Patterns and impacts of deforestation in Rondônia, Brazil

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Abstract

Land development in the Brazilian Amazon has gone through phases of rubber extraction, agricultural development, immigration, road expansion, and promotion of large enterprises in cattle ranching, timber extraction and mining. Land development patterns in the western state of Rondônia provide a place to focus on rapid development and its effects. The expanding land-use activities in Rondônia have resulted in an increase in the human population and the rate of deforestation so that by 1993 about 25% of the forest area had been cleared. In Rondônia the main activities responsible for the deforestation are small farmers, cattle ranchers, miners and loggers. The implications of the Rondônia Natural Resource Management Project (PLANAFLORO), which is just now being implemented, are critical to the future of the environment and economy of the region. © 1997 US Government. Published by Elsevier Science B.V.

Keywords: Tropical rain forest; Land development; Deforestation; Brazil

1. Introduction

The occupation of the Amazon Basin has been a goal of Brazilian governments since the 19th century. The region has the largest track of tropical rain forest in the world (more than 3.3 million km² (Molofosky et al., 1986)) and a variety of mineral resources (Santos, 1983). This combination of natural resources has led to the transformation of the region into the 'last Brazilian frontier'. During the 20th century, the Brazilian government has attempted to obtain more complete control over the region and its resources (Machado, 1991).

This paper discusses the history of land development in the Amazon, agents of land-use changes and their impacts, and environmental implications of the latest zoning program in the state of Rondônia. The most up-to-date estimates of the rate of deforestation in Rondônia are presented, showing a dramatic increase in the amount of forest lost. Together, these discussions convey the great risk that wild lands and wildlife are subject to in Rondônia.

2. History of amazon land development

Mahar (1979) divides modern planning attempts to occupy the Amazon into five historical periods. The first period began in 1912, and was centered in
the Rubber Support Plan that collapsed in 1945. At the end of World War II, a second development plan was mapped out resulting in the creation of the ‘Superintendência do Plano de Valorização Econômica da Amazônia’ (SPVEA) in 1953, which gave high priority to agricultural development to make the region self-sufficient in foodstuffs, and to expand the extraction of raw products for export and internal use. The military government, installed in 1964, imposed an intensified policy of economic development in the region providentially named ‘Operation Amazônia’. This third period revolved around the concept of creating development poles that encouraged immigration, provided incentives to private capital investment for infrastructure development, and supported research on natural resources. In 1967, a key institution called ‘Superintendência do Desenvolvimento da Amazônia’ (SUDAM) was created out of SPVEA to organize public investment in the region.

The early 1970s saw a shift in federal activity in the Amazon from economic development to occupation and physical integration within the First National Development Plan. In 1970, the Federal government established the National Integration Program (PIN). The central goal of PIN was to protect the vast interior of the nation by relocating Brazilian citizens there. The program was based on a proposed ‘terra firme’ transportation system; the largest road being the so-called Transamazon that would link the Atlantic coast to the Peruvian border. The PIN was complemented by the Land Redistribution Program (PROTERRA). The goals of PROTERRA were to facilitate land acquisition, improve rural labor conditions, and promote agroindustry in the Amazon. In terms of colonization, the goal of PIN was to settle 100,000 families (around 500,000 people) in 5 yrs along the Transamazon Highway (Bunker, 1985). However, by 1978, four years after the PIN was initiated, less than 8% of the anticipated number of colonists had been settled. Fearnside (1986) argues that several factors contributed to the failure of the Transamazon settlements including the Federal government’s failure to provide titles, lack of secure loans for agricultural inputs, inadequate governmental support to recently settled farmers, poor maintenance of roads, and the inability of forest soils to sustain agriculture.

