Conservation units: a new deforestation frontier in the Amazonian state of Rondônia, Brazil

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SUMMARY

Over the past several decades, the Brazilian State of Rondônia has been the destination of many rural migrants drawn from Brazil's middle southern regions by massive government colonization projects. Factors such as explosive population growth, logging, mining, small-scale farming and ranching have synergistically fuelled deforestation in the state. The total area deforested in Rondônia in 1978 was 4200 km². In 1988, the area increased to 30 000 km², in 1998 to 53 300 km² and by the year 2003, a total of 67 764 km² of Rondônia was deforested. In response to the high rate of deforestation observed in Rondônia and other Amazonian states, state and federal agencies worked to create a network of conservation units (CUs) in Brazil during the 1990s that was signed into law (Law 9985/00) in 2000. The ability of these CUs to reduce the rate of deforestation was analysed. Remotely-sensed data from Landsat and thematic coverages were used to measure deforestation inside all CUs in Rondônia. A more detailed analysis of CUs with the highest levels of deforestation, including an analysis between soil types and deforestation and a forecast of potential future deforestation, was conducted. The creation of conservation units in Rondônia has been useful in curbing deforestation within their boundaries; however, many CUs face pressure from the combined activities of illegal loggers, cattle ranchers and small-scale farmers seeking new sources of timber and agricultural land. For example, an exponential increase in the amount of deforestation was observed in Rondônia’s Bom Futuro National Forest between 1992 and 2000. A regression model indicated a total of 20 500 ha deforested by 2002, while measurements from 2002 imagery showed an actual total deforestation of 20 720 ha. Should this trend persist, Bom Futuro National Forest could be completely deforested by 2017. CUs in Rondônia must be developed and implemented jointly by all stakeholders through the creation of partnerships between local communities, non-governmental organizations and government agencies.

Keywords: Brazilian Amazon, biodiversity, conservation, conservation units, ecology, remote sensing, tropical deforestation

INTRODUCTION

The conversion of tropical rainforests to pasture and cropland has become a serious environmental and social issue with important global ramifications that include social and biological impoverishment and an important contribution to global warming (Houghton 1991; Brown et al. 1992). At the same time, the advance of deforestation in tropical countries is being followed by the realization that the biodiversity that exists in these forests must be preserved (Gallegos 1997). Many efforts have, however, been tainted by the lack of sound implementation of legally-created unidades de conservação or conservation units (CUs) and, as such, have become the subject of harsh criticisms (Redford et al. 1998). Yet despite concern about the effectiveness of CUs in the tropics, growing evidence indicates that they have been surprisingly useful tools in curbing deforestation (Bruner et al. 2001).

The Brazilian Amazon attracts special attention owing to widespread environmental degradation that arose in part from the implementation of public policies aimed at rapidly developing the region (Hecht 1985; Browder 1988; Mahar 1989). The region has had the highest detected rates of deforestation in the tropical world. Satellite data indicate that between 1978 and 1988, the average rate of deforestation was 1.6–2.2 × 10⁶ ha yr⁻¹ (INPE [Instituto Nacional de Pesquisas Espaciais] 1992; Skole & Tucker 1993). Total deforestation in the Brazilian Amazon increased from approximately 37.7 × 10⁶ ha in 1988 to 58.7 × 10⁶ ha by 2000, at an average annual rate of 1.75 × 10⁶ ha yr⁻¹ (INPE 2004). Laurance et al. (2001) demonstrated that deforestation pressures have not diminished in the Brazilian Amazon and note changes in the spatial patterns of deforestation events that may cause accelerated loss of pristine forest across the region.

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In response to such widespread evidence of environmental degradation, there is an ongoing effort to protect the region’s natural ecosystems (Moran 1993) with the establishment of protected areas identified as a main strategy for conservation (Uhl 1988). Nepstad et al. (2002) have argued that a regional conservation strategy based on the creation of CUs is urgently needed to protect the Amazon. Indeed, within the Brazilian Amazon, the federal government began the creation of CUs in 1959, with the creation of Araguaia National Park, in the state of Tocantins (Rocha 1992). More recently, in conjunction with the World Bank, the Global Environmental Facility and World Wide Fund for Nature (WWF), Brazil committed to tripling the amount of protected areas within the Amazon by 2012 through the Amazon Region Protected Areas (ARPA) programme (World Bank 2002).

