Capturing the Complexity of a Common in the Middle of an Amazonian Urban Area: integrating theoretical approaches and methodologies

M. C. Silva-Forsberg[1] and E. Brondizio[2]

Abstract

Studies showing the overuse of resources in Common- pool Resources - CPR along the World are crescent in the literature. Some studies have also shown successful institutional arrangement to govern them. The complexities encompassing CPRs are not trivial and the efforts to understand them are crucial. In this paper we seek to understand the CPR situations of a Native Forest Reserve in the middle of a highly populated urban area in the Amazon. This study combines and examines three sets of factors and assesses their usefulness in explaining causes of degradation in restricted-use reserves: edge effects, population pressure, and institutional failure. Given the multi-level complexity of restricted use reserves, each set of factors is assessed spatially and temporally. First, they are analyzed spatially, taking in consideration local and regional scales. Second, their historical development is followed. Third, we evaluate the relationship between these factors and the structural attributes of the forest using indicators such as species richness, biomass, and land-cover-changes, over time. Our results show that the biophysical characteristics of the forest are shaped by both local and regional level processes and cannot be explained by any set of factors alone. To conclude we offer some methodological insights on the integration of different approaches to assess this and other complex CPR situations.

Keywords: urban-commons; Amazon; conservation unit; forest system; complexity

INTROCUCTION

The growing awareness of global environmental problems such as tropical deforestation, global warming and loss of biodiversity has motived the creation of national parks and other protected conservation units all over the world, mostly in the last four decades (Guimire, 1994; Chade et al., 2003). Nowadays, most old growth forests are found in small patches around densely populated landscapes, or in national parks and biosphere reserves governed by national and international agencies. These reserves are designed to conserve the most

[1] Escola Normal Superior, Universidade do Amazonas. Av. Djalma Batista, 2470, Chapada. Manaus, Amazonas, Brasil. cforsberg04@yahoo.com, cforsberg@uea.edu.br

[2] Department of Anthropology, Indiana University. Student Building 130, Bloomington, IN, 47405, USA. ebrondiz@indiana.edu.

representative and relatively protected ecosystems in order to conserve endangered species, biodiversity and natural ecosystems. Most of the protected areas created during the 1970s and 1980s were reserves with various restricted human uses. National parks, natural monuments, nature conservation reserves and protected landscapes have the followings goals: (1) to maintain sample ecosystems in their natural state, (2) to maintain ecological diversity and environmental regulation, (3) to conserve genetic resources, and (4) to provide education, research and environmental monitoring.

Thus, it is expected that forest ecosystems managed for these goals would be conserved in its ecological integrity (Araujo, 2007), except for some changes caused by natural factors such as wind, lightning, storms or fires. According to the conservation literature, protected areas have, however, experienced severe environmental negative impacts on their natural attributes. Most of the deterioration has been attributed to human disturbances. Scholars dealing with conservation issues have used different approaches to understanding degradation in protected areas. Ecologists have focused on biophysical aspects of the reserves such as habitat fragmentation and edge effects (e.g., Lawrence, 1991, 1997) to explain the reserves' ecosystem impoverishment. Others, drawing on neo-Malthusian approaches, explain degradation through population pressure and inequality (Green & Sussman, 1990; Godway, 1997). Institutional failure and conflicts between indigenous people and conservation agencies (Acheson 2006; Guimire, 1994; Colchester, 1994) have also been cited by many social scientists. However, each of these three approaches alone explain just part of the problem.

The Campus Forest, a forest reserve located at the heart of the capital city of Manaus, Amazonas, Brazil, was selected in part because it offers an useful case that represents a conservation area as part of the rapid urbanization process that dominates many Latin America areas. The Campus Forest also represents a dynamic case where the existing population, new settlers, research and educational goals are active within a well-defined ecological and institutional landscape. This study helps to understand the dynamics of forest use in urban settings and their contribution to environmental education. In addition, it requires both the integration of methods across scales (remote sensing, archives, interviews, site inventories) and integration of theoretical approaches from several disciplines, including ecology, anthropology and demography and political science. Finally, it allows the testing and comparison of different conservation paradigms such as biophysical and institutional edge effects, land use and land cover changes, and forest restoration.

FOREST DEGRADATION IN PROTECTED AREAS: THREE MAIN APPROACHES

Many types of researchers are interested in forest degradation in protected areas. A great number of them have focused on one or more of three main explanations: i) fragmentation and ecological edge effects; ii) population pressure and inequality; and iii) institutional failure and conflicts between villagers and reserve managers.

Fragmentation and Edge Effects

Biologists concerned with forest ecosystems have been debating whether it is possible to preserve the world's biodiversity in forest patches surrounded by tree plantation or by agricultural, industrial, and urban development. Based on this discussion, the notion of an ideal restricted reserve size to protect biodiversity has been growing throughout this century. Conservation biologists point to the need for large reserve to conserve all native species characteristic of an area (Shafer, 1995). The debate about the minimal size of reserves has been one of the "hottest" in the conservation realm and has been concentrated in the "Single large or several small" (SLOSS) reserve debate (Lovejoy, 1997). However, most discussion has focused on the needs of single species especially large vertebrates.

The edge effect model has thus been offered to explain ecosystem decay (degradation) in forest fragments, by affecting the species' richness and other structural attributes of the ecosystem. Changes in species richness are associated with the tolerance of species to habitat and micro-climatic changes occurring within fragments or along the ecosystem's margins. It is predicted that small fragments should lose many species because they have the highest perimeter-area ratios and mostly habitat edges, while large fragments should gain many species because their main areas are large enough to support original species plus the tolerant species which would colonize the perimeter edge habitats (Wilcove, McClennan, and Dobson, 1986; Laurance, 1991; Malcon, 1994).

Studies have shown that forest fragment edges are more exposed to differences in solar radiation, water, wind, and nutrient regime than continuous forest, thus tree falls and canopy openness increase close to the edges (Laurance, 1991, 1997; Kapos et al., 1997). In the Central Amazon, Laurance et al. (1997:1118) showed that permanent study plots within 100 meters of newly fragmented edges lost more than 30% of their biomass in the first 10 to 17 years after isolation. They predict it is unlikely that forest edges will return to their original condition, because fragmented forest is prone to wind disturbance, which can often kill and damage many trees. Thus, in the presence of fragmentation processes, old-growth rain forests tend to be replaced by shorter, scrubby forests with smaller volume and biomass. Laurance (1997) also reports strong edge effects on forest structure for two very disturbed parks in Australia.

Thus ecologists mostly approach forest reserve degradation issues primarily by looking at the physical and biological aspects of the reserves. Forest fragment size, shape, degree of isolation, location, context, and habitat heterogeneity are the principal factors being analyzed and used to explain degradation and ecological decline in protected areas. Those factors are often used to evaluate animal and plant persistence, community composition and ecosystem processes in forest fragments. A considerable number of these scholars have agreed that species richness declines as a fragment area decrease (e.g. Laurance et al. 1997). The size of a habitat fragment influences the processes occurring therein due to the changes caused by habitat edges that experienced shifts in micro-climatic attributes. Adjacent habitat types, land management regimes, and intensity of human activities are also known and cited by ecologists to have an influence on fragments (Laurance & Gascon, 1997), but ecologists do not go further than the analysis of the permeability of forest fragments' boundaries. Hence, ecologists´ work concerning forest reserve degradation in general do not consider fully the effect of anthropogenic factors in and around those areas.

Population Pressure, Inequality and Human Impacts

In developing countries, population pressure, poverty and inequality are the most cited causes of deforestation and forest degradation, even inside protected areas. Green and Sussman (1990), using Landsat images, showed active deforestation fronts cutting into several Madagascar Natural Reserves. The discussion of whether population growth causes environmental degradation has been discussed by the followers of the historical theoretical tradition associated with Malthus (Ehrlich, 1968; Ehrlich & Holdren, 1971, 1974,1992; see also reviews of Sherbinin,1993; and Marquette, 1994) and Boserup (Simon, 1981, 1990; Harrison, 1990), even though neither Malthus nor Boserup were concerned with environmental degradation *per se.*

The so-called neo-Malthusians point to population pressure and inequality as the "enemies" of forest conservation, a perspective which has been challenged by comparative studies (Lambin et al 2001). Many scholars using neo-Malthusian theories have approached the degradation in reserves by considering population growth and socio-economics status to be the main driving forces. The observed linkages between human activities and forest degradation, however, vary according to context and level of analysis. Several statistical analyses at the national level showed a negative significant relationship between population growth and deforestation (Allen & Barnes, 1985; Rudel, 1989, Turner, 1998).