The fifth period was characterized by the implementation of the Second National Development Plan. In 1974, in a reaction to the perceived failure of the PIN and PROTERRA, the Federal government switched its approach to support large enterprises in the cattle ranching, timber, and mining sectors through a program called POLAMAZONIA (Millikan, 1988). The approach designated 16 growth centers in the Amazon that were supported by redirecting public and private investments into areas deemed to have economic potential (Schmink and Wood, 1992; p. 78). In practical terms, most of the credit provided by POLAMAZONIA favored large cattle ranching projects. However, given the short-term productivity and high economic costs, cattle ranching projects were also abandoned by the Federal government in the late 1970s (Hecht, 1985).

3. Land development in Rondônia

Rondônia (Fig. 1), which is located in the western portion of the Brazilian Amazon, contains 243,044 km² (an area slightly larger than the former republic of West Germany) and originally had approximately 208,000 km² occupied by closed canopy rain forests. The first settlements in Rondônia occurred during two rubber boom cycles (the first in the 19th century and the second during the Second World War), but neither had a lasting impact on the occupation of that portion of the Amazon (Martine, 1990). Cassiterite (tin ore) was discovered in 1952, and it resulted in a new frenzy of extractive activity and population influx to the area (Browder, 1994). The modern rush to Rondônia which began in the late 1960s was caused by the abandonment of colonization schemes in the Transamazon and by massive expulsion of small producers in other regions of the country (Martine, 1990).

Initially, the colonization projects implemented in central Rondônia seemed to face an opposite fate to the Transamazon development project. During the 1970s, a precarious road link with Cuiabá, the capital of Mato Grosso, was established. The construction of this road represented a major turning point for migration into Rondônia (Goza, 1994). The first colonists arrived in 1971 shortly after the establishment of the PIC (Project of Integrated Colonization) in Ouro Preto. The population in Rondônia, which had been
the second lowest in the country only a few years earlier (FIBGE, 1989), suddenly rose from 69,792 in 1960 to 111,064 in 1970 (FIBGE, 1992). Despite a loss of population due to migration to other areas of the Brazilian Amazon, the 1990 census showed the Rondônia population had reached a total of 1,130,400 individuals (Perdigão and Bassegio, 1992). Table 1 shows the unprecedented population growth that occurred in Rondônia from 1950 to 1990.

The increased number of immigrants lured by the colonization settlements, coupled with an increased access to forested areas through the construction of new roads, had a strong effect on the amount and rate of deforestation. The programs of colonization established by the Brazilian government brought a continuous flow of migrants from other regions around the country. Most colonists arriving in Rondônia were expelled from properties in southern Brazil, where many were working as sharecroppers. As a result, most colonists arrived in the region without much capital that could have provided leverage for more sustainable agricultural practices. Instead, most colonists resorted to traditional shifting cultivation methods. In addition, INCRA (National Council of Colonization and Land Reform), the fed-

![Map of the State of Rondônia.](image)

**Table 1**


<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
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<tbody>
<tr>
<td>1950</td>
<td>36,935</td>
</tr>
<tr>
<td>1960</td>
<td>70,232</td>
</tr>
<tr>
<td>1970</td>
<td>111,064</td>
</tr>
<tr>
<td>1980</td>
<td>593,142</td>
</tr>
<tr>
<td>1990</td>
<td>1,130,400</td>
</tr>
</tbody>
</table>

eral agency responsible for land settlements, had established clearing as a demonstrated way of occupying land given to colonists.

The result of the combination of poorly planned policy and unfunded farmers was the rapid increase in the rate of deforestation (Fig. 2). Despite some controversy over the total amount of forest cleared in Rondônia, several studies have shown a steady increase in total deforestation. Malingreau and Tucker (1988), using data provided by the AVHRR satellite, suggested that by 1980 more than 8000 km² of forest were eliminated, increasing to 28,000 km² by 1985, and the total reached 41,000 km² by 1987. A recent study published by SEDAM (Rondônia’s Secretary of Environmental Development) using images provided by LANDSAT satellites indicates that the total deforestation in 1996 covered 48,247 km² (SEDAM/RO, 1996). More important information arising from the SEDAM study shows that after a period of decline between 1988 and 1991, the rates of deforestation are again on the rise in Rondônia (Table 2).

