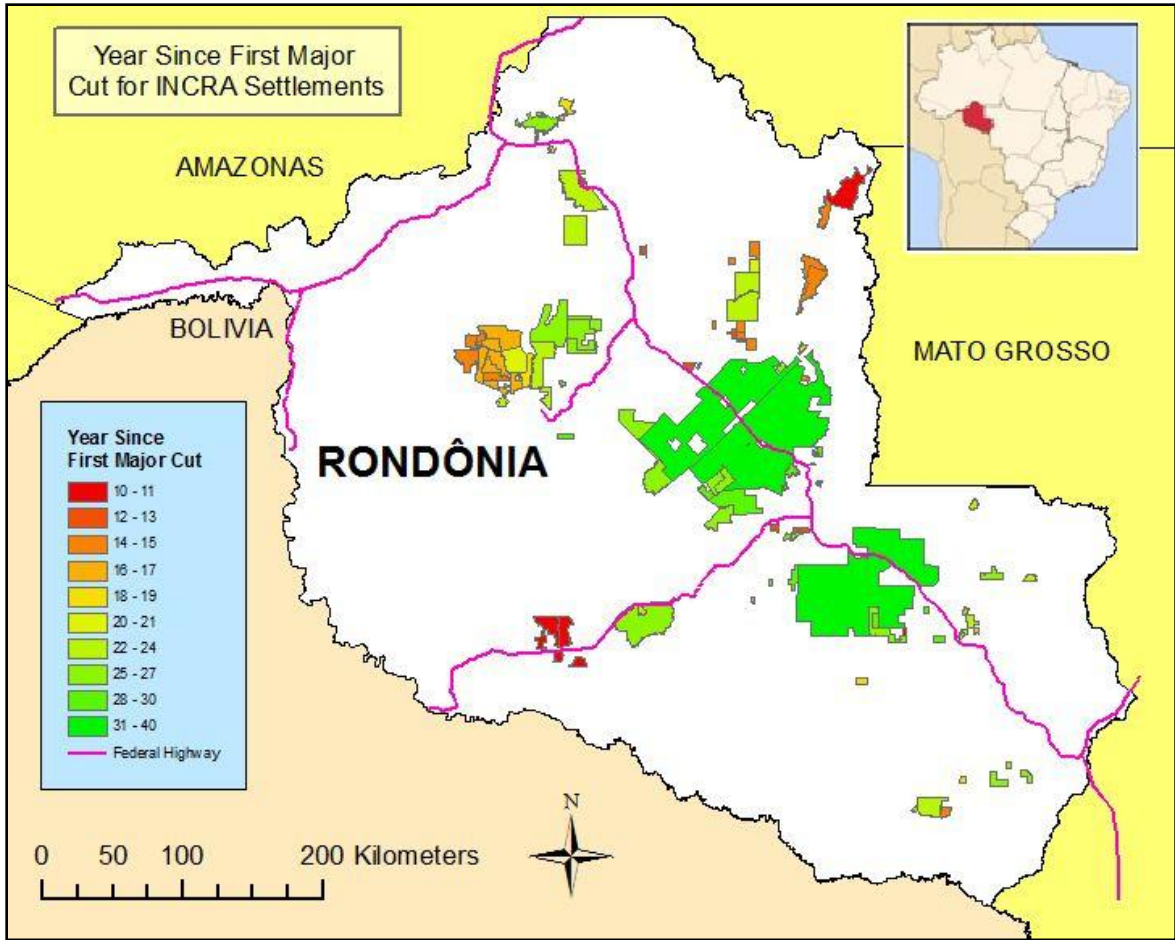
Access to City	GIS Cost Distance measurement for ease of accessing closest city
Access to Federal Highway	GIS Cost Distance measurement for ease of accessing federal highway
Slope Score	Median value of cells of ASTER based slope layer within settlement
% With Definitive Title	Percent of households with definitive land title
Credit	Percent of households currently with financing
Participation in Social Group	Percent of household which participate in a social group (e.g. - cooperative)
% of Farm Households Receiving Government Cash Transfers	Percent of Households Receiving Government Cash Transfers (Bolsa Familia)
% of Farm Households From North	Percent of head of households from North region
% of Farm Households From East	Percent of head of households from East Region
% of Farm Households From Central West	Percent of head of households from Central Ist region
% of Farm Households From South	Percent of head of households from South region
% of Farm Households From	Percent of head of households from southeast region

Southeast	
% of Farm Households From Undeveloped Area	Percent of head of households from North and East
% of Farm Households From Developed Area	Percent of head of households from South and Southeast
% Change From Primary Forest: Pre 1990	Percent of pixels changed from primary forest to any other land use in before 1990
% Change From Primary Forest: 1990-1999	Percent of pixels changed from primary forest to any other land use in between 1990 and 1999
% Change From Primary Forest: 2000-2007	Percent of pixels changed from primary forest to any other land use in between 2000 and 2007
Rate of Deforestation	Gross rate of deforestation from the year of first major cut
Time to half	Time in which it took settlement to deforest half of the forest which was standing at the first year of settlement