In July 2000, Brazil established its National System of Conservation Units through Federal Law 9985/2000 and designated two basic categories of CUs, namely Integral Protection Conservation Units (IPCsUs) and Sustainable Use Conservation Units (SUCUs) (Rocco 2002). IPCUs are CUs in which the use of natural resources is strictly forbidden, and include areas such as national parks, ecologic stations, biologic reserves and wildlife sanctuaries. SUCUs are CUs where the sustainable use and management of natural resources is allowed, and include CUs such as national forests, extractive reserves and sustainable development reserves. Given the existing pressure for the use of Amazonian natural resources, Veríssimo et al. (2002) have emphasized the potential contribution of national forests to establishment of a more rational use of natural resources in the Amazon.

In the state of Rondônia, a consortium of state and federal agencies is working with funds from a World Bank loan to consolidate a network of CUs in the hopes of curbing the destruction of the state’s remaining rainforest. This effort was a direct response to national and international pressures to ease the alarming pace of deforestation associated with land-use and land-cover change resulting from colonization projects established in the region in the early 1970s (Coy 1987; Malingreau & Tucker 1988; Millikan 1988). Remote sensing data from Landsat were used to assess land cover change inside CUs in Rondônia over a period of seven years. Though many CUs have experienced more cryptic forms of degradation such as those brought about by poaching (Peres & Lake 2003) or selective logging and fire (Nepstad et al. 1999), the current research is directly concerned with deforestation. We focus our attention on the case of the Bom Futuro National Forest, where the highest rates of deforestation for the period 1996–1999 were found, to examine possible relationships between deforestation, soil types, and the presence of squatters and illegal loggers. Our ultimate goal is to determine whether the socioeconomic and political reality of the Amazon requires broad programmes to strengthen the institutional capability of environmental agencies and to regulate the use of natural resources by different stakeholders to ensure that success follows the creation of CUs.

The state of Rondônia is located in the western portion of the Brazilian Amazon and contains 243,044 km² (an area slightly larger than Portugal). The first settlements in Rondônia occurred during two rubber booms (the first in the nineteenth century and the second during the Second World War), but neither had a lasting impact on the occupation of the state (Martine 1990). The modern population rush to Rondônia, which began in the late 1960s, was caused by the abandonment of colonization projects along the Transamazon Highway and by changes in land tenure patterns in mid-southern Brazil (Martine 1990). More recently, Rondônia has been characterized by a consolidation of land holdings and the spread of pasture at the expense of forested areas (Ferraz et al. 2005).

In 1987, a World Bank mission went to Rondônia to begin negotiations for the Projeto Agropecuário e Florestal de Rondônia (PLANAFLORO), the Rondônia Natural Resource Management Programme. PLANAFLORO addressed major problems caused by previous development projects and included a series of goals related to environmental protection. The demarcation of CUs and Amerindian reserves was a key aspect of PLANAFLORO’s resource-use component (World Bank 1997). On many occasions mixed tenure patterns resulted in great difficulties for the legal establishment, demarcation and transfer of land ownership between distinct governmental spheres and private individuals (Umaña 1998). During this process, ranchers and colonists encroached on areas known to be targeted for conservation, the end result being that only 40.3% of the 5,355,000 ha originally intended for inclusion in CUs were actually demarcated (Millikan 1998).

Most of Rondônia’s CU natural resources management plans, which are legal documents defining the permitted uses of the natural resources within a given CU, were developed during PLANAFLORO (Olmos et al. 1999). However, most of the areas have no permanent staff and only sporadic protective measures have been taken to enforce their limits. This situation is similar to that observed by Fearnside and Ferreira (1984) during previous development programmes, where the creation of CUs was not followed by a clear commitment to protection and management. In spite of these problems, PLANAFLORO and the funds provided by the World Bank resulted in the consolidation of a network including 51 CUs in both IPCU and SUCU categories that include national, state and municipal entities (Table 1). In addition to the creation of CUs, the demarcation of 22 Amerindian reserves has formally placed 35% of Rondônia’s territory under protection (Fig. 1).

**METHODOLOGY**

Sixty-four Landsat scenes covering the state of Rondônia for the years 1992, 1996 and 1999 were used to calculate the deforested area within 51 CUs (Fig. 1) at the Center of Global Change and Earth Observations (CGCEO) at Michigan State University. Eight additional scenes (path/row 232/067 and
Land use and land cover change analysis

Table 1: Number of IPCUs and SUCUs in different categories of conservation units in the Rondônia conservation units network. 