### Table 2

<table>
<thead>
<tr>
<th>Period</th>
<th>Rate of deforestation (km²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978–1988</td>
<td>2580</td>
</tr>
<tr>
<td>1988–1991</td>
<td>1530</td>
</tr>
<tr>
<td>1991–1993</td>
<td>2730</td>
</tr>
</tbody>
</table>

Source: SEDAM/RO, 1996.

4. Aspects of land-use change and their impacts

To understand the magnitude of the environmental problems faced by Rondônia, we discuss the different agents of land-use changes, their specific impacts on natural environments, and the cumulative impact on the region’s natural ecosystems. In Rondônia, the main actors in the process of land-use change are small farmers, cattle ranchers, miners, and loggers. The fact that these actors may eventually have different economic interests, or even compete for the same type of resource, does not preclude them from acting concurrently on many occasions. Nevertheless, it is interesting to differentiate them to better understand their combined impacts on the environment.

4.1. Small farmers

The clearing strategies adopted by small farmers have been well defined in the existing literature (Coy, 1987; Millikan, 1988). In the past, clearing of land was considered proof of land occupation by the farmers, and it triggered the widespread deforestation in the 1970s. Presently, most farmers continue clearing more forested land to guarantee continuing sources of income. Typical farmers will clear small patches of natural forest to establish a mix of annual and perennial crops and pasture (Pedlowski and Dale, 1992). These patches are irregular in terms of shape, size, and spatial distribution. The combined clearing strategies transform the natural landscape into a rather complex and fragmented one, given the fact that most farmers define the management of each individual property on a very empirical basis (Browder, 1996).

In addition, most farmers will also slash existing secondary growth to increase the area in production without having to clear more natural forest. There are several reasons for clearing, but it is mainly done because areas in secondary growth are easier to slash, and there are no environmental laws preventing their clearing. This strategy is further reinforced by the predominance of poor soils that result in a rapid decline in yields of most annual and perennial crops. Moreover, farmers prefer to establish pasture in older areas and clear natural forest to establish
annual and perennial crops. As a result, the fallow period is greatly reduced and does not permit the needed ecological regeneration in the secondary growth areas.

For example, when analyzing LANDSAT images for Theobroma (a municipality located in central Rondônia), Silva (1995) established that 46% of farmers cleared natural forest every 2 yrs. In addition, 53% of those farmers also slashed secondary growth in the same period. Moreover, the increase of area planted in pasture further indicates that the present rates of deforestation will persist. If this expansion occurs, Silva estimates that Theobroma will be totally deforested in 32 yrs. Given the similar cropping strategies observed in other studies done during the 1990s in Rondônia (Pedlowski and Dale, 1992; Browder, 1994), the scenario observed in Theobroma could reflect the trends occurring in most agricultural areas held by small farmers in the state. Simulation models predict that the current approaches to cropping will lead to almost complete deforestation in 20 yrs (Dale et al., 1994a).

The environmental effects of the clearing for small farms are multiple. The habitat loss causes many animals, especially large mammals, to be lost from the region. The small farms are spatially disaggregated, and most of the farms only have a fraction of the land cleared. Thus, there is also a great deal of fragmentation of the forested landscape. Because much of the farm clearings occur along roads that run in linear patterns, there are intact forest lands along the back of the lots that can serve as corridors for animal movements. Nevertheless, the fragmentation is severe enough that whole groups of animals have their habitats compromised. The types of animals lost are dependent upon the size of the habitat required and the ability of the animals to cross inhospitable habitats (Dale et al., 1994b).