At the regional level, however, factors such as type and size of forest, types of settlement, distribution and density of urban areas, policies and government incentives seem to be stronger determinants (Schmink, 1988; Wood & Schmink, 1993; Rudel, 1993; Wood & Skole, 1998; Turner, 1998). At the local level, household composition, ethnicity, age of settlements, quality of soils, residents' affluence and institutional arrangements are important factors in either driving forest degradation or in preventing it (Brondizio et al 2009; Pichon et al. 1993; Rudel, 1993; Varughese, 1998). Given that the size of national parks and other restricted use reserves vary from several hundreds to millions of hectares, the local and regional level of analysis should be considered when evaluating the status of conservation.

Institutional Failure and Conflict between Local People and Conservation Officers

Two factors related to the creation, establishment and management of restricted reserves have also been studied to understand the underlying causes of degradation in forested reserves: institutional failure and conflict between people and park managers. Failure of institutions in implementing environmental protection programs in terms of technical, administrative and financial constraints are the most widely cited problems. They are related to the size of the budget and to the limitations on the quality and quantity of human resources to patrol and administer protected areas (Peres & Terborgh, 1994; Fearnside & Ferreira, 1985; Dourojeanni and Padua, 2007).

Conflicts between people and parks managers have also been used to explain reserve resource degradation. These conflicts are primarily due to the lack of compensation to local people who have lost their homes or means for livelihood in the process of creating protected areas (Ghimire, 1994). The expansion of protected areas has concentrated land control in government hands. In general, areas designed to become restricted reserves are or were inhabited by local residents who often have their own kind of resource management and institutional arrangement (West et al 2006).

Conflicts between local populations and conservation officers have been well-documented (e.g. Ghimire, 1994; Colchester, 1994; Capobianco, 1995). Most of these studies conclude that conflicts between conservation agencies and indigenous people have made protected areas unmanageable. However, the majority of studies looking at both the effects of institutional failure and conflicts between people and park managers do not show the direct linkages between these two variables and degradation in forest reserves.

Protected areas such as national parks and natural reserves, in general forest ecosystems, are defined by institutional analysts as common-pool resources (CPR), where excluding users is difficult (but not impossible) and the yield of the resource system is subtractable (Ostrom & Ostrom 1977; Ostrom et al., 1994). Conceptualizing restricted-use reserve ecosystems as CPR helps in understanding the dilemma of protecting reserves and its possible solutions.

The term CPR refers to the physical qualities of the natural resource systems and the social institutions that human beings have attached to them. Two traits define CPR: (1) exclusion problems-- it is costly to develop physical or institutional means to exclude potential beneficiaries from them. Without institutional mechanisms to exclude non-contributing beneficiaries from CPRs, they become essentially open-access resources; (2) subtractability-- the units harvested by one individual are not available to others. They are subtractable or rivalrous in consumption, and can be degraded (Ostrom et al., 1994; Ostrom et al., 1999). The difficulty of excluding beneficiaries and the extractability of resource units thus create CPR dilemmas. When CPR users interact without establishing a set of rules to limit access and define rights and duties, two forms of free-riding are expected: (1) overexploitation, and (2) lack of provision or supply for maintaining and improving the CPR itself.

The effective capability to monitor, sanction and arbitrate property right rules in regard to the use of common-pool resources has been considered essential to accomplish long-term CPR sustainability. Ostrom (1990) summarized a set of design principles that characterize robust institutions with which individuals using CPR have overcome "the tragedy of the commons" and achieved long-term resource management. It assumes that where individuals create rules that can solve appropriation and provision problems related to the use of CPR, successful governance of forest resources will be reached. These rules include: (1) boundary rules that limit who can use, for example, a forest; (2) authority and scope rules that specify how much of what type of forest product can be extracted; (3) authority rules that empower monitoring, sanctioning, and arbitration. Thus, protected areas where agencies do not have ways to monitor boundaries or to solve conflict-resolution problems with villagers in regard to resource use are unlikely to reach sustainable resource management.

Nevertheless, when agencies invest a great amount of resources in reserve monitoring through policing and punishment, they can restrict non-allowed users from the core area of the reserves, but, in general, intense patrolling causes edge effects. Albers and Grinspoon (1997) analyzed the effect of enforcement of access restriction in the Khao Yai National Park-KYNP (Thailand) where managers use policing and punishment mechanisms to deter resource use. They concluded that the KYNP's policing and punishment policy has successfully deterred extraction from the central core of the park, but the policy has not prevented extraction in the outer regions of the park, and has also induced villagers to undertake socially-costly avoidance activities to reduce the chance of being caught.

Institutional failure and conflict between park managers and local villages can indeed be good indicators of unsuccessful management strategies and, consequently degradation of forest in reserves. However, the majority of studies do not show the direct linkages between these two variables and degradation on the forest reserves. Given the complexity involving restricted-use reserves, the linkages between forest degradation and institutional failure, and conflicts between local populations and park managers need to be analyzed based on historical, geographical, economic, political, cultural and social contexts (Acheson 2006). In summary, the potential and intensity of conflicts will depend on the attitudes of the residents related to reserves which can vary among communities and also within a community, depending on residents' attributes such as age, affluence, knowledge about parks, level of education and relation with reserve staff.

RESEARCH DESIGN AND DATA COLLECTION

We combine and examine these three sets of factors to assess their usefulness in explaining causes of degradation in restricted-use reserves: edge effects, population pressure, and institutional failure. Given the multilevel complexity of restricted-use reserves, each approach is assessed spatially and temporally. First, edge effects, population pressure and institutional arrangement are analyzed spatially, taking into consideration local and regional scale. Second, their historical context is followed over time. Thus this study adopts both an interdisciplinary framework and integrates a set of methodological tools to examine the long term degree of conservation of a forest reserve. It evaluates the relationships between physical, biological, historical, social, economic and institutional factors and the structural attributes of the forest using indicators such as species richness, biomass and land cover changes at three time points and over time[3].

In this study, the land use dynamics around the reserve are analyzed over time (1977-1995), taking into consideration the demographic transition driven by industrialization and urbanization of Manaus and its indirect effect on the reserve. Since such attributes of the communities as population size and density, affluence, origin, cultural background, and household structure are important variables in how people use forest products, they are examined here to evaluate outcome on the forest's structural attributes. As cited earlier, enforcement of rules that govern a forest also directly affects its conservation. The creation and evolution of the rules in managing the forest reserve are throughly analyzed and integrated to evaluate the preservation of the reserve, as well as the performance of the agency in charge of its governance.

The Campus Forest of the Federal University of Amazonas was selected as "the case study" to test three hypotheses derived from the theoretical approaches discussed above. Because it experienced problems common to tropical restricted use reserves during its creation, establishment, and management, the Campus Forest is a useful empirical case to be studied. Studying the historical development of this reserve will also contribute to a better understanding of the dilemma of protecting national parks and other restricted use reserves in tropical regions.

With the creation of Campus Forest as a forest reserve in the beginning of the 1970s, the University faced problems with former landowners upon acquiring control of the area. During the same decade, the Manaus area where the forest reserve is located, experienced fast demographic changes due to industrialization and urbanization that resulted in invasions of Manaus' rural and semi peri-urban forested lands, including the Campus Forest area. The land invasion process continued to cause conflicts between settlers and reserve officers for at least 5 years. In addition to the forested land lost due to invasions, the areas surrounding the reserve were deforested during the last two decades, transforming it into a forest fragment. Neighborhoods of different socio-economic status were established, thus increasing the number of potential users of the forest. A management plan was designed and partially implemented by the University of Amazonas to conserve the area, but it always faced budget problems, which influenced its ability to control the entrance of

---

[3] We draw on the Institutional Analysis and Development – IAD framework. This framework is a useful general analytical tool for helping to understand the queries undertaken in this study because it integrates three basics elements: attributes of the physical world, attributes of community, and rules-in-use. By identifying and analyzing how attributes of the physical world interact with those of the general cultural setting and with specific rules which govern a specific situation, the IAD framework is an essential tool on helping to examine the theoretical approaches used in this study. The IAD framework has been used by social scientists to analyze a variety of questions. One among them is how rules affect the behavior and outcomes achieved by individuals using CPRs (Ostrom, Garden & Walker, 1994).

outsiders into the forest. As is common in most tropical forest reserves, the Campus Forest officers also claimed that the forest was degrading because of the unallowed use of the forest products by neighboring residents.

The Hypotheses

Three hypotheses related to each set of factors described above are used to explain forest degradation (biophysical edge effects; population pressure and inequality; and institutional failure and conflicts between reserves managers and villagers) are tested separately using Campus Forest data:

H1- Forest degradation is caused by edge effects resulting from fragmentation: a substantial number ecologists argue that when forests are cut the remaining fragments are affected by wind and other edge effects. Thus, forest structure attributes such as stand height and basal area will be poorer closer to the edges.

H2 - Forest degradation is a result of population pressure and inequality: forests located near or around densely populated areas and areas experiencing high population growth will be cleared or overused by people living near them, especially in areas of low income and higher dependency on forest products.