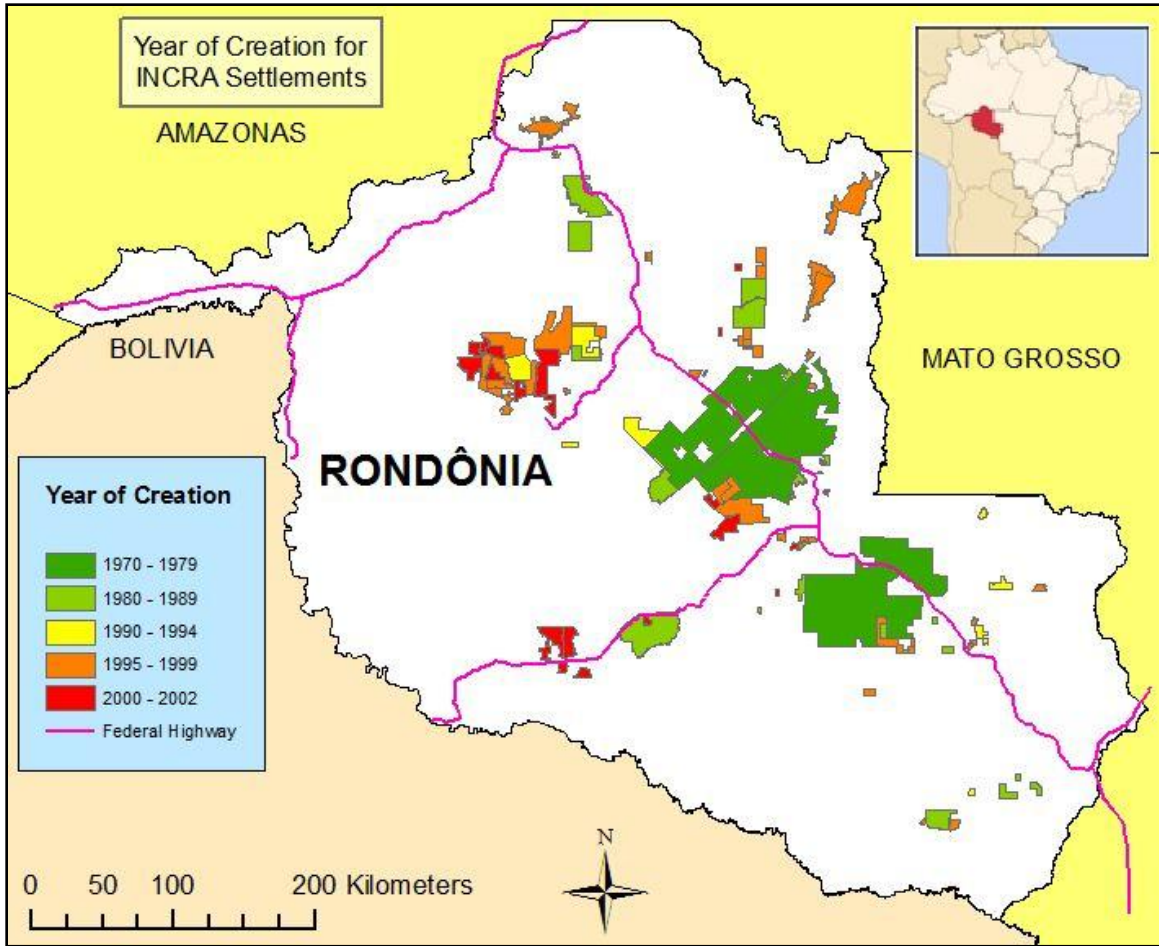
2. Maps



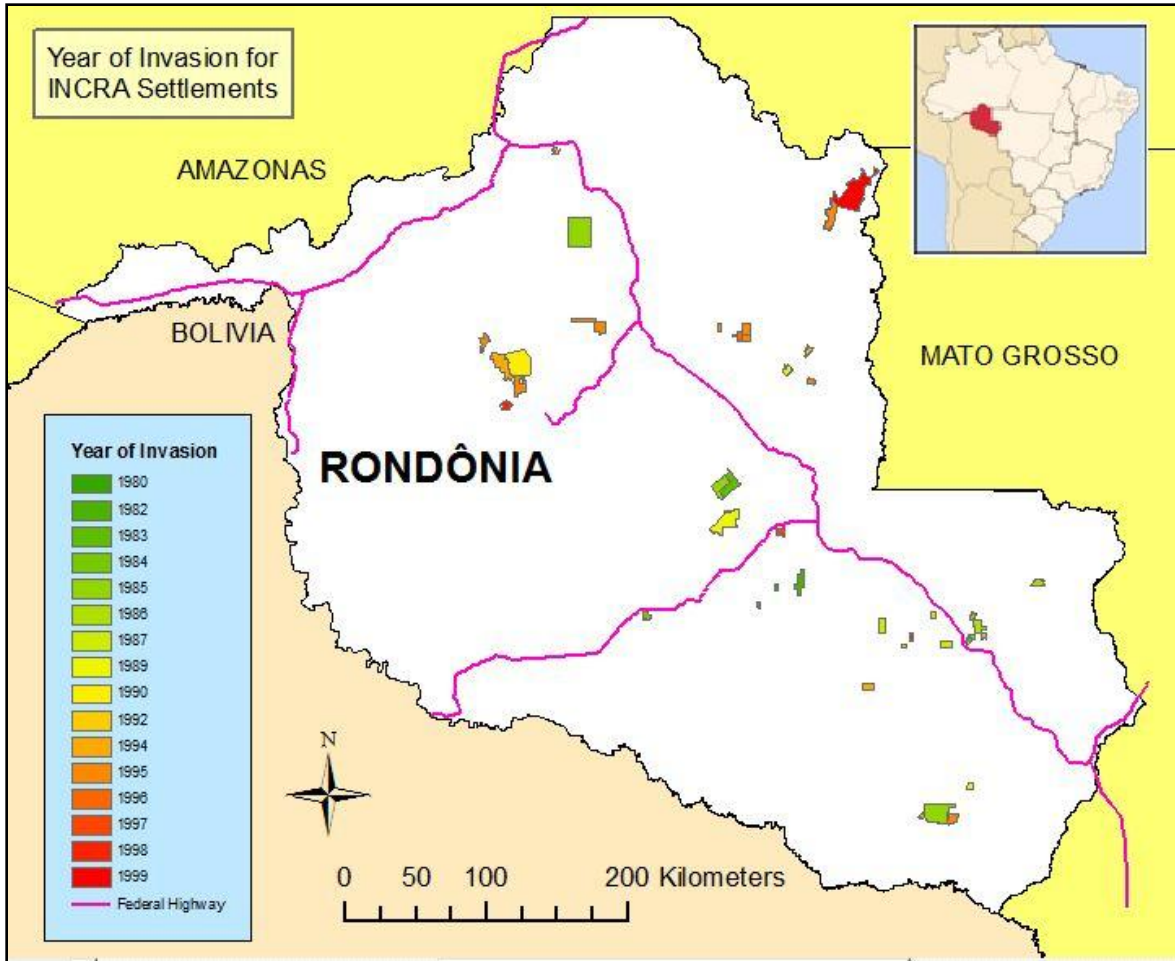
Map 1 – Year of First Cut



Map 2 – Years Since Major First Cut (Age)

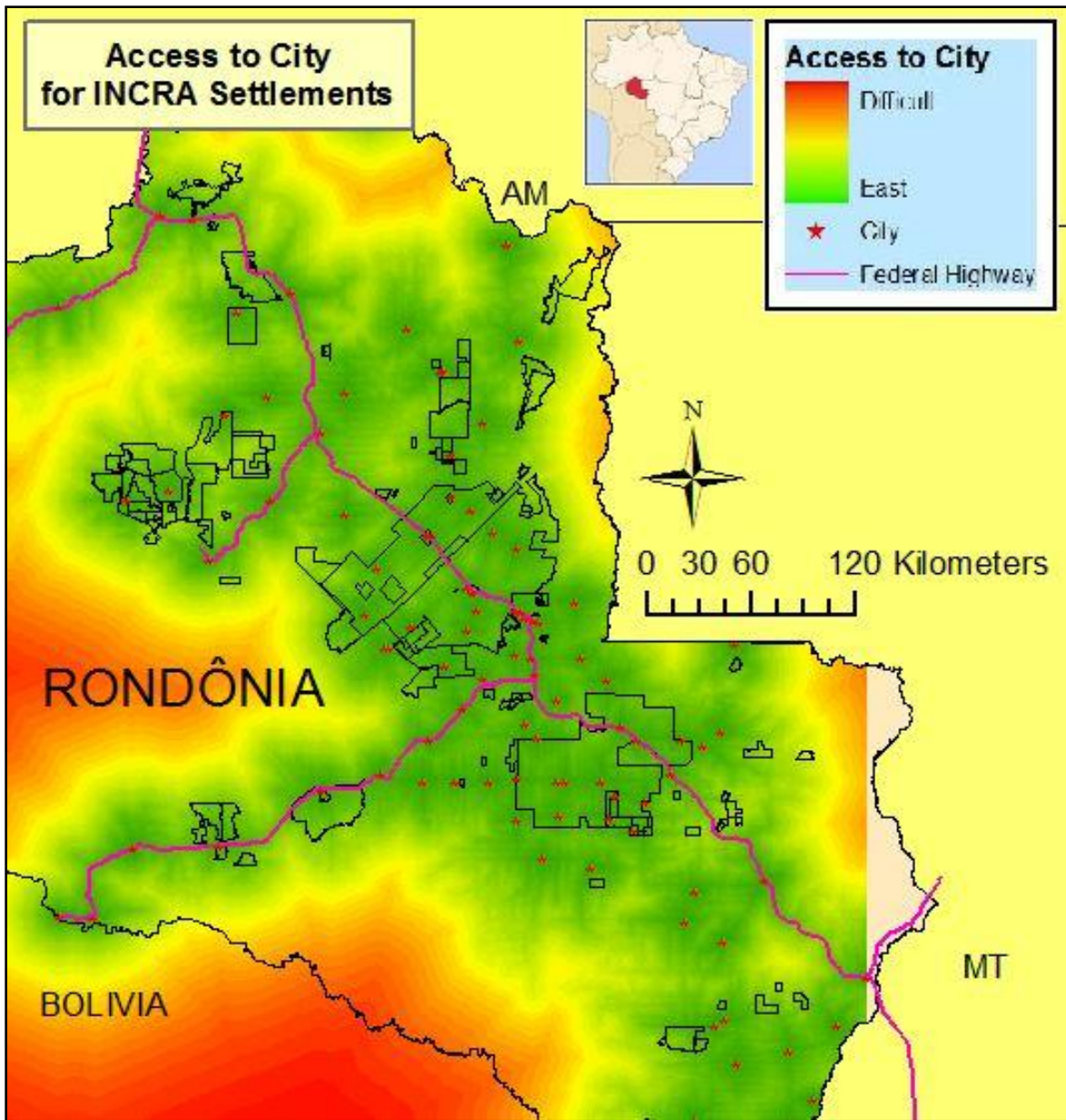


Map 3 – Year of Creation (Official Founding Date by INCRA)