<table>
<thead>
<tr>
<th>Category</th>
<th>IPCU</th>
<th>Area (ha)</th>
<th>SUCU</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological station</td>
<td>4</td>
<td>195,321</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Biological reserve¹</td>
<td>3</td>
<td>550,787</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Municipal park</td>
<td>4</td>
<td>1,329</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>State park</td>
<td>3</td>
<td>672,035</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>National park²</td>
<td>1</td>
<td>687,476</td>
<td>25</td>
<td>1,333,262</td>
</tr>
<tr>
<td>Extractive reserves</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1,333,262</td>
</tr>
<tr>
<td>State forest</td>
<td>–</td>
<td>–</td>
<td>9</td>
<td>267,251</td>
</tr>
<tr>
<td>National forest</td>
<td>–</td>
<td>–</td>
<td>2</td>
<td>483,397</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>2,106,948</td>
<td>36</td>
<td>2,083,910</td>
</tr>
</tbody>
</table>

¹A portion (~95 km²) of the Jarú Biological Reserve overlaps part of the Igarapé Lourdes Indigenous Territory. ²The total area (687,476 km²) of the Pacaás Novos National Park overlaps part of the Uru-Eu-Wau-Wau Indigenous Territory. Source: SEPLAN (1999).

Figure 1: Diagrammatic map of conservation units and Landsat tile system for the state of Rondônia in the Brazilian Amazon.

All images were geometrically corrected by using nearest-neighbour resampling with the four points derived from ephemeris data supplied with the images at the time of ordering. Additionally, the corrected images were validated and tested using collected GPS ground points from several locations in the Amazon. Image classification procedures for each year were carried out in ERDAS Imagine using an unsupervised classification of Digital Numbers (DNs) to create clusters of distinct land uses. Once spatial clusters were generated, interpreters determined the nature of the clusters and provided a classification. The final deforestation layers or grids contained seven classes, namely forest, deforestation, cerrado, secondary forest, water body, cloud and cloud shadow. Forest degradation that results from logging and fire was not included in this analysis as it cannot be accurately detected using unsupervised techniques (Nepstad et al. 1999; Asner et al. 2002).

A map containing the CU’s limits at a scale of 1:250,000 was used as a cartographic base for measurements. In addition, deforestation grids produced by CGCEO were tabulated according to the CU’s map. Total deforestation in CUs was calculated for the period 1992 to 1999 using the deforestation grid information. In areas where we observed higher levels of deforestation from 1992 to 1999, we used a time-series for 1992, 1996 and 2000 to calculate the temporal variation in deforestation. In the case of Bom Futuro National Forest, deforestation was measured for 1992, 1996, 1998, 1999, 2000 and 2002 and an additional
Table 2 Deforestation in six conservation units in the state of Rondônia (1992, 1996 and 1999).

<table>
<thead>
<tr>
<th>Conservation unit</th>
<th>Total CU area (ha)</th>
<th>Deforestation 1992</th>
<th>Deforestation 1996</th>
<th>Deforestation 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bom Futuro National Forest</td>
<td>269 144</td>
<td>413 0.15</td>
<td>2230 0.83</td>
<td>6906 2.57</td>
</tr>
<tr>
<td>Corumbiara State Park</td>
<td>433 157</td>
<td>899 0.21</td>
<td>899 0.21</td>
<td>1493 0.34</td>
</tr>
<tr>
<td>Jaci-Paraná State Extractive Reserve</td>
<td>200 635</td>
<td>267 0.13</td>
<td>290 0.14</td>
<td>480 0.24</td>
</tr>
<tr>
<td>Jamari National Forest</td>
<td>216 101</td>
<td>5338 2.56</td>
<td>5660 2.62</td>
<td>6581 3.05</td>
</tr>
<tr>
<td>Ouro Preto Federal Extractive Reserve</td>
<td>207 450</td>
<td>2849 1.37</td>
<td>7044 3.4</td>
<td>8964 4.32</td>
</tr>
<tr>
<td>Pacás Novos National Park</td>
<td>690 718</td>
<td>69 0.01</td>
<td>411 0.06</td>
<td>864 0.13</td>
</tr>
</tbody>
</table>

information layer, soil composition as derived from soil maps produced in 1999 by the Rondônia Planning Secretariat (SEPLAN [Secretaria de Estado do Planejamento e Coordenação Geral] 1999) was used to investigate the possible links between deforestation and endogenous environmental variables.

We also conducted fieldwork during June 2002 that included field observations and GPS ground control point measurements in Bom Futuro National Forest. We compared the areas mapped on the satellite imagery with the field observations around the roads. Ground truthing of imagery classification was used to reclassify areas that were originally misclassified, such as several small areas of rock exposures that were provisionally classified as deforestation.