H3 - Forest degradation is a result of institutional failure: this hypothesis argues that institutions which do not develop a set of rules and measures to manage, control, and sanction inappropriate forest use will transform a protected area into an open access one and create conditions similar to the "tragedy of the commons" will take place. Thus, forest degradation will be a function of both internal and external variables such as uncoordinated land use decisions by the different agencies' and the attributes of the human communities that live surrounding the protected area.

Predictors and indicators used to test hypotheses

Biomass decay on the edges : the traditional edge effect model predicts ecological decay on the edges of recently fragmented forests due to biophysical factors. For the Central Amazon, it is expected that forest fragments within 100 meters of newly fragmented edges will lose, at least 30% of their biomass in the first 10 to 17 years after isolation (Laurance et al., 1997). Mature forests around Manaus present an average basal area (BA) of around 35 m^2/ha. Thus, according to the biophysical edge effect model, the earlier the isolation period, the lower be the basal area found in forest plots close to the forest edges.

Social and institutional factors also have edge effects on forest attributes (institutional edge effects). Forest reserves surrounded by populated areas are more prone to the use of outsiders. When agencies invest in policing and punishment policies to protect reserves, outside users will undertake socially-costly avoidance activities to reduce the chance of being caught by extracting products mostly from the outer regions of the forest (Albers & Grinspoon, 1997). Hence, if people use the forest for consumptive purposes and reserve patrolling is effective at its core, the biomass will be lower closer to the borders of the forest.

The attributes of the household and the communities also influence people's behavior in regard to the use of the forest. Depending on their needs and preferences, residents can use the forest for consumptive and non-consumptive uses. Consumptive uses are expected to contribute to forest degradation much more than non-consumptive uses. Thus, if the residents use the forest for consumptive uses and the forest agency does not control outsiders' access, residents will not only use the borders but also all areas of easy access, for example, along trails, and other non-forested areas where it is easy to extract forest products. There are several trails of 1-4 meters wide around the campus which would probably be minimally affected by biophysical effects but which present a network access for forest users. Thus, one should expect to find lower biomass closer to the non-forested areas located near the neighborhoods.

<u>Land cover change over time:</u> ground based data from forest surveys such as basal area, height and species richness are reliable indicators to evaluate the ecological conditions of a forest. But they can show only what is happening in ecosystems at one point on time. To evaluate the temporal dynamic of a forest, it is necessary to take measurements over time (Laurance et al., 1997), and/or use a combination of ground indicators with remote sensing, and other socio-economic data. Remote sensing images of both MultiSpectral Scanner (MSS) and Thematic Mapper (TM) sensors provide multi-spectral data to analyze land cover change over time. Even with the limitations of MSS imagery (e.g., Moran et al., 1994; Mausel et al., 1994), this lower resolution satellite instrument can provide useful data to evaluate changes on the forest biomass, showing when a patch of forest changes to a clear area or to secondary succession and vice-versa.

Data collection strategy

Given the complexity and interdisciplinary nature of the theoretical and methodological approaches used in this paper, the collection of data and information for this study followed a combination of strategies. First, the methodology of the International Forestry Resources and Institution (IFRI), a research program coordinated at the time of this research by the Workshop of Political Theory and Policy Analysis and Center for the Study of Institutions, Populations, and Environmental Change (CIPEC) at Indiana University Bloomington, was used. IFRI methodology collects information about different types of biological and sociological entities, cataloging data about trees, sapling, ground cover, and soils, as well as forest user groups and products and rules that are used by these groups. The information required by IFRI methodology was mostly collected in the summer of 1996 when 61 forest randomly collected plots were measured around all Campus forest area. In that season, the social organization and history of each of the surrounding settlement was also completed by interviewing elder residents, leaders of local associations and other residents. A copy of the 1991 census data was obtained from the State Communication company (TELAMAZON) through the University of Amazonas.

A map covering the entire study site was obtained from Brazilian Census Bureau (IBGE) (1:5,000), and several thematic maps of the campus area were obtained at the University of Amazonas (e.g., topographic map, vegetation classification map, construction planning map, and a land use map). Three satellite images (MSS of 1977 and Landsat TM of 1988, 1995) were obtained. A 1-hour flight was made covering the study site on June 21, 1996. The study area was videotaped and aerial photographs were taken.

During the summer of 1997, 10 additional more IFRI forest plots were measured and the University of Amazonas archives were explored to obtain historical information about the creation, development and current status of the governance of the Campus Forest. During this visit, over 30 interviews were conducted with Campus Forest officials including officers, professors and forest guards. The forest guards' patrolling routine was followed twice to observe their behavior and attitudes during their activities. A household survey was also undertaken in two neighborhoods to evaluate residents' behavior in regard to the forest reserve.

To address the questions and hypotheses raised in this study, we considered the multiple factors which could influence forest attributes such as different types of vegetation, different age of fragmentation around the Campus Forest limits, and socioeconomic aspects of the neighborhoods and its locations, as well as the distribution of triails and roads around the forest. Thus the data analysis was based on the spatial experimental design (Figure 1), dividing the area in different forest sectors. We divided the area in Sectors between the Campus main road and the limits of neighborhoods that were fragmented in different periods, as followed: sector I- Acariquara (15 years), II- Nova Republica (10 years), III- Ouro Verde (4 years) and IV- Coroado (25 years). Also, we divided the area drew the lines among according to different types of vegetation, Vz (vegetation zone): 1. Dense forest, 2. Secondary forest, and 3. Campinarana.

CAPTURING COMPLEXITY: HISTORY AND LAND COVER AND USE CHANGE ON THE AREA

Land cover change in Manaus from 1977 to 1995: The regional remote sensing analysis

Manaus underwent rapid demographic, industrial, and infrastructure changes since the creation of its 'free trade/indtustrial zone in 1967. The rapid demographic changes in Manaus under the Zona Franca Era related to both the industrial installation plants and urban services drastically modified the city landscape. The dramatic change on the land cover traced by remote sensing analysis using three image dates (Landsat MSS 1977, TM 1988 and 1995), is reported on Table 1. Even though rapid changes started to occur in the late 1960's, by 1977 the urban area of Manaus was concentrated in a rectangle which was about 5 by 20 km in size along the east side of the Rio Negro. At that time, the urban area covered 6,434 hectares representing 7.9% (Table 1) of the

Manaus uplands selected for this analysis. In 1977, the Campus Forest and the Reserva Ducke still were part of the same continuous forest patch.

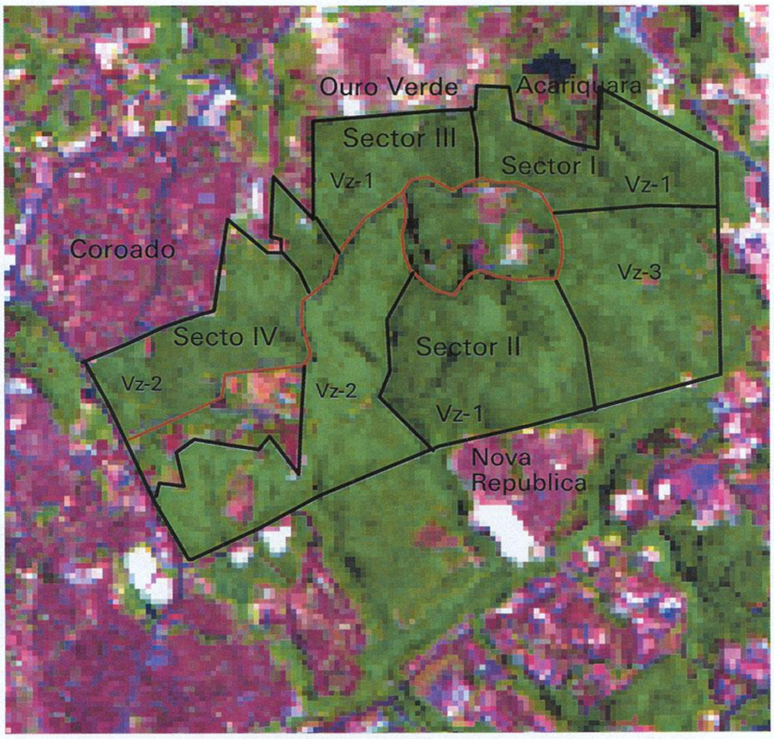

Figure 1. Spatial distribution of the Campus Forest Sectors located between the campus mainroad and neighborhoods: I. Acariquara (15 years), II. Nova Republica (10 years), III. Ouro Verde (4 years), and IV. Coroado (25 years). Vz (vegetation zone) 1. DF- dense forest, 2. SS- secondary succession, and 3. CC- campinarana. Lansat TM RGB, 345 composite.