4.2. Cattle ranchers

Cattle ranchers have less complex strategies of land clearing and use, because their major interest is to plant pasture to feed their herd. The pattern of cattle ranching in Rondônia is initiated by the activities of small farmers who clear a few hectares and establish their usual annual and perennial crops. However, in most cases, these small farmers are obligated to move when the economic returns are below a critical margin. That piece of land is then bought by another small farmer or by a more capitalized cattle rancher (Coy, 1987; Millikan, 1988). Most of the older areas around the central part of Rondônia have already experienced this pattern. Therefore, there is a clear move to land aggregation. Given the primary option for cattle raising, these larger farmers are much more prone to complete clearing. The remote sensing data corroborates this pattern. The total impact of cattle ranching on deforestation is bigger than that of small farmers because they tend to control larger areas of land. Given the low productivity of most grasses imported to the region, most cattle ranchers tend to clear large areas to feed their cattle continuously throughout the year. In addition, most cattle ranchers see efforts to protect forests as a barrier to their economic viability. Moreover, the inability of state agencies to enforce environmental laws is exacerbated by the existing political influence of cattle ranchers on top administrators inside the state. As a result, cattle ranchers are not concerned about obeying the 50% rule of the Brazilian Forestry Code (a rule stating that a farm can only clear half of his ownership). Furthermore, most large properties have much of their area under pasture, and only small portions are occupied by forested areas or secondary growth. SEDAM/RO (1996) using LANDSAT images established that between 80% and 95% of cleared areas in medium (from 250 to 1000 ha) and large properties (> 1000 ha) are occupied by pasture.

The impact of cattle ranchers on deforestation rates in Rondônia can be more clearly shown in areas where large properties are dominant. Examples of the dominance of large properties can be found in several municipalities in southern Rondônia where the settlement projects were based on the formation of large holdings, or in central Rondônia where the process of aggregation of small lots into larger farms is more advanced. In these areas, the amount of deforestation is well beyond what is allowed by the Brazilian law. Rolim de Moura, a traditional area of cattle ranching in southern Rondônia, had only 13% of natural forest, and Vale do Paraíso, a municipality considered to be the milk basin of central Rondônia had only 27% of natural forest in 1993 (SEDAM/RO, 1996).
Matricardi (1994) indicates that the size of the cattle herd has steadily grown since the 1980s. From 250,286 heads in 1980, the herd reached 2,773,896 animals in 1992, with a rate of growth of 263% between 1980 and 1992, and estimates for 1994 were 3,000,000.00 animals in the entire state. From this total, Matricardi indicates that 70% of the herd is owned by large farmers, and the remaining 30% are split by small and medium farmers. The continuous growth in the number of cows certainly will lead to further planting of pasture, given the high requirement of pasture to feed an individual cow under the ecological conditions existing in Rondônia (1.27 ha of pasture for each cow). On the other hand, small farmers and cattle ranchers have different uses for their herd. While cattle ranchers are mainly interested in raising cows for the beef market, small farmers are more interested in the milk sector.

Effects of cattle ranches on animals and their habitats is similar but more severe than the effects from farming. Because large areas of land that was originally forests are cleared and maintained in pastures, lasting habitat conversion is in place. As a result, animals that require large intact forests are lost from the region.

4.3. Miners

Among the non-agricultural activities, gold mining has become the most common option for colonists who have failed in their agricultural enterprises. Schmink and Wood (1992) believe that this fact is related to the low level of capital necessary for the nonmechanical forms of gold mining practised in the Brazilian Amazon. Not surprisingly, Coelho and Cota (1986) found that most gold miners in south Pará originate from areas where the process of land aggregation was already advanced. The increasing number of people leaving agricultural activities has been a continuous source of newcomers to mining activities. Nevertheless, the bulk of these activities is conducted outside the law which makes it even more difficult to assess their scale and intensity.

Digging for gold can be done in different ways. Lacerda et al. (1989) describing the gold rush in the Madeira River point out that it was initially a non-mechanical activity, mostly on the river and sand banks, where miners were basically using manual tools. Manual tools were rapidly followed by the use of boats and divers, and then by mechanical dredges.