RESULTS

The percentage of the total area of CUs in Rondônia (roughly 4 200 000 ha) classified as deforested increased to roughly 0.7% from 1992 to 1999. This measure may underestimate the actual amount of deforestation because of the exclusion of areas covered by cloud and cloud shadow (around 0.1% per year) in the imagery. Approximately 19 000 ha of new deforestation were observed between 1992 and 1999. Although the area of deforestation can be regarded as relatively low, the total area deforested increased 350% over this period. A large portion of this deforestation, 64% in 1999, is concentrated in only six of the state’s 51 CUs (Table 2). Five of the 51 CUs investigated showed no increase in deforested area over the study period.

The highest absolute levels of deforestation were found in Ouro Preto Federal Extractive Reserve, Jamari National Forest and Bom Futuro National Forest, with 4.32%, 3.05% and 2.57% of total area deforested by 1999, respectively. These CUs also exhibited the greatest increase in deforestation over the same period. In Ouro Preto Federal Extractive Reserve and Jamari National Forest, deforestation is attributed to agents operating legally within the confines of each CU’s natural resources management plan; rubber tappers in the case of the former and cassiterite miners in the latter. The process of deforestation in the Bom Futuro National Forest is the result of activities by exogenous and illegal agents (i.e. squatters, cattle ranchers and loggers).

DISCUSSION

Though experiencing relatively low levels of deforestation in comparison to the state as a whole, CUs in Rondônia face increasing pressure from the incursion of illegal loggers and squatters. Only 10 of the 51 areas studied here had no...
Table 3 Soil types and deforestation in Bom Futuro National Forest. Source: SEPLAN(1999).

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Total area (ha)</th>
<th>1996</th>
<th>1998</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ha</td>
<td>%</td>
<td>ha</td>
<td>%</td>
</tr>
<tr>
<td>Dystrophic cambisols</td>
<td>13 144.97</td>
<td>324.1</td>
<td>2.47</td>
<td>324.1</td>
</tr>
<tr>
<td>Gley dystrophic</td>
<td>3400.47</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>Yellow dystrophic latosols</td>
<td>124 574.95</td>
<td>816.5</td>
<td>0.66</td>
<td>893.9</td>
</tr>
<tr>
<td>Red-yellow dystrophic latosols</td>
<td>60 218.67</td>
<td>974.5</td>
<td>1.62</td>
<td>1994.5</td>
</tr>
<tr>
<td>Yellow dystrophic podzols</td>
<td>65 997.38</td>
<td>114.8</td>
<td>0.17</td>
<td>450.5</td>
</tr>
<tr>
<td>Sandy soils</td>
<td>832.14</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>268 168.58</td>
<td>2230.9</td>
<td>3663.2</td>
<td>9445.0</td>
</tr>
</tbody>
</table>

settlements detected within their borders. Where these agents gain a foothold, such as in Bom Futuro National Forest, their actions can lead to an exponential increase in deforestation, a trend often observed in newly opened frontiers. Owing to the complex process involved in the creation of CUs in Brazil, it can take years or even decades for a targeted area to become eligible for full legal protection. During this time, incipient CUs are vulnerable to invasion. The reduction in the area of CUs created under PLANARFLORO was largely caused by the exclusion of areas that had been invaded during this process. Fearnside (2003) notes that after the formation of Brazil’s national system of conservation units (SNUC), delays in legislation provided loopholes that were exploited by many groups.

Within Rondônia’s network of CUs, areas experiencing the lowest levels of disturbance have been those most isolated owing to lack of access via the expanding road network. Proximity to previously deforested areas has been shown to be a good predictor of future deforestation (Alves et al. 1999; Alves 2002). A possible explanation for the bulk of deforestation being present in a few CUs is their proximity to old settlements where land aggregation into large estates has expelled small farmers from their properties. Landless farmers tend to form alliances with illegal loggers to generate income needed to meet their material needs and gain access to new land. The interaction between these social agents results in the construction of illegal roads for the extraction of timber resources, encroaching on the CUs with networks of access roads (Fig. 3). This also provides the opportunity for squatters to establish themselves within CU boundaries. The results of this study confirm the notion that proximity to actively deforested areas increases the chance of a CU suffering encroachment and consequently having its natural resources exploited by a multitude of social actors.