In the short span of a decade (1977-1988), however, deforestation reached 10.7% of the Manaus area (Table 1). This situation, dramatically increased the size of the city. The core urban area of Manaus increased more than two-fold from 6,434 to 15,525 hectares (Table 1). Forest degradation which describes the changes from forest to early secondary succession also represented land cover change during that decade. An amount of 7,047 hectares of forest was cut down and began to regrowth during 1977-88 (Table 1). By considering the two land cover change processes together, we estimate that around 19% of the Manaus forest area was cut down to make space for urban expansion and to provide raw material for house construction. But, it is also important to note that afforestation and regrowth occurred during that period as well.

Nevertheless, these processes only account for 5% of the land cover change in the area (Table 1). Land cover change in Manaus between 1977-1988 occurred almost totally on the west side of the city where Cidade Nova, Sao Jose I, II, and III were established, just to cite a few of the neighborhoods created in that period. Besides deforestation and forest degradation, another process evident on the west part of the city was forest fragmentation which almost isolated the Campus Forest. The Campus Forest and Reserva Ducke which were part of just one forest corridor became totally separated. The Campus Forest was basically transformed into an urban forest fragment but for 2 or 3 small forest buffer areas. By 1988, the boundaries of the Reserva Ducke also became to be more easily visualized through remote sensing images. Thus, during the decade of 1977-88, the urbanization process in Manaus not only transformed the Campus Forest into an urban forest fragment, but also started to transform the Reserva Ducke into a peri-urban forest reserve.

During the next seven years, 1988-1995, deforestation in Manaus followed the same trend as earlier in the decade reaching 8.5% (Table 1). More than seven thousands hectares of forest were cleared. Still, the forest area experiencing

Table 1- Distribution of land cover change processes in Manaus, 1977-1988-1995.

	1977-1988			1988-1995
Process of Change	ha	%	Ha	%
Deforestation	9043.54	10.7	7130.34	8.5
Degradation	7047.45	8.8	2176.29	2.6
Afforestation	2850.3	3.4	6898.9	8.2
Regrowth	1390.4	1.6	2407.8	2.8
Drying	1479.2	1.7	1221.5	1.4
Flooding	237.9	0.3	187.7	0.2
In forest	44504.2	52.9	42163.4	50.1
In water	8148.1	9.7	7164.6	8.5
In ss	3803.8	4.5	3326.5	3.9
In urban	5667.3	6.7	11395.5	13.5
Total	84172.3	100	84072.6	100

forest degradation was much smaller than that of the earlier decade. While during 1977-1988 deforestation and forest degradation affected around 19% of the Manaus forest area, from 1988 to 1995 these two processes together explained only 11 % of its land cover change. However, afforestation was as high as deforestation in Manaus during that same period.

Around 6,898 (8.2%) hectares of land returned to forest, and 2,407 (2.9%) hectares turned into early secondary succession. Afforestation and forest regrowth also explain 11.1% of the land cover change in Manaus during 1988-1995 period. As a whole, we can say that afforestation and forest regrowth compensated for forest lost due to deforestation and forest degradation. However, it is important to analyze the spatial distribution of these processes and the consolidation of the urban core area of Manaus.

Most of the area deforested from 1988-95 was located in the now central part of Manaus and also on its west side between the Campus Forest and Reserva Ducke. This process expanded the urban core area from 15,525.63 hectares in 1988 to 23,703.84 in 1995 (see Table 1). Most of the afforestation and forest regrowth happened in the peri-urban area of Manaus located mostly on the east side of Reserva Ducke.

By 1995 the Manaus core urban area was delimited from the banks of Rio Negro to the Eduardo Gomes airport and south side of Reserva Ducke except for the forest fragments close to the Rio Puruquequara. During that 17-year period (1977-1995) a significant amount of primary forest was cut down to open space to urban facilities in Manaus. The fast urbanization process not only cleared a large amount of forest around the Manaus peri-urban area as one can see through the remote sensing images, but it was responsible for clearing small forest patches and tree cover which were distributed around downtown Manaus.

BIOPHYSICAL AND INSTITUTIONAL EDGE EFFECTS OF FOREST FRAGMENTATION

<u>Biophysical Edge effects</u>: the relationship between basal area and distance from both the mainroad and from outside borders in the three vegetation zones are given in Table 2. These indicate that the basal area in the three types of vegetation do not depend on distance from both the main road and the outside border, even within the first 100 meters. Since the outside borders experienced different timing of isolation, or non–isolation such as at the campinarana limits, the results are not surprising. Even though both dense forest and campinarana were isolated by the Campus mainroad, the forest plots measured close to these two types of forest did not show any influence of distance from the road edge on the basal area.

The relationship between basal area and distance from both the mainroad and from outside borders in the four forest fragment sectors are also given in Table 2. These results indicate that only in sector I- Acariquara, where the outside border was isolated 15 years ago, its basal area was influenced by the distance from both forest edges.

Table 2. Regression on basal area and distance from both the Campus Forest main road and the outside border (*Statistical significant at the 0.05; SS-OD= secondary succession of dense forest, OD- dense forest, CC= campinarana)

Basal Area (m²/ha)							
Independent variable (distance from the main road [m]				Independent variable (distance from outside border [m]			
	R^2	p	n		R^2	p	n
SS-OD	0.01	0.62	15	SS-OD	0.00	0.81	15
OD	0.00	0.56	36	OD	0.02	0.34	36
CC	0.10	0.17	19	CC	0.12	0.14	19
Sector I	0.70	0.01	7*	Sector I	0.62	0.03	7*
Sector II	0.11	0.15	20	Sector II	0.12	0.11	20
Sector III	0.00	0.98	11	Sector III	0.00	0.95	11
Sector IV	0.00	0.96	8	Sector IV	0.09	0.44	8

The relationship is statistically significant, with distance from the mainroad explaining 70%, and distance from the outside border 62 %, of the basal area variance. However, basal area is higher when close to the road edge than inside of the forest, showing an opposite trend to what is predicted by the edge effect model. In this sector, edge effects do not seem to have a negative influence on the forest biomass in the way that basal area decreases progressively toward the forest core area. Nevertheless, it is difficult to justify this trend due to biophysical edge factors. However, soil is probably one of the physical factors that could influence the biomass distribution related to distance in this sector. The Acariquara sector shares borders with campinarana forest on white sand soils. White sand (Spodosols) is the poorest soil type in the Amazon, and forests on this type of soil present, in general, lower biomass than dense forests.

Acariquara's proximity to Ouro Verde is another factor that may affect basal area distribution in the Acariquara sector. Residents from these two neighborhoods have behaved differently in regard to the Campus Forest. Acariquara is a middle class neighborhood where residents are very concerned with forest conservation, particularly within the campus. In the last 7 years, not only have Acariquara residents organized environmental education program involving their children, but also their security guards have watched the forest borders that they share with the campus. One of the Acariquara residents´ concern was the presence of Ouro Verde residents collecting products in the forest.

Ouro Verde is a neighborhood created through land invasion in 1992. Ouro Verde residents formerly gathered forest products from the campus, mostly during the neighborhood establishment period. However, Ouro Verde residents may also gather forest products around the Acariquara sector. However, given the presence of Acariquara residents and security guards, they do not use the forest close to the Acariquara border, or close to the campus main road, where students, staff, professors and guards often circulate. However, they would probably use trail network to gather forest products in the forest sector core areas. This strategy reduces the probability of being observed by a guard.

Institutional Edge Effects : no relationship between land cover and distance from the edges was detected in the remote sensing analysis during the period of 1977-1988-1995. Secondary succession is distributed in patches around the Mini-campus and some in the campinarana area instead of being located along the edges. From 1977-1988, the spatial distribution of the land cover changes shows forest changes inside the campus areas and several pixels with land cover changes on the borders mostly on the north side. However, changes on the borders are not consistently associated with degradation (i.e., changes from forest to secondary succession). Instead of degradation, land cover change analysis shows a progressive afforestation around the whole Campus Forest area (Table 3). Deforestation occurred when campus buildings and other services were installed.

Table 3. Distribution of the three upland cover classes in Campus Forest, 1977, 1988 and 1995

Classes	1977			1988			1995		
	pixels	HA	%	pixels	HA	%	pixels	HA	%
forest	4751	427.6	81.5	4500	405	77.2	5097	458.7	87.5
ss	805	72.4	13.8	866	77.9	14.9	275	24.7	4.7
urban	270	24.3	4.6	460	41.4	7.9	454	40.9	7.8
total		524.3	100	5826	524.3	100	5826	524.3	100

Land use and land cover change in the Campus Forest

In the beginning of the 1970s, the Campus lost 119 hectares of forest caused by the Coroado invasion. According to Campus Forest officers, since that invasion, the Campus Forest has been in a progressively degrading process. Instead, analysis of land cover over time shows a different trend. In 1977, 81.5 % of the Campus Forest was covered by forest, 13.8 % by secondary succession, and 4.6 % by cleared areas (urban) (Table 3). Even though 65 hectares of the forest were cleared by the University of Amazonas to build its main road, the main campus buildings, and also the Agronomy School training area, the level of afforestation and regrowth increased substantially in the same period, reaching more than 50 hectares. In the last period, 1988-1995, the afforestation area was three times larger than the deforested area, showing a high level of forest recovery instead of progressive forest degradation. In 1995, instead of having less area covered by forest due to campus infrastructure expansion, which covered 3% the Campus Forest, more area was covered by forest than in 1977, increasing the area covered by forest by around 6% (Table 3).