The process of mining involves the release of mercury which has detrimental impacts on the aquatic life and the people who eat fish from the rivers. Mercury is present at two separate stages of gold exploration: agglutination and amalgamation (Mallas and Benedicto, 1986). The agglutination stage takes place in the riffles, where the gravel is pumped with water to be washed. The riffle is a wooden box with an inclined bottom roughly shaped like stairs. The bottom is lined with cloth—usually burlap or wool. The cloth is continuously impregnated with mercury to make fine and heavy metallic particles of the gravel agglutinate in the cloth. Large amounts of mercury are used to prevent the water from washing away the gold particles. The amalgamation process consists of mixing elemental mercury with the sediment from the riffles. This homogenous mixture is burned to separate the gold particles from other minerals present in the gravel, such as iron. An anonymous source within the Rondônia Environmental Department estimated that from 1979 to 1985 approximately 100 tons of mercury were released into the Madeira River, the major aquatic body in the state (Pfeiffer and Lacerda, 1988). Several studies conducted in Rondônia have indicated that fish and plants are heavily impacted by the process (Malm et al., 1990; Martinelli et al., 1988). The potential environmental threat of mercury arises from the fact that mercury is transformed within the aquatic systems into the lipid and water-soluble compound, monomethylmercury (CH$_3$Hg$^+$, MeHg), which can readily accumulate in biological tissue and quickly reach the upper levels of the food chain.

The physical disruption related to mining activities has an additional and striking effect on the environment when miners start digging river banks to search for gold. The destruction of river banks can alter the hydrological patterns and seriously compromise the natural ecosystems in the area where mining is occurring. This latter pattern is the one that best characterizes the present mode of operation adopted by gold miners in Rondônia since the reserves in the Madeira River were not profitable enough to justify the continuation of mining in the river itself.
4.4. Loggers

The impacts of logging in the Amazon have been well documented (Uhl and Buschbacher, 1985; Nesptad et al., 1992; Verissimo et al., 1992), and they include changes in humidity content, depletion of food resources for wild animals, and acceleration of erosion. Similar to mining, the challenge of identifying logging pressures on the land is that its impacts are not easily detected through satellite images, and are spatially dispersed. Logging also has some perverse social effects, especially on Indian communities. These effects include high levels of diseases and corruption of the leadership which have already led to the cultural and physical disintegration of several groups in Rondônia (Greenbaum, 1989).

Logging has been a widespread and unregulated activity since the 1970s when the colonization settlements were established throughout Rondônia. Unfortunately, no formal study has been done to determine the overall impact of logging in the different ecosystems existing in the region. Despite the existence of regulations that require the development of management plans for the extraction of timber, the legal procedures are largely ignored and the official control almost nonexistent. However, the importance of logging is demonstrated by a study published in 1995 by the Federação das Indústrias de Rondônia (FIERO, 1995) which shows that despite a decrease in the number of establishments in relation to a census made in 1987, sawmills and furniture builders represented 34.5% of the state industries in 1994. The fact that the natural density of marketable hardwoods is quite low in Rondônia's terra firme forests (Browder, 1994), requiring large portions of forest to be disturbed to make logging a profitable activity, is cited by FIERO as a reason for the shrinking number of sawmills in Rondônia. In addition, most existing reserves of valuable timber species are located in areas where the Rondônia Agro-Ecological Zoning (legally established in 1988) does not allow logging (e.g., Indian and extractive reserves, national and state parks, and biological reserves). As a result, most logging in the last decade has been done illegally. Logging in Rondônia is thus done without proper care. Environmental damages are greatly enhanced because heavy equipment (i.e., trucks and tractors) is often taken into work areas at a rapid pace to avoid possible apprehension by state officials. Given their important role in the region, sawmill operators, like the cattle ranchers, have a powerful influence within the state apparatus, which makes the repression of illegal logging very difficult.

A typical example of this situation is the Uru-Eu-Wau-Wau reservation (the largest Indian reservation in Rondônia). A document prepared by the Inspection Panel (World Bank, 1995) points out that the deforestation in the Uru-Eu-Wau-Wau reservation was equivalent to 126.71 km² between 1992 and 1995, and that the estimated economic losses associated with illegal logging was about US$2 million in the three-year period. The losses include loss of wildlife, direct habitat loss, indirect loss of habitat via fragmentation, and timber resources lost because only the prime species are harvested, while the rest is cut and left in place or burned.