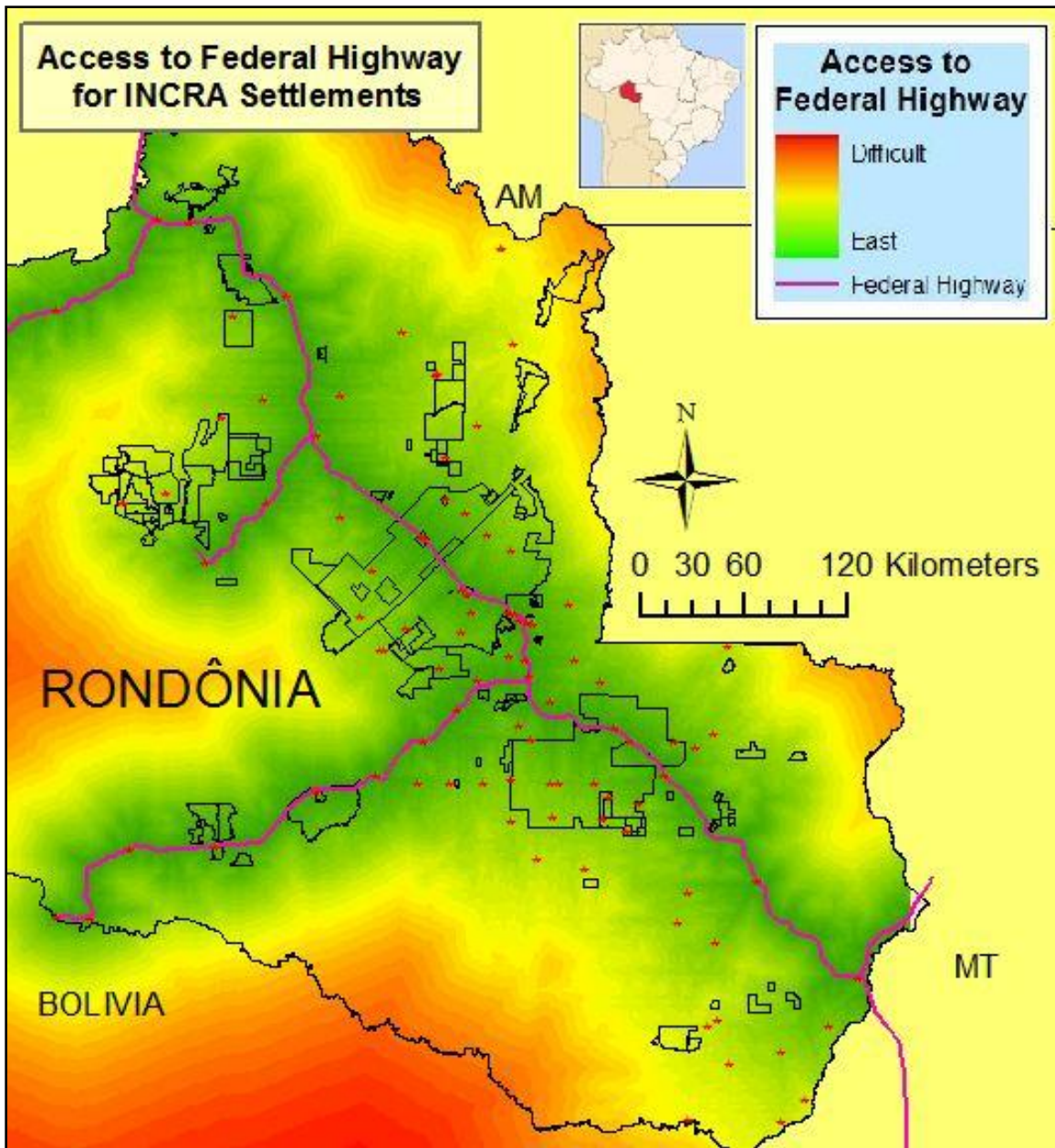


Map 4 – *Year of Invasion*⁶

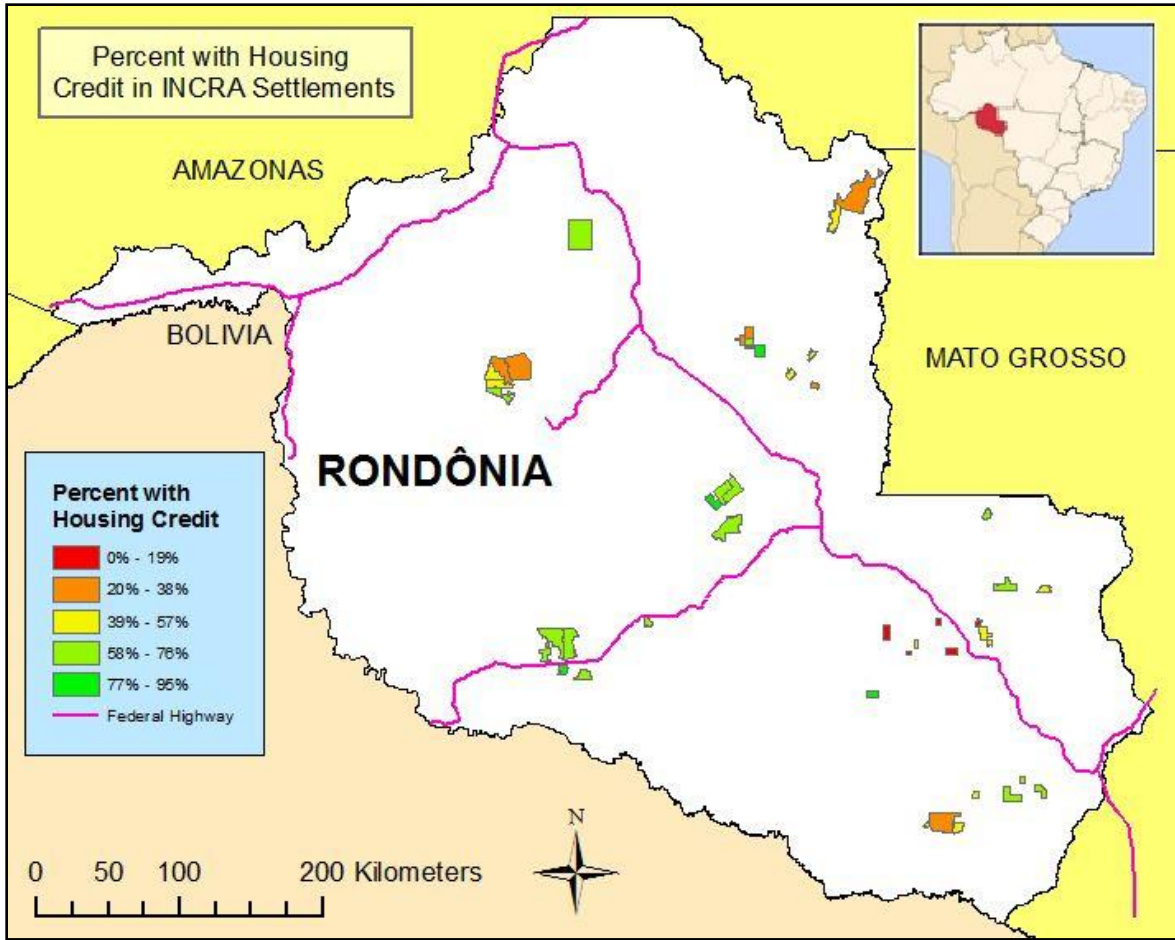
⁶ Only settlements which were founded via land invasions are included in this sample



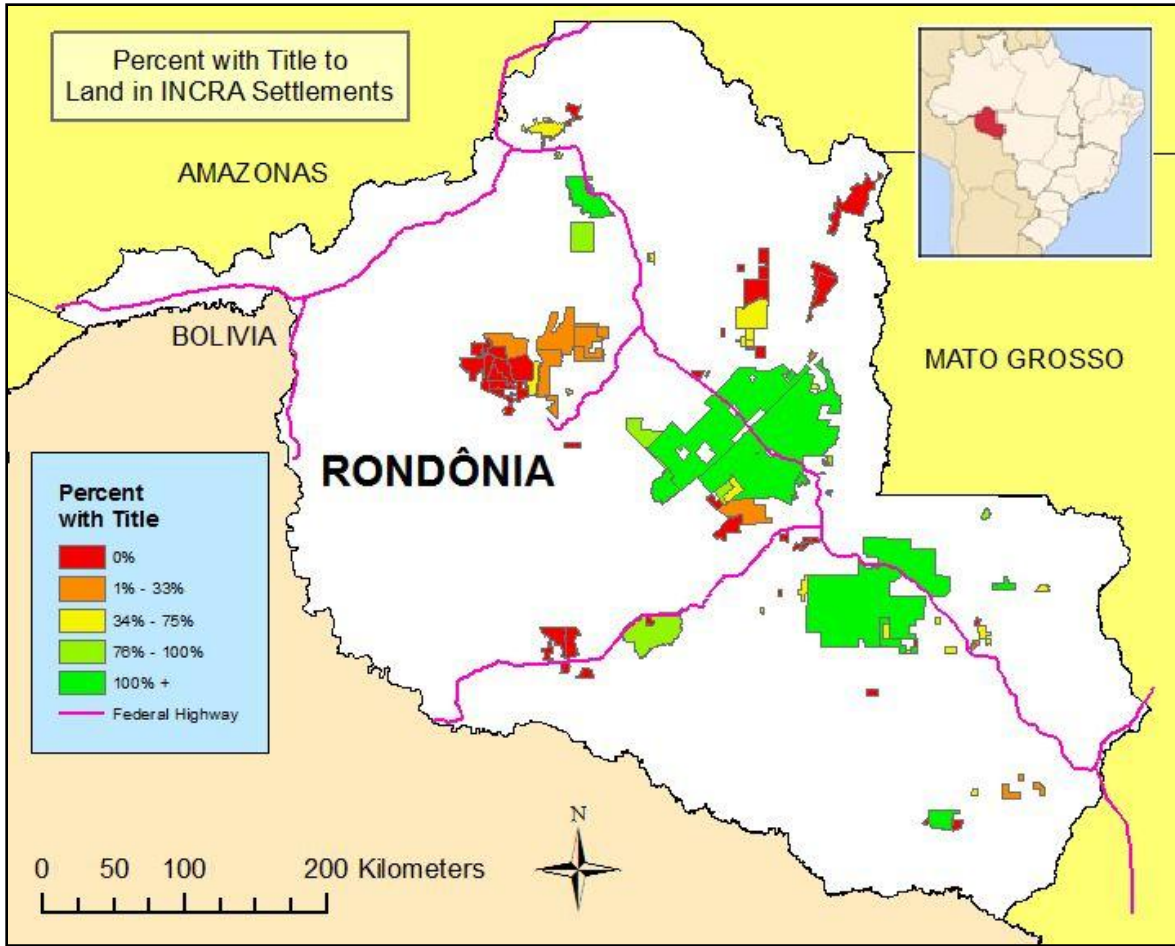
Map 5 – GIS Cost Distance Based: Access to City