In contrast to both biophysical and institutional edge effect models and the reports of Campus Forest officers, the area has been progressively gaining biomass instead of being degraded around the edges, since 1977. It was not possible to show any influence of biophysical and institutional edge effects on its attributes by using indicators such as basal area and land cover changes over time. Therefore, do these results mean that the University is successfully managing and monitoring the Campus Forest? Are the communities around the campus forest not using the consumptive forest products? How can we explain the ecological recovery in the Campus Forest under different internal and external pressures?

Governance and Institutional Arrangements in the Campus Forest

Looking at the current level of monitoring and enforcement of rules that governed the Campus Forest, one may think that it is almost an “open access area”. The University of Amazonas does have formal rules to regulate the use of forest products. Trees, herbs, and animals can be collected only for scientific or educational purposes, although there is no systematic monitoring of those forms of use. The Campus Forest is sporadically patrolled by the Security Department (Departamento de Vigilância) of the University.

Even though the Campus Forest is accessible only to University users, people from outside have also used the forest in several ways such as getting water, opening and using soccer fields, and for recreation and appreciation of nature. These uses are informally allowed, whereas collecting vegetation products and hunting are not. However, no sanctions exist for people who do not follow these rules.

Since 1996, the area has been patrolled twice a week, only during daylight hours, by six guards. The guards are divided into two teams of three men. Each team leaves the main entrance at around 8:00 a.m. and walks in different directions, always following a large trail on the external limits of the campus. They arrive back at the principal entrance between 4-5 pm. If a guard meets a person cutting a tree or hunting, he must act as an educator, trying to convince that person to preserve the forest by not collecting products. The maximum penalty the guards can apply is to confiscate the product and expel the poacher. In the past, there were cases where guards took guns, but this is always a dangerous situation.

Given these circumstances, why is the campus as a whole not only maintaining its ecological attributes but also recovering its biomass through afforestation? It is counter intuitive since the forest is located in a very populated region and does not have a strong enforcement system to prevent the forest from being used by outsiders. It is important, however, to know the history of the creation and establishment of that reserve as well as its relationship with those who live around it in order to explain this trend.

CREATION AND EVOLUTION OF INSTITUTIONAL ARRANGEMENTS GOVERNING THE CAMPUS FOREST

Invasion and the Institutional Establishment, 1968-1975.

The University of Amazonas Foudation bought the campus land in1968 when Manaus was starting to become a frontier area.The main goal of the University was to have a campus where all academic units could be close to their respective training sites around an Amazon native forest that could also be used for scientific and educational purposes. At that time, the Campus Forest was located in a peri-urban region and the university could have the legal right to the whole area only after a legal process of seven years. Before any of its infrastructure could be built or its borders delimited, part of the land was invaded by squatters on its north side (Sector IV- Coroado). The demographic changes in Manaus and the process of invasion were so rapid in the beginning of the 1970s that the University did not have the structure and coordination to expel people from the area. Thus, the Campus Forest institutional arrangement was created and established within two different processes: 1) conflict with squatters to control the land invasion, and 2) hard negotiation with some of the small landowners who were resistant to the idea of selling and leaving their land.

The land invasion started in the northeast corner of the campus and spread to other areas in three waves, creating the current Coroado I, II and III. From the original 800 hectares bought by the University, 119 were invaded. Until 1973, the University had just four guards to control the land invasion. By 1974, the security department was created and the number of guards increased to 25 and others were progressively hired. The security department was organized by an army lieutenant. In that time the country was ruled by the military. Those guards tried to control the invasion with the help of the State Police and the Army on several occasions. During 1974 and 1975, the campus area closer to the invaded area was intensively patrolled and fences were repaired almost daily.

By 1975, a street was opened around the Campus Forest to help the patrolling effort. At that time around 80 guards composed the security unit. Each guard was trained in four basic points: how to use a gun, how to approach and identify a person in the campus area, how to take care of the forest patrimony, and how to make an arrest. The guards had orders to arrest any non-allowed person found around the area. The security department spelled out a set of rules about the use of the forest to guide the guards and other University employees. No forest product could be taken from the campus, including sand and water. In the case of a stranger being caught inside the area, the product and the gun had to be taken out and the person sent to the state police to be treated as a thief. In addition to these measures taken by the security department, the University Chief Secretary created an informal rule that any person residing or involved with the Coroado invasion could not be hired as an employee, enforcing thus a long term sanction on the people involved direct or indirectly with the land invasion. This rule worked until the middle of the 1980s.

Besides dealing with the invasion, the University of Amazonas was also consolidating the process of patrimonial property. Sixteen small land owners were not pleased to sell their land to the University. Most of their complaints were associated with the low price defined by the Fundação Universidade do Amazonas to buy their land. It was not a free market deal. After seven years of litigation, the most resistant land owner left the area, but without receiving his payment. The payment transaction process was very slow and most of the sellers only received payment long after leaving their land. The state justice department gave all its support to the University, and when a resistant “seller” was not following the “agreement,” the police were called in to help with conflict resolution.

Thus, during this era, the relationship between the University officers and the remaining landowners was one of “force,” since most of them were forced to sell their land. According to guards, they were always armed and did not even agree to talk with University employees. They continued using their land, cutting the forest, burning it, hunting and in a couple of cases, facilitating access of invaders. However, after 1975 when the last landowner left, the University had total control of the area.

Institutional Consolidation of the Campus, 1975-1977

After controlling most of the land invasion and having control over the whole campus area, the University eventually gained the legal status of the campus area ownership and was respected for that. The guards also started to mobilize themselves in order to transform the security service into a full-fledged department. As part of the prefecture of the campus through the Division of General Affairs, they did not have much autonomy. Since the conflicts between them and both invaders and former owners were solved or minimized, they experienced institutional crises. They wrote a document entitled “the need to institutionalize the campus security service.” In the document, they gave a historical description of their activities. Because the security service was created within a context of invasion, their principal activities were to watch the Coroado border and remake that border fence almost every day. However, in order to avoid becoming a group of “jagunços” (gunman), the security group was trying to institutionalize its activities by: a) acquiring legal and constitutive status; b) concentrating all people related to security activities into just one unit; and c) organizing and instrumenting their work structure in order to carry out their task of preserving and taking care of the ecological and physical patrimony of the campus.

GT Biota and Conservationist Concerns: Designing a preliminary management plan for the Campus Forest, 1977-1985

A working group named Grupo de Trabalho - GT Biota (Biota working group) was created on September 22, 1977 (GR # 886/77) to design a preliminary management plan for the Campus Forest. Basically, the GT Biota was formed to: (1) create rules and procedures for the selection of areas on which to construct physical infra-structure (buildings and other services); (2) establish rules on planning, executing and conserving the campus road network; (3) elaborate rules and proceedings for maintaining the security and physical integrity of the campus; and (4) identify and catalogue plant and animal species, as well as streams and other environmental features in order to elaborate a program to conserve them.

During the GT Biota period (1977-1985), the rules governing the use of the forest continued to be the same as those used in the invasion period. These rules were similar to those used in reserves of restricted-use (i.e., national parks, natural monuments, nature conservation reserves and protected landscapes). The goals of these rules are to: (1) maintain sample ecosystems in their natural state, (2) maintain ecological diversity and environmental regulation, (3) conserve genetic resources, and (4) provide education, research and environmental monitoring.

The main goal of the GT Biota was to restrict any use of the forest besides what is necessary for research or educational purposes. Through its regulations and monitoring, a master plan for the Campus Forest was designed and executed as part of the physical expansion of the campus´ infra-structure, including construction of roads, buildings and parking lots. The work of GT Biota was divided into several commissions, dealing with internal and external environmental problems concerning the Campus Forest.

A special working group was designed to structure an environmentally-integrated project aiming to study the relationship between the local environment (forest ecosystems) and the construction of buildings. The three main goal pursued by the group were to: (1) undertake studies about the interactions between the forest environment and the physical construction of the campus; (2) plan urban expansion; and (3) develop methodological tools to plan and manage ecological systems capable of providing a more adequate framework to economic development planning in the Amazon. After intense work, the environmental integration was developed with the “Plano Diretor I da Universidade do Amazonas” (the Universidade do Amazonas’ master plan), which established the distribution and architectural profile of the physical infrastructure of the campus.