The amount of deforestation does not entirely reflect the problems experienced by the Indian population in that area. The bulk of deforestation, as widely reported by the regional press, is related to illegal logging, which impacts not only the natural forest but also causes increased siltation in the rivers. CIMI/RO (the Indian Missionary Council) has repeatedly listed the local Indian population as the most endangered Indian group in Rondônia, because the presence of illegal loggers within the limits of the reservation not only preclude the Indians from carrying out ordinary activities such as fishing and hunting, but also because they instigate an increase of disease outbreaks (e.g., malaria, measles, tuberculosis).

5. PLANAFLORO and the possibilities and limitations of Rondônia's agro-ecological zoning

Since 1992, a program funded mainly by the World Bank has been carried out in Rondônia to curb the high levels of environmental degradation occurring in the region and develop sustainable systems of utilization of the existing natural resources. The so-called Rondônia Natural Resource Management Project (PLANAFLORO) is funded mainly through a loan of US$167 million dollars by the World Bank representing 75% of the total amount of the US loan in Brazil (the remaining 25% were to be
Table 3

<table>
<thead>
<tr>
<th>Zone</th>
<th>Land-use allowed</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intensification of agriculture, agroforestry, cattle</td>
<td>61,950</td>
</tr>
<tr>
<td>2</td>
<td>Small production in community-based units</td>
<td>30,150</td>
</tr>
<tr>
<td>3</td>
<td>Riverine: utilization of alluvial soils along margins</td>
<td>&gt;890</td>
</tr>
<tr>
<td>4</td>
<td>Extractivism: extraction of nuts, native rubber gum</td>
<td>35,000</td>
</tr>
<tr>
<td>5</td>
<td>Forestry management: selective logging</td>
<td>24,350</td>
</tr>
<tr>
<td>6</td>
<td>Conservation and permanent preservation</td>
<td>64,000</td>
</tr>
</tbody>
</table>


The stated goals of PLANAFLORO are: (a) to institute policy change at state agencies; (b) to conserve biodiversity in Rondônia; (c) to protect the boundaries of protected areas and Indian reserves; (d) to develop integrated farming and forest management systems; (e) to make priority investments in socio-economic infrastructure and services needed to implement the state’s agro-ecological zoning in areas already occupied and deforested areas; and (f) to improve the infrastructure of state institutions (World Bank, 1992). Moreover, PLANAFLORO is based upon an Agro-Ecological Zoning, which divides the state into six different ecological zones with respective types of land-uses defined for each zone (Table 3). Despite fierce opposition from local politicians and interest groups, in June 1988 the state government signed a decree making official the use of agro-ecological zoning in its development planning (it was later transformed into a state law in 1991).

Unfortunately, despite some progress in the creation of extractive reserves and restoration of limits of Indian lands, the implementation of most of the goals established throughout the initial three years of the program has faced great delays, especially those goals included in the environmental components. Moreover, the loose enforcement and protection of limits set for extractive and Indian reserves and other units of conservation has further stimulated the invasion of these conservation units by loggers, cattle ranchers, squatters, and fishermen (World Bank, 1995).

On the other hand, after a three-year delay the state has initiated studies which will define a more accurate profile of the environmental and socio-economic conditions of Rondônia. These studies will be used to redefine the area comprising each of the six zones of the state’s Agro-Ecological Zoning. There is no doubt that these studies are needed to improve knowledge on the functioning of different natural ecosystems found in Rondônia. In addition, the de facto socioeconomic dynamics have greatly diminished and compromised the validity of the original zones established in 1988. However, it is essential that a reliable set of state environmental agencies be established to guarantee the enforcement of the regulations of the different zones, because otherwise this second version will also be easily compromised. Given the strategic position of Rondônia in the economy and as a wildlife reserve for the Brazilian Amazon, the risk of further environmental deterioration would certainly be felt throughout the Amazon basin.

References