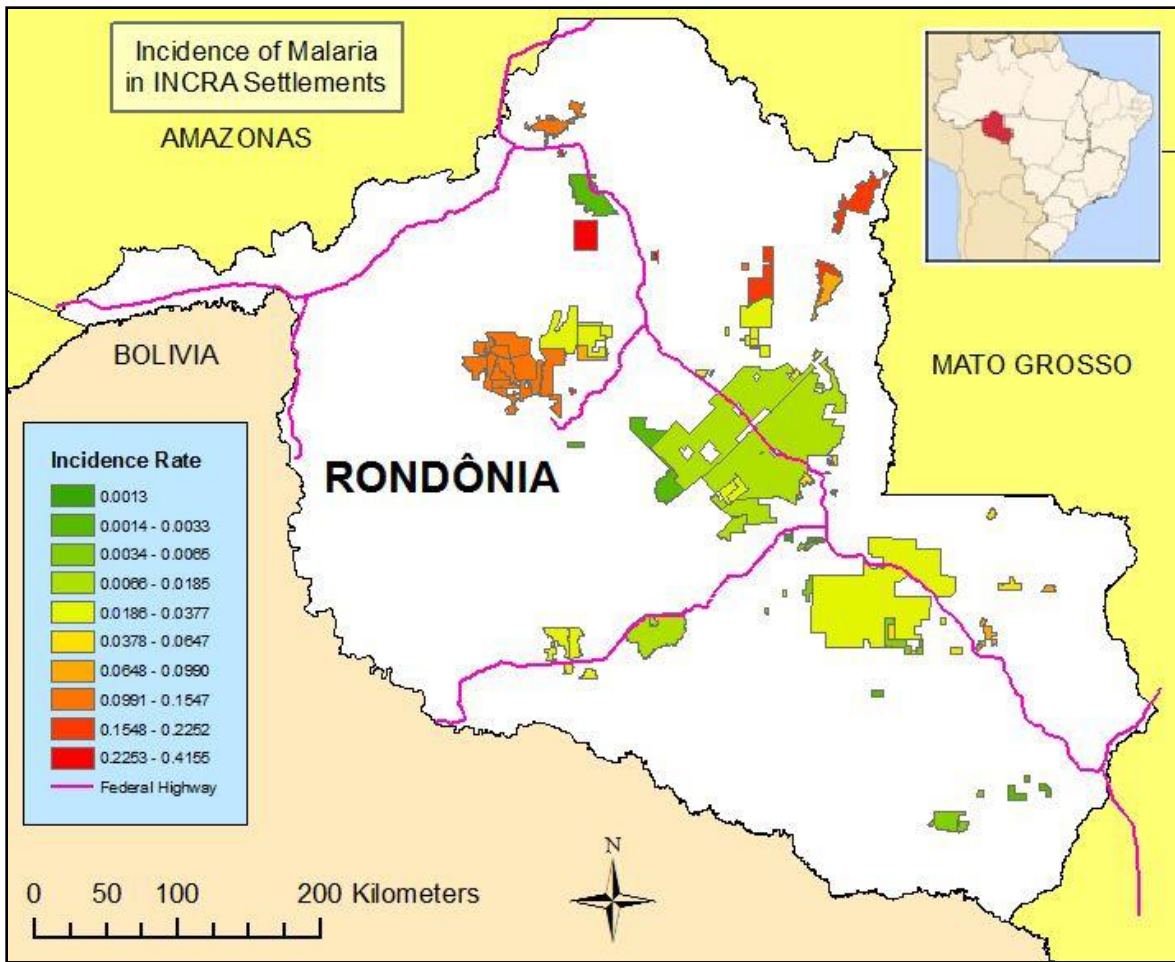
Map 6 - GIS Cost Distance Based: Access to Federal Highway



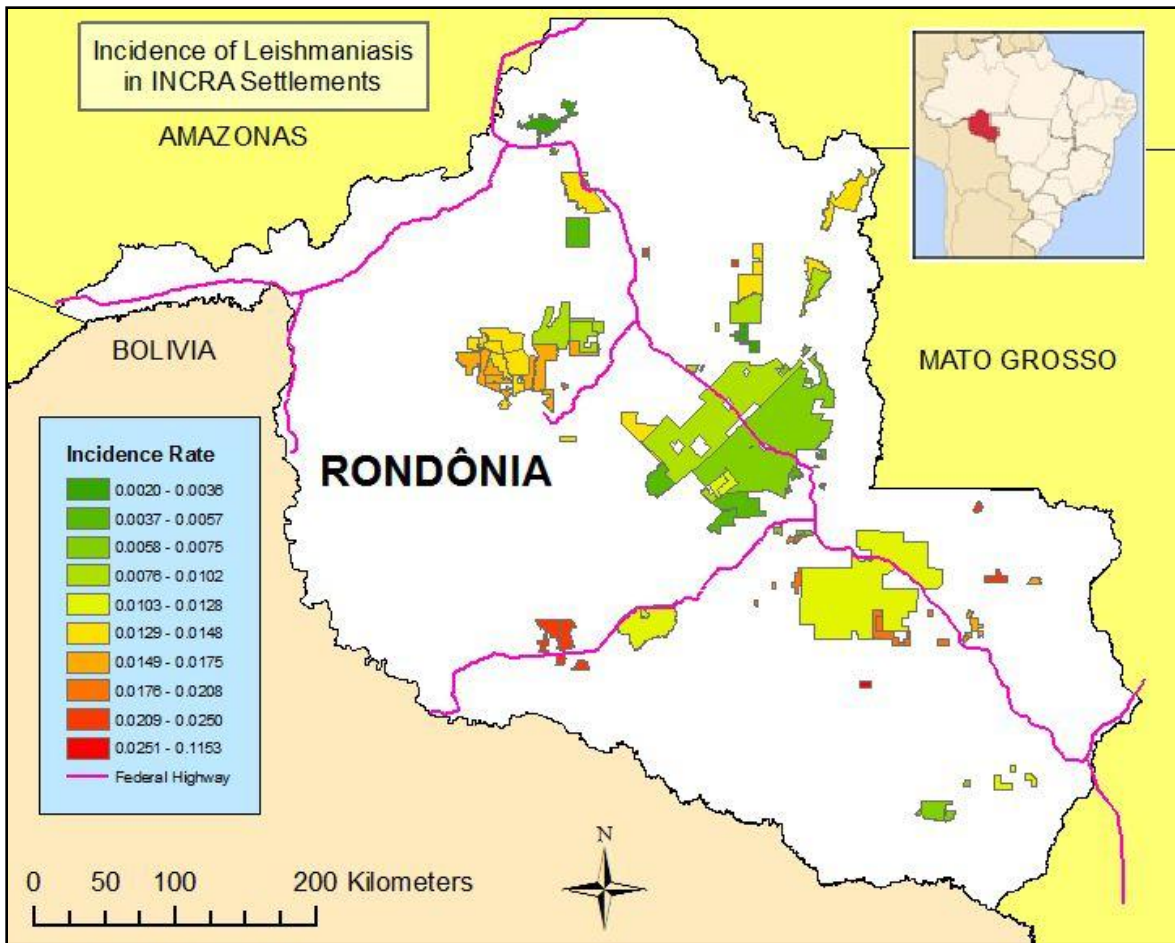
Map 7 – Settlements in the Study Sample Classified by Percent with Credit



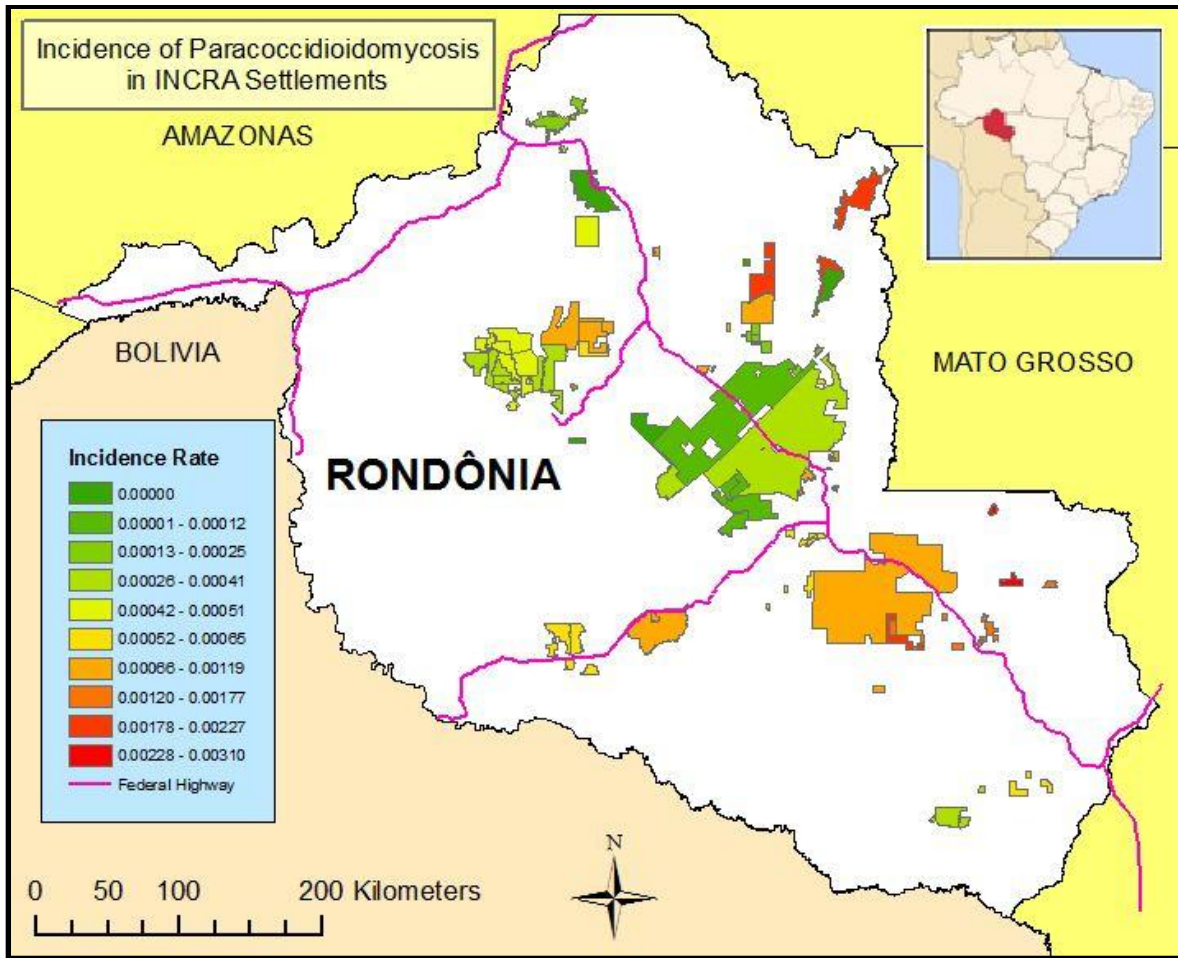
Map 8 - Settlements in the Study Sample Classified by Percent with Definitive Land Title