To monitor and control the entrance of outsiders, the GT Biota worked on an assessment to identify the areas more prone to invasion and the activities which could damage the forest and its products. They concluded that from the total perimeter of 11,806 m, the only area relatively well-monitored was the 1,400 m that covered the main principal entrance The remaining 10,400 m was susceptible to squatters and poacher’s invasions since the monitoring system capability had decreased over time in number of guards. With the construction of new buildings, part of the guards were allocated to patrol the new installations, and the number of guards in charge of the forest decreased progressively from 80 to 20.

Some specific Campus Forest points were considered dangerous, putting at risk the life of guards. Alarmed by the poor monitoring, GT Biota members started also to watch the most vulnerable areas. In their final report, entitled “Segurança e defesa dos recursos naturais da area global do campus da Universidade do Amazonas” (security and defense of the natural resources of the University of Amazonas Campus), they identified the most vulnerable points around the campus, and proposed types of instruments and numbers of people to be allocated during days and nights, as well as weekends in order to be able to protect the area.

Besides the 14 most vulnerable points where the 20 available guards were located during nights and weekends, it was recommended that more guards be hired to undertake permanent and continuous patrol around the borders, preferably on horseback. All points to become security stations were drawn on a map and sent to the Campus prefecture. Several other measures were recommended by the GT Biota to complement the monitoring activities to: (1) increase the number of guards, (2) provide guards with clothes and shoes compatible with their activities and roles, (3) adopt a permanent communication service among several security stations and the central post, (4) build shelters at all station points, including necessary facilities for effective performance independently of the time of day and weather.

Finally, they highlighted the importance of implementing the measures recommended to monitor the Campus Forest, indicating that for guards to perform their job properly they needed to have the means to be noticed and respected by anyone without the need of armed conflict or violence. And they also needed to remain at their posts, inform the central post of occurrences or ask for help from the state police as soon as possible. Another point highlighted by them was the role of the station houses to become scientific field laboratories where plants and animals could be measured and scientific instruments could be stored, since good information about the campus biota was still lacking. However, most of the GT Biota project's recommendations to complement the Campus Forest monitoring on its outside borders were not implemented; the number of guards was not increased, a permanent communication was not adopted, and no shelters were built at any station points, except for four stations that were constructed, but later abandoned.

Zoning Commission-- Designing and Implementing a Management Plan for the Campus Forest, 1985-1992

By 1985, most of the Plano Director I (the Campus master plan) had already been implemented. New buildings needed to be planned in order to allow for the expansion of the University of Amazonas. A zoning commission was created on July 5, 1985 (GR# 812/85), in order to define locations on which to install new buildings and facilities by following the ecological criteria already established for the campus. The zoning commission was also asked to define the Campus Forest vegetation zones and regulate their use and conservation now that the University had expanded and the forestry and agronomy schools were applying for training sites around the forest area.

During the zoning commission period, some of the Campus Plano Diretor 1 definitions were modified to attend to the University community's needs. Thus, part of the green area located around the Mini-campus which had been planned to become an Amazonian Green Museum was used to expand the agrarian sector project, the Social Activities Center, the Center of Environmental Science and other buildings related to the Biological Science Institute. Another master plan was developed, however.

By November 1989, the commission released the first version of "Planejamento Estratégico da Universidade do Amazonas" (Strategic Plan of the University of Amazonas), including the "Projeto de Manutenção da Integridade Física do Campus Universitário" (project of maintenance of the physical integrity of the campus) as its main subject. In order to develop its strategic plan, the zoning commission worked through two steps. The first step was to evaluate future academic and administration expansion and project the first approximation of a potential final physical plan. As a second step, the commission members worked on three measures to maintain the physical integrity of the Campus, its forest lands and the ecological attributes of the forest. Three projects resulted from their work: (A) construction of an outer boundary wall, (B) Campus Forest zoning, and (C) improvement of the vigilance system.

Those projects were designed to solve two types of threat that could damage the campus: (1) outsiders' threats that could violate the property limits and disturb the forest by cutting trees, and hunting; and (2) inside threats by the University community itself, which could use the area without coordination, causing as many problems as outsiders. Thus, project A, a wall 11.8 km long and 3 m high covering the whole perimeter, and project C, which dealt with the security system and patrolling of the campus, were developed to solve the first problem. Project B, which deals with the Campus zoning and space use regulations, was developed to solve the second problem.

The commission made several site visits to the campus area to elaborate a final zoning for its management plan: the campus management zoning map was divided into 8 zones: (1) Forest park (covering the whole north side from Coroado to the limits of Campina, below Acariquara). This zone has the objective of conserving and restoring forest areas located around the park. It is designed to be used for educational, recreational and scientific activities; (2) Biological station (the whole area of sector II- Nova Republica): The biological station has the objective of preserving and reconciling the area with its scientific uses; (3) Ecological station of the Campina (Area located at vegetation zone 3): It is an area of the Campina ecosystem to be preserved and used only for ecological and biological research; (4) Agrarian Science Area (the whole area of Atilio Andreazza sector): An area to instal the agrarian sciences facilities and the food production project; (5) Native fruit species project (a mall area located on the south part of Mini-campus facilities): It is a project of environmental education to promote and disseminate the use and plantation of native fruit species in urban areas; (6) Agroforestry experimental station (a small area located on the west part of the mini-campus): Area designed to execute research projects in agro-silviculture, restoration of degraded land and models of ecologically adapted agro-ecosystems; (7) Construction areas and lines of access: Areas already constructed as buildings and roads, and some areas projected for future installations; (8) Protection zone: Buffer line 50 m wide along the streets and around the buildings which serves as a transition area between the urban and protected areas of the campus. These areas will be maintained free of any kind of occupation except for installation of a bus shelter, vigilance station, or power network.

By the time the commission finished the strategic plan for the campus, they already had the final design to build the wall (Project A), as well as a complete inspection around the whole campus perimeter to be constructed. A budget to start the construction was the one thing lacking in that endeavor, but they were in advanced negotiations with SUFRAMA to obtain enough support. However, that project was never implemented. Since the Coroado invasion, the campus borders have been delimited by fences made with wood and barbed wire.

Once the area had been zoned and the use for each zone defined (Project B), the next step was: (a) to send copies of the projects to all academic and administrative units to disseminate information related to the use of the campus land; (b) to include in the University´s constitution a chapter describing the zoning plan and all rules associated with it, as well as institutionalize the zoning commission; (c) elaborate projects to establish zones defined by the commission, and search for financing to execute the plans.

The improvement of the surveillance system (project C), an updated version of the GT Biota project that was never fully implemented, continued to be only a project on paper for monitoring the campus borders and restricting outsiders' access to the forest areas. During the GT Biota time, as mentioned earlier, four security stations were built, but later abandoned. The number of guards allocated to monitor the forest decreased over time. In the late 1980s, around six men patrolled the forest daily, and four to six men twice per week during the 1990s. Small improvements in the communication system to connect the central station and the guards located in the different buildings and sites were installed in 1995/96.

THE EFFECTS OF SURROUNDING NEIGHBOR COMMUNITIES ON CAMPUS FOREST STRUCTURAL ATTRIBUTES

Effect of Residents' Consumptive Use on the Structural Attributes of Campus Forest

The statistical results indicated that basal area does not depend on distance from non-forest areas in the four sectors. However, there is a clear, although not statistically significant, trend in sector III- Ouro Verde where the basal area is smaller close to the non-forest area's edge. This trend may be a result of the settlement phase of Ouro Verde. As described earlier, Ouro Verde was established through land invasion on the border of Campus Forest. Residents claim to have used forest products during the invasion process (Lima, 1997). During the forest survey, in two plots inside of sector III, several trees were observed in phases of regrowth that were cut years ago, showing human use of that forest area. In sector I-Acariquara, there is also an opposite trend, basal area is higher close to the non-forest area's edges than deeper in the forest. Acariquara's residents do not use forest products. Nevertheless, they complain about neighboring residents who come close to their Campus Forest area to use its products. The opposite trend shown in the Acariquara sector may also be a result of the Ouro Verde residents using that forest sector since Ouro Verde is the closest neighborhood to Acariquara.

In the Coroado and Nova Republica forest sectors (IV and II, respectively), the distribution of basal area does not show trends related to the distance from non-forest area edges. Basal area in the Nova Republica sector varies mostly from 10 to 30 m^2/ha independent of the distance from non-forest area. In Coroado, basal area also varies independently from distance from the non-forest areas, but from 1 to 10 m^2/ha, since the Coroado sector is covered by younger secondary succession with lower biomass. These results may indicate that even without systematic patrolling, the Coroado and Nova Republica residents are still not using the Campus Forest for consumptive use.

The Use of Campus Forest by Coroado and Nova Republica Residents

A total of 235 households was visited and 233 agreed to be interviewed. In some cases, informants refused to answer certain questions, particularly those related to income. From the 233 households, 115 were interviewed in Coroado and 118 in Nova Republica.