In Bom Futuro National Forest, visual analysis of satellite images indicates patterns of land-cover change that reflect the presence of land-use systems adopted by small farmers and cattle ranchers inside the area. According to Brazil’s Colonization and Agricultural Reform Agency (Instituto Nacional de Colonização e Reforma Agrária, INCRA), most landholders within Bom Futuro were not living permanently inside the area (INCRA 2002). However, 550 families claimed land within the national forest and had cleared roughly 9900 ha for agriculture (INCRA 2002). Half of the families with agricultural plots were living in nearby urban areas, with 15% of the families being only part-time dwellers and 35% permanent residents. Typically, illegal logging agents enter the area and establish verbal contracts with the squatters to exploit the timber resources under their control, providing income and capital to reinvest in further forest clearing.

Similar to Jones et al. (1995), we did not find a direct relationship between deforestation and soil type. However, given the relatively low fertility of the area’s soil types, we predict that pasture will become the dominant use of land cleared for agriculture in Bom Futuro National Forest. We note that a growing demand for pasture already exits, and that there are many areas within the CU that are susceptible to illegal deforestation. Although Bom Futuro National Forest has neither had its demarcation concluded, nor a natural resources management plan in place, most squatters realize the illegality of their presence inside the area. This sense of illegality creates a climate of uncertainty about the future that may serve as an additional incentive for the rapid, and consequently unsustainable, exploitation of natural resources.
in Bom Futuro National Forest as illegal agents seek to ‘mine’ all the resources that they can while the opportunity to do so exists.

We observed illegal selective logging activities inside Bom Futuro National Forest, with loggers using heavy machinery such as skidders, bulldozers and large trucks to log and quickly move out of the area. There was a steady growth in permits issued by the Brazilian Institute for the Environment and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, IBAMA) for logging and sawmill operations from 1992 to 2002 in four municipalities in the vicinity of Bom Futuro National Forest (Table 4). Although our fieldwork did not establish a direct link between illegal logging and legally established timber companies, we believe that there is a synergy between illegal loggers, squatters and the wood sector in the surrounding municipalities. This belief is reinforced by the fact that Buritis and Alto Paraiso are respectively located at the southern and eastern limits of Bom Futuro and have become focal points for timber sawing in Rondônia. Additionally, we observed sawmills operating within Bom Futuro National Forest without proper authorization from IBAMA. We expect that these clandestine operations are likely to expand their influence to neighbouring Jamari Extractive Reserve in the near future.

A final explanation for the deforestation observed within Rondônia’s CUs and, in particular, Bom Futuro National Forest is the lack of institutional capacity to effectively monitor and administer these areas. Agencies responsible for enforcing Brazil’s environmental laws are often characterized as lacking the institutional strength or the resources needed to achieve their goals (Rocha 1992; Peres & Terbough 1995; WWF 1999). Oliveira (2002) notes that the success of conservation programmes in the Brazilian state of Bahia hinged on the successful formation of alliances between federal, state and municipal agencies in conjunction with non-governmental organizations and local interest groups. As the objectives of different stakeholders are often at odds with each other, finding ways to forge new coalitions is an important step in promoting more effective conservation within the region.

**CONCLUSIONS**

CUs have slowed the pace of deforestation in areas of pristine forest in Rondônia; however, the borders between CUs and settled areas are permeable, and increasing demands for pasture and new areas for logging are putting pressure on the protected resources. The creation of CUs alone is not enough to stop land clearing for agriculture and other forms of resource exploitation. Areas juxtaposed with previous settlements are at the greatest risk, as the demands being placed on a shrinking resource base push further afield. This situation is compounded by the fact that CUs are normally located in areas rich in natural resources and are easy targets for illegal agents. In Rondônia, the bulk of land clearing is occurring either in areas where old settlements previously existed, or where unofficial new settlements have been created recently. Although we did not find that soil composition helped to explain deforestation in CUs, we argue that there is a gap in the knowledge about how such environmental factors serve to enhance or preclude the occurrence of deforestation on protected lands. A fact that may further complicate the future of conservation efforts in Rondônia is the lack of management plans for most of the newly-created CUs. Moreover, only three CUs have the required staff to conduct the routine tasks necessary to protect their territory.

Bom Futuro National Forest presents a worst-case scenario of what can happen in the absence of sufficient institutional capacity to manage protected resources. As timber and agricultural land become scarcer, greater pressure will be brought to exploit protected resources. Consolidation of Rondônia’s CUs under PLANALFLORO is a first step toward a more effective management of these areas. Future efforts should be aimed at better management and sustainable use of resources both within CUs and without. As a SUCU, Bom Futuro National Forest is open to sustainable resource use, including logging, provided that it is done under an approved management plan. Involvement of the diverse group of stakeholders including local, state and federal agencies, as well as private logging firms and local communities in formulating management plans for all CUs should be a top priority lest the case of Bom Futuro set a precedent for other areas.

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