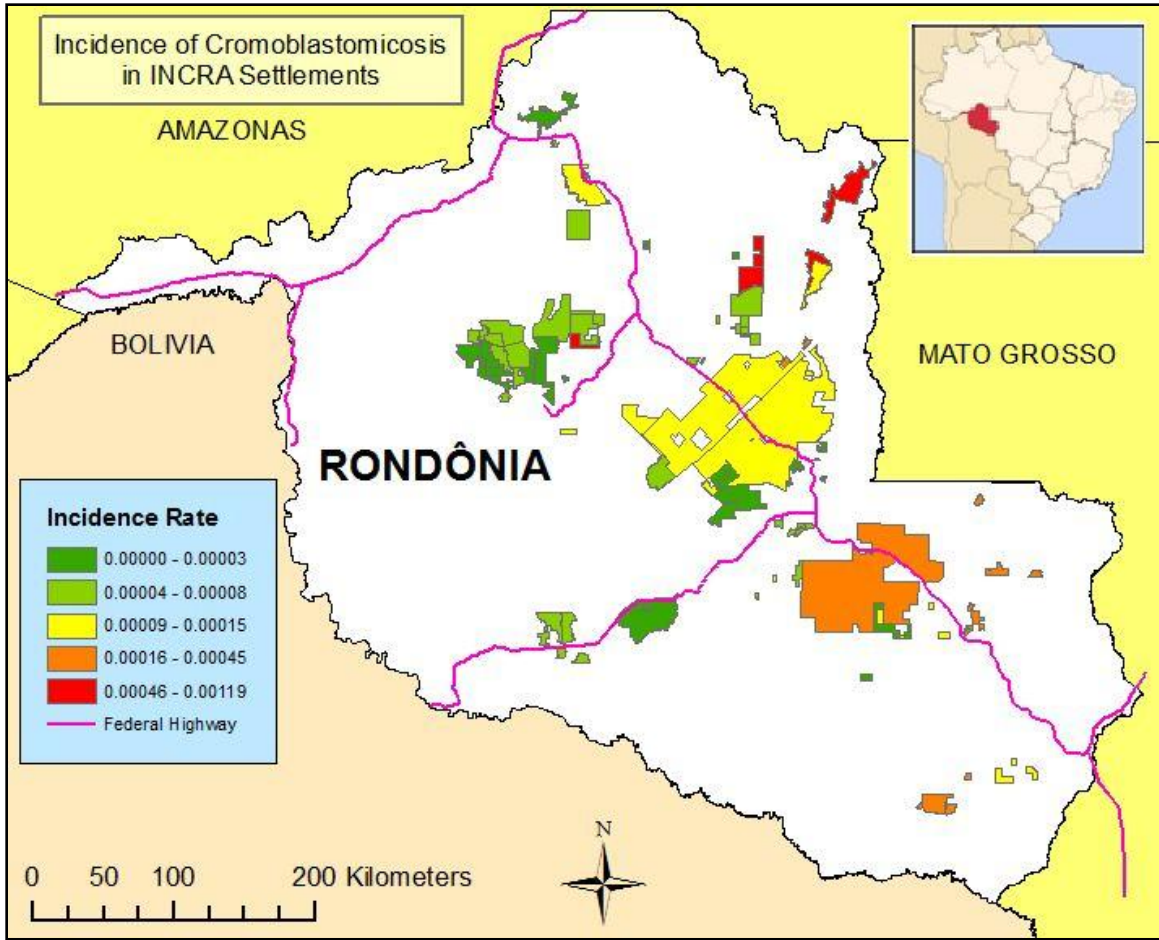
Map 9 - Settlements in the Study Sample Classified by Disease Incidence



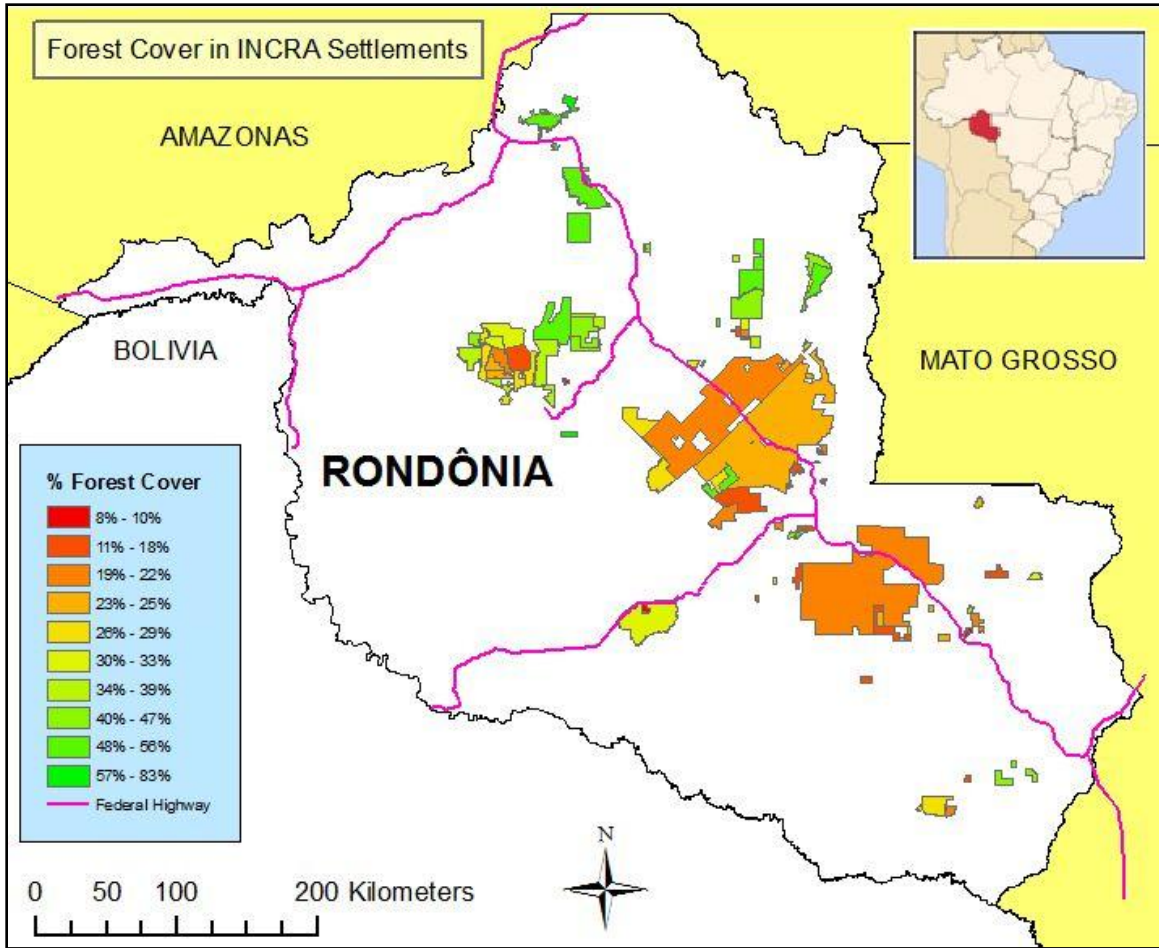
Map 10 – Settlements in Study Sample Classified by Incidence of Leishmaniasis