The use of the Campus Forest products by residents and the restrictions on using them were evaluated based on several statements that followed the two first questions related to their perception of the Campus. The follow-up questions and statements were asked sequentially: 1) "Who in your family uses the area of the Campus Forest for any reason? Could you tell us her/his age, sex, types of product and use, and the location where the products are collected or used?; 2) Do you or your family members use the Campus Forest products with the same intensity that you did five, ten, fifteen, or twenty years ago?; 3) Do you or your family members have any intention to continue using the Campus Forest products?; 4) Are you able to use any products from Campus Forest? If not, what kind of constraints prevent you?; 5) What do you or your family do to overcome these constraints?; 6)Someone told me that during the installation of Coroado, the University of Amazonas had a strong and restrictive control over the forest. Did those measures in some way influence the decisions made by your family regarding the use of Campus Forest products?; 7) Did you observe any change concerning Campus Forest patrolling during the last twenty years? If so, what kind of changes?; 8) How does the Campus Forest monitoring work now?; 9) What should the University of Amazonas be delivering to you and your family that it is not doing?"

The number of households using the forest was very similar in both neighborhoods -- 40 (35%) households in Coroado and 43 (36.5%) in Nova Republica. The proportion of types of use was a little different between them. Most households use the Campus Forest for non-consumptive purposes such as recreation (i.e., trails, streams, and soccer fields), however, in Coroado consumptive use was slightly higher than in Nova Republica. In 10 (8.7%) Coroado households, residents admitted collecting some forest products (i.e., vine, pole, palm leaves and fruits, ornamental and medicinal plants, and game).

Even though used consumptively, the intensity of the forest use in the Coroado and Nova Republica sectors has been light enough to leave few traces on the structural attributes of the Campus Forest. Of those forest products collected, only the extraction of poles could contribute to a measurable decline of the biomass in these sectors. Harvesting of vines, palm leaves and fruits, ornamental and medicinal plants, or game would not be captured by the biomass measurement of trees equal to or higher than 10 cm of diameter at breast height (dbh).

Given the similarity of the socio-economic and historical characteristics of Ouro Verde, one could expect that Ouro Verde residents use the Campus Forest similarly to Coroado residents, and that Acariquara resembles Nova Republica's profile of non-consumptive use. The decline in basal area related to the distance from non-forest area edges found in Ouro Verde seems to be an effect of its time of establishment. Ouro Verde residents in that time (1992) used many more poles and trunks in order to build their houses, fences and other facilities. With time, the demand for those products has declined. Palm leaves are used during June and July to decorate areas in celebration of St. John and St. Peter festivities, while the use of medicinal plants has been substituted increasingly by pharmaceutical products.

DEALING WITH COMPLEXITY

In the Central Amazon region where Campus Forest is located, permanent study plots within 100 meters of newly fragmented edges lost more than 30% of their biomass in the first 10 to 17 years after isolation (Laurance et al.,1997). Laurance and colleagues (1997) predict that it is unlikely that forest edges will return to their original condition, because a fragmented forest is prone to wind disturbance that can kill and damage many trees. Thus, in the presence of fragmenting processes, old-growth rain forest tends to be replaced by shorter, scrubby forests with smaller volume and biomass.

In the Campus Forest case, however, no edge effects on the total forest biomass were found. Nevertheless, these results do not mean that Campus Forest has not been affected by biophysical edge effects. The main cause of the lower distribution of basal area around the Campus Forest is associated with the history of land use of that area. Before the creation of the reserve, the former owners had used several parts of that forest for agriculture and timber activities. Small holders were using their areas for slash and burn agriculture while the larger farmers were using their areas for timber extraction. Those activities impacted differently the Campus Forest ecological attributes.

In the Campus Forest case, no institutional edge effects were found on the forest structural attributes. The forest biomass was not lower on the forest edges than in interior areas. This result could mean that the monitoring has not been enforced in this forest as assumed by institutional edge effects, and consequently the whole forest would lose biomass since the forest property rights´ rules have not been enforced and local residents used products not only on the edges, but also in any place accessible. However, the forest has been regrowing instead of losing biomass. At the same time, both monitoring activities undertaken around the campus have been very mild without any kind of sanctions on non-allowed users in the last 10 years or so. The surrounding residents have been using consumptive and non-consumptive forest products for a long time. Like biophysical edge effects, it seems that both a lack of strong monitoring and the residents' use of the forest have not significantly affected the attributes of the forest. However, population pressure and a poor monitoring system during its creation and establishment had significant impact on the Campus Forest.

Starting in the 1970s, fast population growth in Manaus, motivated by policies and governmental incentives through industrialization and urbanization, caused irreversible changes around Manaus and Campus Forest´s land. Immigration of thousands of rural natives and non-rural natives to Manaus caused high rates of deforestation, forest fragmentation and human invasion in Manaus' rural and peri-urban forested lands. Thus, at the regional level, population pressure caused forest destruction and degradation in Manaus, having a serious impact even on the Campus Forest area. Rural landless native Amazonians arrived without much education and means to settle in the new area. They invaded several forest patches around Manaus to build their housing. The north part of the Campus Forest was invaded at that time, and 119 hectares of forest were lost during this process. No Campus Forest land was lost during and after the invasion because the University started to patrol and monitor the area.

At the local level, however, Campus Forest has not been significantly affected by population pressure and inequality. Since 1977, the forest has been recovering its ecological attributes by gaining biomass. Residents surrounding Campus Forest use this forest mostly for non-consumptive purposes. The current level of extraction of forest products used for consumption is very low. Only 8.7% of the households in Coroado use the forest for any consumption activity. However, during the installation of two neighborhoods (Coroado and Ouro Verde), the new settlers relied on some Campus Forest products to build their houses, fences and other facilities. With time, the demand for those products has declined. Hence, the demand for non-consumptive use such as recreation has increased.

Thus, population pressure has caused a great deal of large forest destruction in Manaus in the last decades. The fast demographic change experienced in this region also had serious impact on the Campus Forest by shrinking its forested land by 119 hectares in the beginning of the 1970s. At the local level, however, no significant influence of population pressure on the forest ecological attributes was found.

The examination of institutional failure and conflicts between reserve managers and residents seems to be a strong factor explaining forest degradation during its installation and establishment of the Campus. The inability of the University to enforce Forest property rights resulted in a land invasion and the loss of 119 ha of forested land in the beginning of the 1970s. Conflicts which lasted for at least 5 years with squatters also had a negative influence on the ecological characteristics of the forest, as well as did conflicts with former land owners. In addition, it is important to highlight the fact that institutional arrangement is an important dimension to explain degradation and/or successful conservation achievement in restricted-use and multiple-use reserves.

Final Remarks

To approach the complexities and multi-level factors related to reserve conservation, we drew on a framework that examines the direct and indirect causes of forest reserve changes. Locating these causes spatially and temporally, the study shows different factors and processes that have shaped the degree of preservation in the studied reserve. Considering the historical, economic and social factors affecting the forest areas around the reserve, our results show that current ecological attributes were shaped, not only by the proximate and underlying factors acting at the local level, but also by those affecting forested lands regionally and over time. Edge effects, whether biophysical or institutional, may affect the preservation performance of a forest reserve but they do not explain ecological degradation or improvement on their own. The history of land use inside and outside of the reserve, government incentives motivating in-migration, which resulted in forest land invasion, conflict between squatters and reserve managers, and the creation and evolution of the reserve's institutional arrangements proved to be key variables explaining such change.

REFERENCE CITED

Acheson JM. 2006. Institutional failure in resource management. *Annu. Rev. Anthropol.* 35:117–34

Albers, H.J., and Grinspoon, E. 1997. A Comparison of the Enforcement of Access Restriction Between Xishuangbanna Nature Reserve (China) and Khao Yai National Park (Thailand). *Environmental Conservation* 24(4):351-362.

Allen, J.C. and Barnes, D.F. 1985. The Causes of Deforestation in Developing Countries. *Annals of the Association of American Geographers* 75(2)

Araujo, M.A.R., 2007. *Unidades de Conservação no Brasil: da República à Gestão de Classe Mundial*. Belo Horizonte: SEAGRAC, 272p.36

Brondizio, E. S., A. Cak, M. Caldas, C. Mena; R. Bilsborrow, C. T. Futemma, E. F. Moran, M. Batistella, and T. Ludewigs. Small Farmers and Deforestation in Amazônia. In M. Keller, M. Bustamante, J. Gash, and P. Silva Dias (eds.) *Amazônia and Global Change: A Synthesis of LBA Research.* World Scientific Publishing (American Geophysical Union, Geophysical Monograph Series 186). Pp. 117-143.

Capobianco, J.P. 1995. Ilha do Cardoso Expôe Crise das Unidades de Conservação. *Parabólicas* 2(10):2-5.

Chade, S. et. al. 2003. *United Nation list of protected areas.* IUCN/UNEP World Conservation Monitoring Center, 56p.