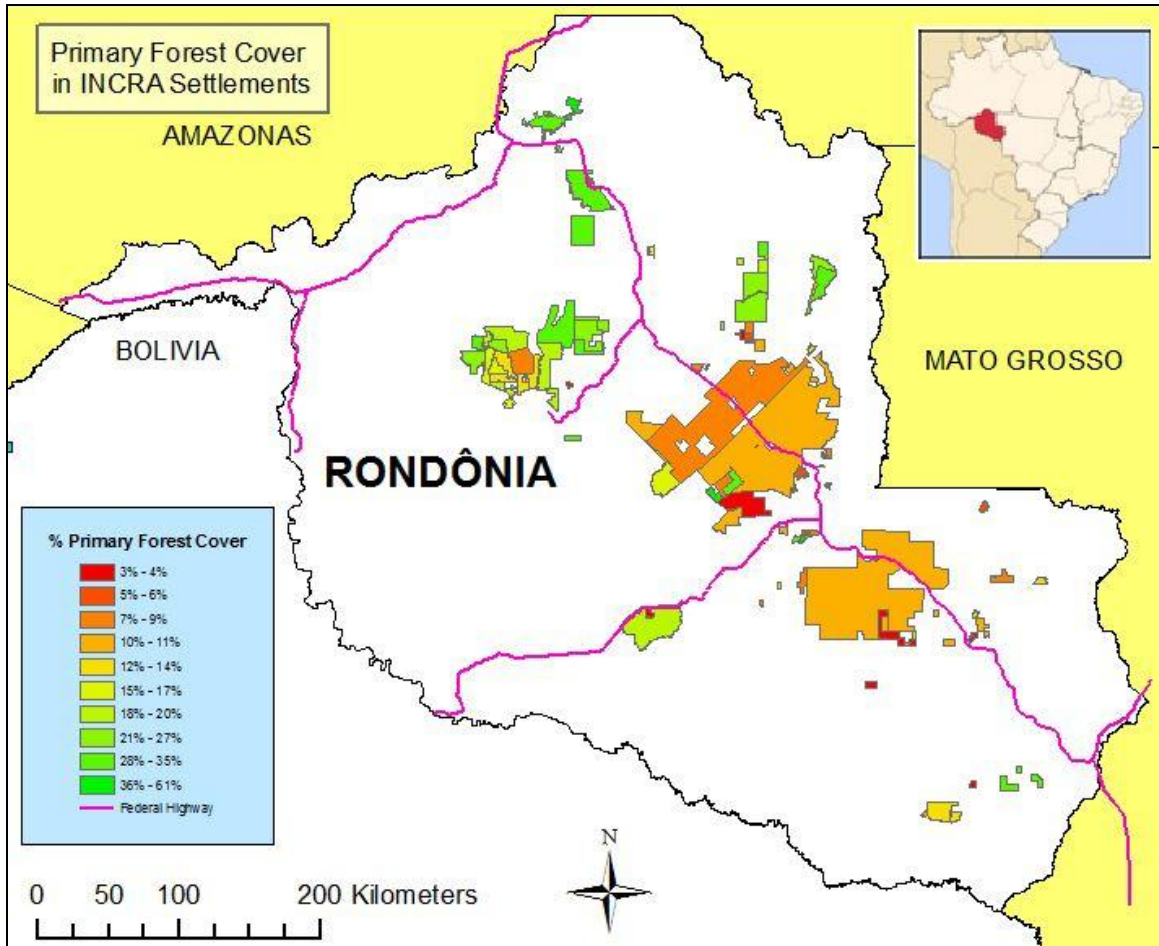
Map 11- Settlements in the Study Sample Classified by Incidence of Paracoccidioidomycosis



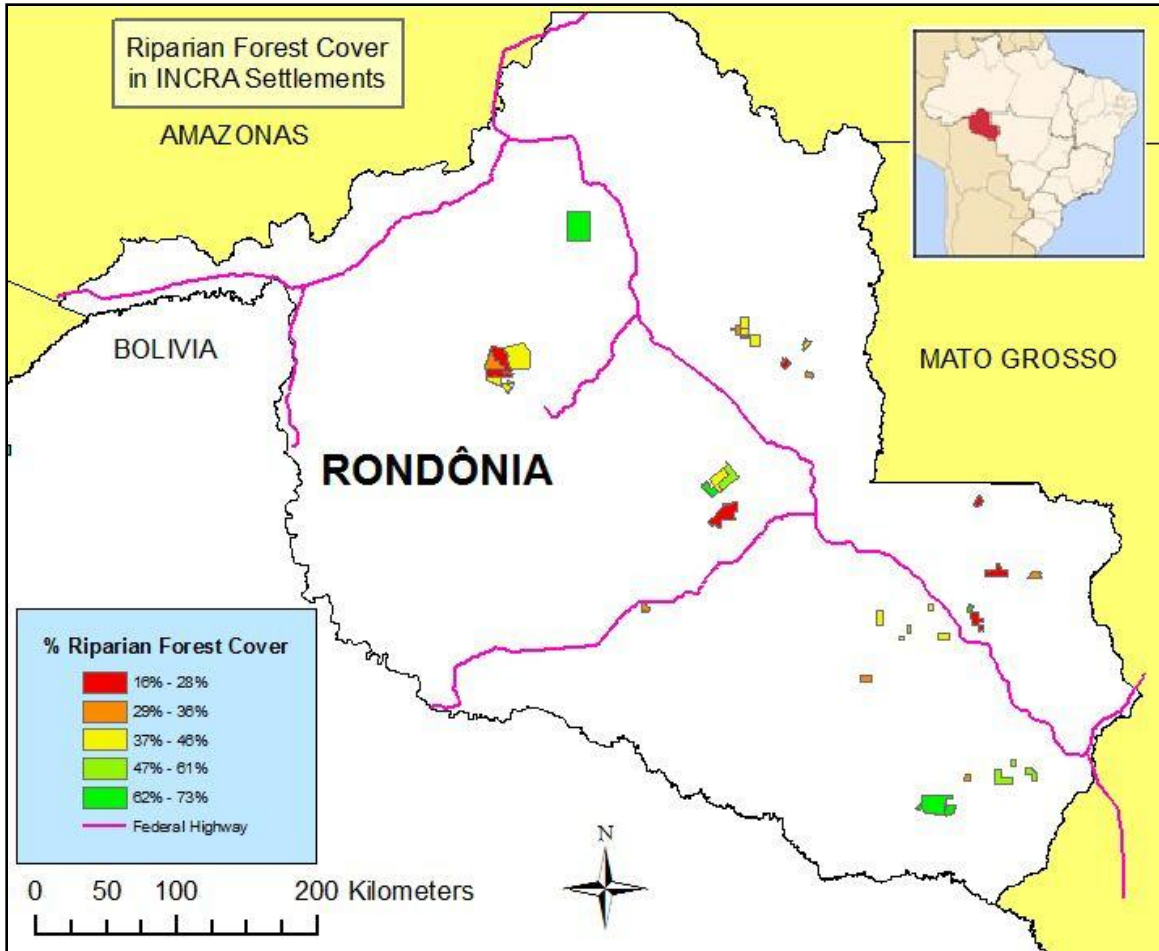
Map 12- Settlements in the Study Sample Classified by Incidence of Cromoblastomycose



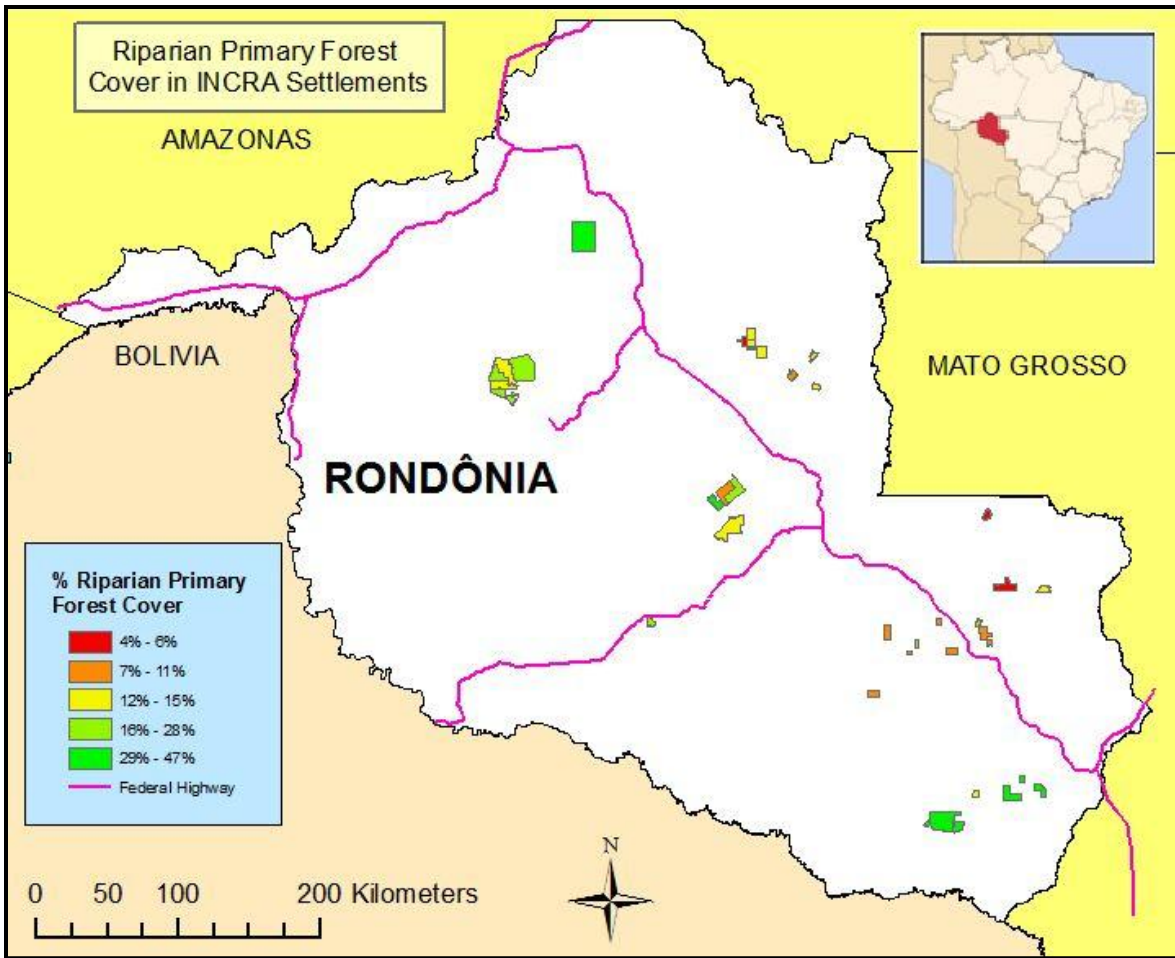
Map 13 - Settlements in the Study Sample Classified by Forest Cover: 2007



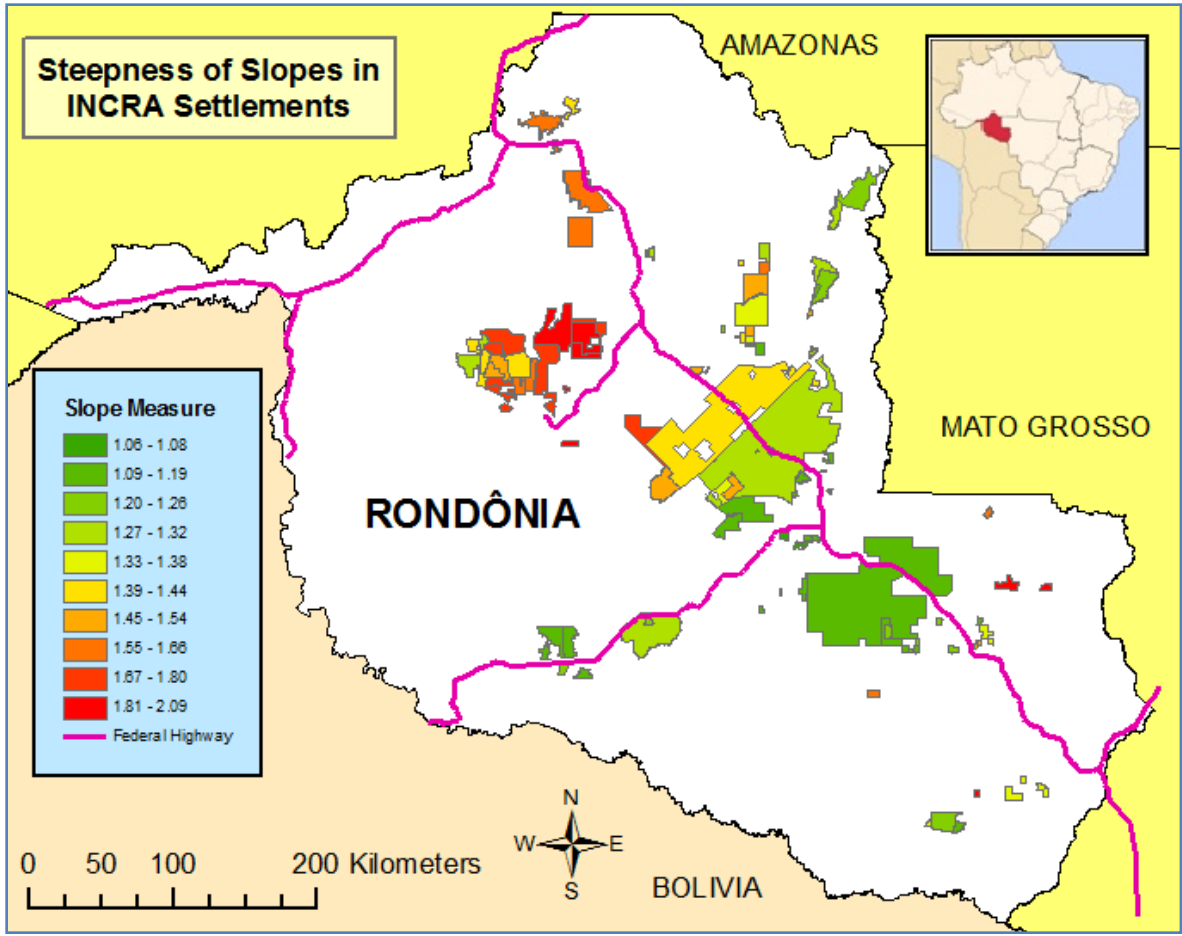
Map 14 - Settlements in the Study Sample Classified by Primary Forest Cover



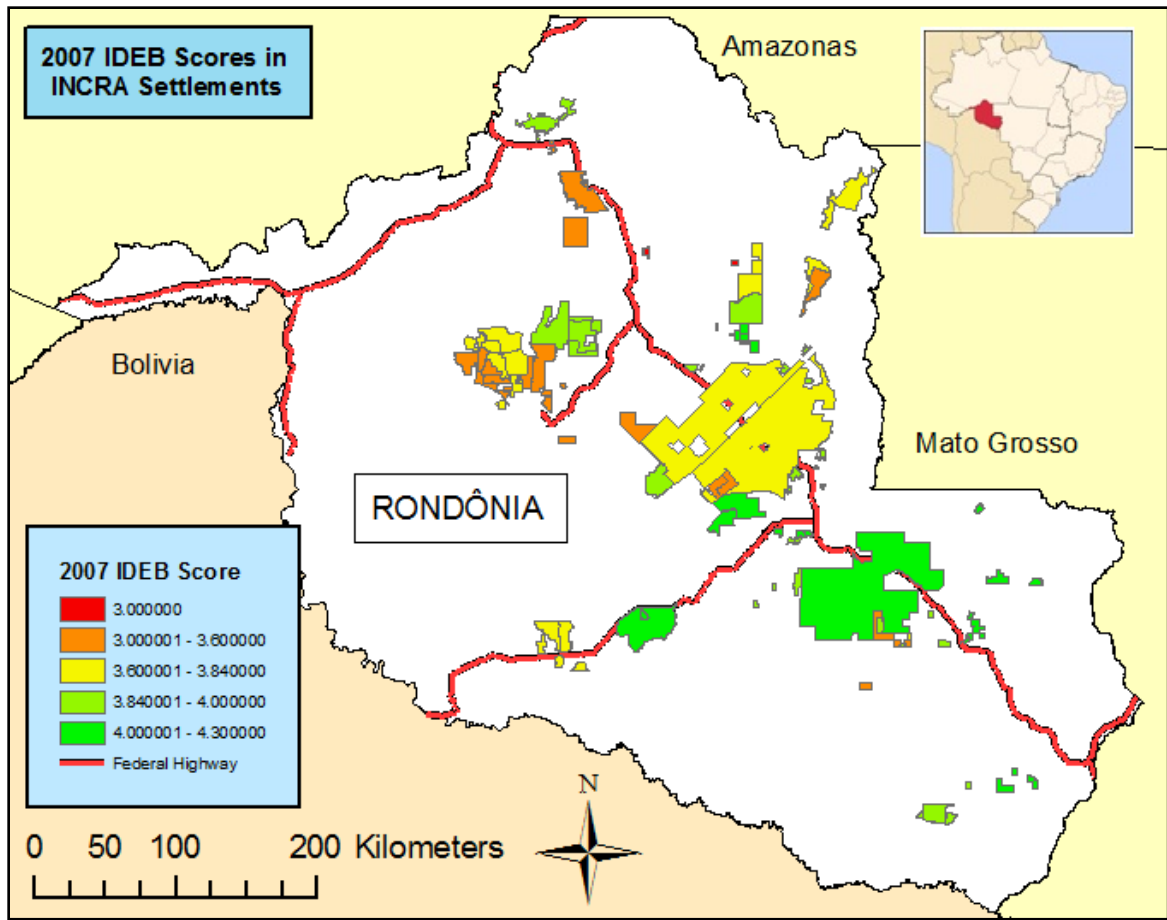
Map 15 - Settlements in the Study Sample Classified by Riparian Forest Cover



Map 16 - Settlements in the Study Sample Classified by Primary Riparian Forest Cover:
2007



Map 17- Settlements in the Study Sample Classified by Steepness of Slopes



Map 18 - Settlements in the Study Sample Classified by IDEB Scores

3. Work Script: Cost Distance Analyses

Create Layer For Slope and Reclassify

Spatial Analyst > Surface > Slope

Input: DEM –SRTM Data

Output: Slope

Spatial Analyst > Reclass > Reclassify

Input: Slope

Classes: 1 through 10

Output: Reclass_Slope

Create Layer for Landuse Including Road Network and Reclassify

Data Management Tools > Raster > Raster Dataset > Mosaic to New Raster

Input: Roads_rstr, Rondonia_2008

Output: lnd_use

Spatial Analyst > Reclass > Reclassify

Input: lnd_use

Classes: 1 through 4 for roads, 10 for the rest

Output: Reclass3

Create Cost Layer

Spatial Analyst > Math > Trigonometric > Plus

Inputs: Reclass_Slope, Reclass3

Output: cost2

Calculate Cost Distance for City

Spatial Analyst > Distance > Cost Distance

Input: feature location > federal highway OR city

Input: cost2

Output: cst_city

Calculate Cost Distance for Highway

Spatial Analyst > Distance > Cost Distance

Input: fed_hgwy

Input: cost2

Output:cst_hgwy

Analysis 2: Cost Distance Analysis of Education and Markets – Based Upon LandUse

Create Layer for Landuse Including Road Network and Reclassify

Data Management Tools > Raster > Raster Dataset > Mosaic to New Raster

Input: Roads_rstr, Rondonia_2008

Output: lnd_use

Spatial Analyst > Reclass > Reclassify

Input: lnd_use

Classes: 1 through 4 for roads, 10 for the rest

Output: Reclass3

Calculate Cost Distance for Education

Spatial Analyst > Distance > Cost Distance

Input: ro_2007_ensino

Input: Reclass3

Output:cst_edtn2

Calculate Cost Distance for Market

Spatial Analyst > Distance > Cost Distance

Input: fed_hgwy

Input: Reclass3

Output:cst_hgwy2

Analysis 3: Cost Distance Analysis of Education and Markets – Based Street Speed

Data Management > Fields > Add Field

Input: Roads_rstr

Field: Speed

Start Editing

Add speeds for each road type (100 for federal, 50 for highways, 20 for local highways and 100 for local roads)