Colchester, M. 1994. *Salvaging Nature: Indigenous People, Protected Areas and Biodiversity Conservation*. United Nations Research Institute for Social Development (UNRISD) Discussion Paper No. DP55. Geneva: UNRISD.

Didham, R.K. 1997. The Influence of Edge Effects and Forest Fraagmentation on Leaf Litter Invertebrates in Central Amazonia. In *Tropical Forest Remnants: Ecology, management, and Conservation of Fragmented Communities*, Ed. W.F. Laurance and R.O. Bierregaard, Jr., 55-70. The University of Chicago Press, Chicago

Dourojeanni, M.J. and Padua, M.T.J. 2007. *Biodiversidade a Hora Decisiva*. Curitiba: Ed. UFPR, 284p.

Ehrlich, P. 1968. *The Population Bomb*. Ballantine, New York.

Ehrlich, P. and Holdren, J. 1971. The Impact of Population *Growth*. *Science* 171:1212-1217.

Ehrlich, P. and Holdren, J. 1974. Human Population and the Global Environment. *American Scientist* 62:282-292.

Fearnside, P.M. and Ferreira, G.L. 1985. Roads in Rondonia: Highway Construction and the Farce of Unprotected Reserves in Brazil's Amazon Forest. *Environmental Conservation* 11: 358-60.

Ghimire, K.B. 1994. Parks and People: Livelihood Issues in National Parks Management in Thailand and Madagascar. *Development and Change* 25:195-229.

Godway, J.M. 1997. The value of Biodiversity: Markets, Society and Ecosystems. *Land Economics* 73(1):25-41

Green, M.G. and Sussman, R.W. 1990. Deforeestation History of the Eastern Rain Forests of Madagascar from Satellite Images. *Science* 248:212-215.

Harrington, G.H., Irvine, A.K., Crome, F.H.J., and Moore, L.A. 1997. Regenaration of Large-Seeded Trees in Australia Rainforest Fragments: A Study of Higher-Order Interactions. In *Tropical Forest Remnants: Ecology, management, and Conservation of Fragmented Communities*, Ed. W.F. Laurance and R.O. Bierregaard, 292-303. The University of Chicago Press, Chicago

Harrison, S. 1990. *Population, Land Use and Deforestation in Costa Rica, 1950-1983.* Morrison Institute for Population and Resource Studies, vol.24, Stanford, California.

Kapos, V., Vandelli, E., Camargo, J.L., and Ganade, G. 1997. Edge-Related Changes in Environment and Plant Responses Due to Forest Fragmentation in Central Amazonia. In *Tropical Forest Ramnants: Ecology, management, and Conservation of Fragmented Communities*, Ed. W.F. Laurance and R.O. Bierregaard, 138-155. The University of Chicago Press, Chicago.

Lambin, E. et al. 2001. The causes of land-use and land-cover change: moving beyond the myths Global Environmental Change 11 (2001) 261–269

Laurance, W.F. 1991. Ecological Coorrelates of Extinction Proneness in Australian Tropical Rain Forest Mammals. *Conservation Biology* 5:79-89.

Laurance, W.F. 1997. Hyper-Disturbed Parks: Edge Effects and the Ecology of Isolated Rainforest Reserves in Tropical Australia. In *Tropical Forest Remnants: Ecology, management, and Conservation of Fragmented Communities*, Ed. W.F. Laurance and R.O. Bierregaard, 71-83. The University of Chicago Press, Chicago.

Laurance, W.F. and Gascon, C. 1997. How creatively to fragment a landscape. *Conservation Biology* 11(2): 577-79.

Laurance, W. F., Laurande, S., Ferreira, L. V., Rankin-de-Merona, J. Gascon, C., Lovejoy, T.E. Biomass Collapse in Amazônian Forest Fragments. *Science* 278: 1117-1118.

Lima, A. C. de. 1997. *Educação Ambiental para as Comunidades do Entorno do Campus Universitário da Universidade do Amazonas*. Monograph. Universidade do Amazonas,

Lovejoy, T.E. 1997. Foreword. In *Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities*, Ed. W.F. Laurance and R.O. Bierregaard, Jr.,ix-x pp. The University of Chicago Press, Chicago.

Malcolm, J.R. 1994. Edge Effects in Central Amazonian Forest Fragments. *Ecology* 75:2438-2445.

Marquette, C.M. 1994. *Population and the Environment in Developing Countries: Literature Survey and Research Bibliography*. Department for Economic and Social Information and Policy Analysis, United Nations Secretariat, New York.

Mausel, P., Wu, Y., Li, Y., Moran, E., and Brondizio, E. 1994. Spectral identification of successional stages following deforestation in the Amazon. *Geocarto International* (4): 61-71.

Moran, E., Brondizio, E., Mausel, P and Wy, Y. 1994. Integrating Amazonian vegetation, land use and satellite data. *Bioscience* 44(5): 329-39.

Ostrom, V. and Ostrom, E. 1977*. Public goods and public choices. In Alternative for delivering public services. Toward improved performance*, Ed. E. S. Savas, 7-49. Westview Press, Bolder.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action.* Cambridge University Press, New York.

Ostrom, E., Gardener, R., and Walker, J.M. 1994. *Rules, games and common-pool resources*. University of Michigan Press, Ann Arbor.

Ostrom, E., Burger, J., Field, C.B., Noorgard, R.B. and Policansky, D. 1999. Revisiting the Commons: local lessons, global challengers. *Science* 284: 278-82.

Peres, C.A. and Terborgh, J.W. 1994. Amazonia Nature Reserves: An analysis of the *defensibility status of existing conservation units and design criteria for the future. Conservation Biology* 9(1):34-46.

Pichon, F., Vosi, S. and Witcover, J. 1993. Determinants of land-use practices in the Humid Tropics; farm level evidence from Ecuador. *International Food Policy Research Institute*. Working Paper.

Rudel,T. 1989. Population, Development and tropical Deforestation: a Cross National Study. *Rural Sociology* 54(3): 327--338.

Rudel, T.K. 1993. A theory of tropical deforestation. In *Tropical deforestation: small farmers and land clearing in the Ecuadorian Amazon*, Ed. T. K. Rudel and B. Horowitz, 13-41. Colombia University Pres, New York.

Schmink, M. 1988. The Case of the Closing Frontier in Brazil. In *Power and Poverty, Development and Development Projects in the Third World*. Ed. D. Altwood et al., 135-153. Westview Press, Bolder.

Shafer, C.L. 1995. Values and shortcomings of small reserves. *Bioscience* 45: 80-88

Sherbinin, A. 1993*. Population and Consumption Issues for Environmentalists: a Literature Search and Bibliography*. Population Reference Bureau and Pew Charitable Trust, Washington.

Simon, J. 1981. *The Ultimate Resource*. Princeton University Press, Princeton.

Simon, J. 1990. *Population Matters: People Resources, Environment and Immigration*. Transaction Publishers, New Brunswick, New Jersey.

Turner, P. W. 1998. *Constitutional orders and deforestation: a cross-national analysis of the Humid Tropics*. PhD Dissertation. Indiana University, Bloomington.

Varughese, G. 1998. Coping with changes in population and forest resources: institutions mediation in the Middle Hills of Nepal. In *Forest Resources and Institutions*, Ed. C. Gibson, M. Mckean, and E. Ostrom, 163-193. Forest, Tree, and People Programme. Working Paper #3. Rome, Italy, FAO.

West, P., Igoe, J., & Brockington, D. (2006). Parks and peoples: the social impact of protected areas. *Annual Review of Anthropology 25*, 251-277

Wilcove, D.S., McClennan, and Dobson, A.P. 1986. Forest Fragmentation in the Temperate Zone. In *Conservation Biology: The Science of Scarcity and Diversity,* Ed. M.E. Soule,237-256. Sinauer Associates, Sunderland , Mass.

Wood, C. and Schmink, M. 1993. Frontier Expantion in Amazonia: Implications for the Theory and Methods of Migration Research. Paper presented at the Population Associatio of America, Cincinati, Ohio, April 1-3.

Wood, C. and Skole, D. 1998. Linking satellite, census, and survey data to study deforestation in the Brazilian Amazon. In *People and pixels: linking remote sensing and social science*, Ed. D. Liverman, E. Moran, R. Rindfuss, and P. Stern, 70-93. National Academy Press, Washington, DC.

ACKNOWLEDGMENT

The development of this study was only possible with the financial support from the National Science Foundation (Grant # SBR-9521918) through the Center for the Study of Institutions, Population, and Environmental Change (CIPEC), and the National Institute for Global Environmental Change through a grant to the Anthropological Center for Training and Research on Global Environmental Change. Thanks to all our colleagues and friends for the help, discussion, orientation and support, in special Emilio Moran, Lin Ostron, J.C. Randolph, Fabio de Castro, Celia Futemma, Joby Jerrells, and Aldeniza Lima.