Assign Travel time per cell in hmys
Spatial Analyst > Raster Calculator
Expression: roads_rcls = con(IsNull([roads_rstr]),5,[roads_rstr])

Spatial Analyst > Raster Calculator
Expression: str_trv = 0.018641 / roads_rcls

Calculate Cost Distance for Education

Spatial Analyst > Distance > Cost Distance
Input: ro_2007_ensino
Input: Roads_rcls
Output:cst_edtn23

Calculate Cost Distance for Market

Spatial Analyst > Distance > Cost Distance
Input: fed_hgwy
Input: Roads_rcls
Output:cst_hgwy3

Create Tables to Display Results

Spatial Analyst > Zonal > Zonal Statistics as Table
Input: cst_edctn
Output: cst_edctn1

Export Data as Text file

Spatial Analyst > Zonal > Zonal Statistics as Table
Input: cst_hgwy
Output: cst_hgwy1

Export Data as Text file

Spatial Analyst > Zonal > Zonal Statistics as Table
Input: cst_edctn
Output: cst_edctn2

Export Data as Text file

Spatial Analyst > Zonal > Zonal Statistics as Table
Input: cst_hgwy
Output: cst_hgwy2

Export Data as Text file

Spatial Analyst > Zonal > Zonal Statistics as Table
Input: cst_edctn
Output: cst_edctn3

Export Data as Text file

Spatial Analyst > Zonal > Zonal Statistics as Table
Input: cst_hgwy
Output: cst_hgwy3

Export Data as Text file

4. Multivariate Regressions: Forest Cover 2007⁷

OLS Multivariate Regression: Forest Cover 2007			
Sample of 84			
P Value		R-Square	
0.096		0.111	
Variable	Coefficient	P Value	N
Years Since First Cut (Age)	-0.00438	0.1559	84
	-	0.5951	
Access to Federal Highway	0.00069832		84
Steepness of Slope	0.05692	0.281	84
Parcel Size	0.00116	0.1997	84
	-	0.2612	
Definitive Land Title	0.00025866		84
Sample of 31			
P Value		R-Square	
0.6781		0.2381	
Variable	Coefficient	P Value	N
Years Since First Cut (Age)	0.00138	0.7794	31

⁷ The same inputs used in the multivariate regressions for riparian forest cover are used here

Access to Federal Highway	0.00005401	0.9833	31
Steepness of Slope	-0.05839	0.5598	31
	-	0.8765	
Parcel Size	0.00030809		31
Definitive Land Title	0.00005302	0.9302	31
Participation in Social Group	0.00169	0.1829	31
HDI: Income (2000)	0.17683	0.7903	31
Origin: North	0.00779	0.1121	31
Credit	0.00027637	0.7462	31

OLS Multivariate Regression: Primary Forest Cover 2007			
Sample of 84			
P Value		R-Square	
0.0085		0.177	
Variable	Coefficient	P Value	N
Years Since First Cut (Age)	-0.00038688	0.8689	84
Access to Federal Highway	-0.00091406	0.3633	84
Steepness of Slope	0.02241	0.5774	84
Parcel Size	0.00185	0.0086	84
Definitive Land Title	-0.00039783	0.0254	84

Sample of 31			
P Value		R-Square	
0.0634		0.4878	
Variable	Coefficient	P Value	N
Years Since First Cut (Age)	0.00761	0.0265	31
Access to Federal Highway	0.0001905	0.9103	31
Steepness of Slope	-0.02792	0.6697	31
Parcel Size	0.00145	0.2694	31
Definitive Land Title	-0.00046772	0.2456	31
Participation in Social Group	0.00163	0.0559	31
HDI: Income (2000)	0.11659	0.7889	31
Origin: North	0.00505	0.1155	31
Credit	0.00040116	0.4754	31

5. Additional Charts

Forest Figures Chart

Bivariate Correlations, P-Value, and Sample Size								
Age	Forest Cover: 2007	Primary Forest Cover: 2007	Riparian Forest Cover: 2007	Primary Riparian Forest Cover: 2007	% Change From Primary Forest: 2000-2007	% Change From Primary Forest: 1990-1999	Rate of Deforestation	Time to Half Forest
Years Since First Cut (Age)	-0.20679 0.0591 84	-0.05161 0.641 84	-0.12147 0.5151 31	0.02061 0.9124 31	-0.68935 <.0001 84	-.22235 .0421 84	-0.73587 <.0001 67	0.6825 4 57
Year of Settlement Creation	.176 .1093 84	.1723 .1164 84	-.06323 .1164 31	-.00062 .9973 31	.54816 <.0001 84	.05338 .6296 84	.36748 .0022 67	-.41781 .0012 57
Mean Deforestation Figures Classified by Age								
Year of First Cut (Age)	Forest Cover: 2007	Primary Forest Cover: 2007	Riparian Forest Cover: 2007	Primary Riparian Forest Cover: 2007	% Change From Primary Forest: 2000-2007	% Change From Primary Forest: 1990-1999	Rate of Deforestation	Time to Half Forest
1995-2002 N=31	0.4167	0.1992	0.4994	0.2345	0.4666	.4437	0.0518	7.6818
1985-1994 N=38	0.3928	0.2003	0.5046	0.2438	0.2811	.5629	0.0386	10.7917
1972-1984 N=21	0.3446	0.1877	0.4259	0.2124	0.1843	.3949	0.0335	13

* Yellow Highlight denotes significance at .20 confidence level using Pearson's Correlation

* Rates of deforestation classes were broken into even groups of 28

6. Agrarian Land Reform: Cause of Action

Taken together, several pieces of legislation lay the groundwork and legal framework for the establishment and practice of agrarian reform. Article 16 of the Land Statute of 1964 states that "land reform aims to establish a systematic relationship between humans, property and rural land use, capable of promoting social justice, progress and Welfare of rural workers and economic development of the country, with gradual extinction of very small farms and large estates." The Brazilian Constitution of 1988 in Article 5 guarantees the right to property subject to its social function (Brazilian Constitution). Together with the Lei Agrária (n° 8.629/93) and the Lei Complementar which defines the state right for expropriation, the legal basis for agrarian reform is established in Brazil

The dominant role INCRA plays today in the Amazon region is rooted in the history of land tenure in Brazil. The question of agrarian reform in Brazil dates back to 1530 and the system of hereditary rights by which large tracts of land were distributed by the Portuguese crown in return for one sixth of production (Hackbart 2009). In this system the entire territory was divided into stripes called *Captanias Hereditárias* which were distributed to the elite few who maintained close ties to the crown (Lambais 2008). Another land grant scheme was the *sesmarias* which gave large tract of land to colonizers following Portuguese military aims. After independence in 1822 conflicts arose between land owners and squatters back by armed militias which resulted in the Land Law of 1850 which reinforced the power of land

owners by outlawing squatting and making necessary cash payment for land rights (Hackbart). The founding of the Republic in 1889 and the abolition of slavery a year and a half later did little to improve the agrarian situation which continued to be dominated by large land owners. Not until the late 1950s and the military takeover of the government in the along with the industrialization of the country in the early 1960s, did this issue of land rights become addressed by society which was rapidly urbanizing.

In 1964 the military governmental regime took its first step in rectifying the land ownership gap by passing Lei nº 4.504 which amended the Estatuto da Terra and created the Brazilian Institute of Agrarian Reform (IBRA) and the National Institute of Agrarian Development (INDA), replacing the Superintendence of Agrarian Reform (SUPRA). In 1970, by Decreto nº 1.110 these two entities themselves were replaced, this time by the National Institute of Colonization and Agrarian Reform (INCRA), which remains to this day. Redemocratization in 1984 revitalized agrarian reform policies and the National Plan of Agrarian Reform was instituted in 1985 with the expressed goal of using 43 million hectares for the settlement of 1.4 million families by 1989. However, five years later after hardly a tenth of this lofty goal had been realized, INCRA was terminated, though brought back to existence 2 years later. After briefly falling under the guise of the Ministério Extraordinário de Política Fundiária, INCRA came under the control of the Ministério do Desenvolvimento Agrário (MDA) to which it remains to this day. Before moving on to discuss the dominant role INCRA has

played in the development of the Amazon region, and as such the development of my study area, the state of Rondônia, a brief history of the state will be given.

7. Master Correlation Sheet: Confounders and Confounders

	Years Since First Cut (Age)	Access to Federal Highway	Access to City	Steepness of Slope	Parcel Size	Definitive Land Title	Credit	Social Group	Govt. Cash Transfers
Definitive Land Title	0.5443	0.1626	0.1775	-0.0764	0.5732		0.1080	0.2843	0.15586
	<.0001	0.1256	0.096	0.4741	<.0001		0.5069	0.0753	0.3369
	93	90	89	90	93		40	40	40
Credit	0.1018	0.4449	0.240	-0.0044	-0.0639	0.1080		-0.0279	0.0441
	0.5316	0.0058	0.1515	0.979	0.6957	0.5069		0.8639	0.787
	40	37	37	37	40	40		40	40
Participation in Social Group	0.0831	0.0209	0.36641	0.1479	-0.1487	0.2843	-0.028		0.4144
	0.6102	0.902	0.0257	0.3823	0.3597	0.0753	0.8639		0.0078
	40	37	37	37	40	40	40		40