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Colonization, Road Development and Deforestation in the Brazilian Amazon Basin of Rondonia

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Environmental Sciences Division

Publication No. 3394

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ENVIRONMENTAL SCIENCES DIVISION

COLONIZATION, ROAD DEVELOPMENT AND DEFORESTATION IN THE BRAZILIAN AMAZON BASIN OF RONDONIA[1]

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Environmental Sciences Division
Publication No. 3394

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ABSTRACT

Two decades of colonization schemes and road construction in the once-undisturbed rainforests in the Brazilian Amazon Basin of Rondonia have resulted in large-scale deforestation in that state. Attempts to colonize the Amazon began in the early 1970s with the implementation of the National Integration Program (PIN) and construction of the Transamazon Highway. The PIN failed to settle families along the Transamazon Highway, however, because planning and implementation were poor and area soils were incapable of sustaining agriculture for the settlers. By the mid-1970s, the Brazilian government decided to divert funding from Transamazonian colonization to industrial ranching operations.

The southern Amazonian state of Rondonia was successful in attracting settlers despite the fact that Transamazonian colonization, in general, had not fared too well. Rondonia was successfully colonized mainly because area soils, though not good, were much better than those along the Transamazon Highway. Migrants from the highly mechanized South, where available land was scarce, entered Rondonia at a pace with which the government could not keep up. By the late 1970s, as cattle production of large ranching companies declined because of degrading pastures, the Brazilian government redirected funds from large-scale cattle ranching to continued colonization of Rondonia by drafting and implementing a new colonization plan, the POLONOROESTE.

The Northwest Development Pole (POLONOROESTE) called for the

paving of the main highway, BR 364, which runs through central Rondonia; the development of new colonization projects; and the consolidation of older settlement projects. Because of colonization schemes and road construction, Rondonia has attracted an enormous number of immigrants, and, consequently, its population growth has shown exponential trends.

The majority of immigrants to Rondonia search for an accessible piece of forest (usually along roads or on official or unoccupied lots), slash and burn the forest, and plant agricultural crops for a few years-until the soil is too nutrient deficient to sustain agriculture. More land is then cleared to plant pastures for raising cattle, which is sustainable for 6 to 8 years. By this time, the pasture is degraded and the once-forested land is barren and incapable of sustaining any form of farming or grazing. The farmer either cuts more forest and begins the land degradation process anew or moves elsewhere. The end result is large-scale deforestation in Rondonia.

As road construction and immigration continue, deforestation will increase in Rondonia. Colonization in the Amazon is not a feasible alternative to providing landless migrants a place to farm and settle because the soils underneath the forest simply will not sustain farming. Alternatively, the costs and benefits of road building and Amazonian colonization should be critically evaluated. Better ways to address the land tenure situation of Brazil should be considered in order to slow deforestation and provide Brazilian citizens with sustainable incomes.

1. INTRODUCTION

The Amazon Basin of Brazil has the largest tract of moist tropical rainforest in the world [more than 3.3 million km^2 (Molofsky et al. 1986)]. Within the past two decades, the forests of Brazil have undergone widespread and large scale clearing. Recent estimates of cumulative deforested area in the region range from 7 to 17% of the total forested area (based on Golden 1989), with the upper bound area being larger than Madagascar. Causes of deforestation in the Brazilian Amazon vary spatially and include large cattle-ranching operations, commercial mining, hydrological development, timber extraction, and small-farmer settlement.

The clearing of tropical rainforests may have serious global and local consequences. Global effects include a decrease in biodiversity with the elimination of plant and animal species; increases in atmospheric carbon dioxide, which may affect climate; and disruption of hydrological regimes. Local effects include soil erosion, siltation, decreases in soil fertility, loss of plant cover and extractive resources, and disruption of indigenous populations.

Nowhere in the Brazilian Amazon has deforestation increased at a faster rate than in the state of Rondonia. Rondonia is located in the south central portion of the region and occupies an area (243,000 km^2) the size of West Germany. The state contains a wide range of plant and animal communities, soil types, and indigenous cultures. However, Rondonia's great cultural and biotic diversity has been threatened by large-scale deforestation.

Deforestation in Rondonia has grown at increasing rates during the past decade mainly because of official colonization schemes, road construction, and the subsequent settlement of farmers. This paper contains a historical summary of colonization and road construction in the Amazon Basin of Brazil relative to deforestation in Rondonia.

2. INITIAL PLANS FOR DEVELOPMENT OF THE BRAZILIAN AMAZON

In 1970, Brazilian President Medici announced plans for the construction of a 14,000-km network of highways to connect paved and secondary roads of the Amazon with the northeastern highway system of Brazil. At that time, the northeastern region of Brazil was suffering economically and socially from a drought. The construction of a Transamazon highway system, along with the establishment of a National Integration Program (PIN) to colonize Amazonia, was a promising solution to growing national concerns. The highways would serve as corridors for small farmer settlements and other colonization schemes in a seemingly endless supply of land and resources. This plan would provide families in the Northeast, where extreme inequalities in land ownership exist, a portion of land to farm and settle. The colonists, through agricultural and cattle raising practices, would provide a surplus of goods for widespread distribution and trade and thus would relieve much of the economic tension that the country faced. The rapid colonization of Amazonia would also be a good defense against invasion by the western bordering countries by concentrating a population of Portuguese speaking citizens along the boundaries of Brazil. In addition, the establishment of a large scale colonization program would divert attention from social and economic problems and help maintain political prestige (Moran 1984, Fearnside 1986a).

Construction of the Brazilian highway system began three months after President Medici's announcement of June 16, 1970. The new transportation system was to include five major highways (Figure 1). The largest of these would be the Transamazon Highway, which would extend from the Atlantic coast to the Peruvian border. The other major highway running east-west would be BR 210, which would parallel the Brazilian northern boundary and connect the Atlantic Coast with Colombia. The three major highways running north-south would be BR 307, which would connect Venezuela to the Brazilian state of Acre; BR 163, which would connect Cuiaba to Santarem; and the Rondonia-Manaus-Roraima highway, BR 174, which would join the Bolivian and Guiana boundaries (Goodland and Bookman 1977). In Rondonia, one major unpaved highway, BR 364, had already been constructed to connect Porto Velho with Cuiaba.

2.1 PLAN OF NATIONAL INTEGRATION FOR TRANSAMAZON COLONIZATION

The construction of the Transamazon highway system was part of larger plan of national integration, the PIN. The goal of the project was to settle 100,000 families (~500,000 people) along the Transamazon Highway in five years (Jordan 1987, Fearnside 1986a). The first step was establishment of the National Council of Colonization and Agrarian Reform (INCRA), which was given jurisdiction of all land within 150 km of international boundaries and within 100 km along each side of federal roads and highways (World Bank 1981). The

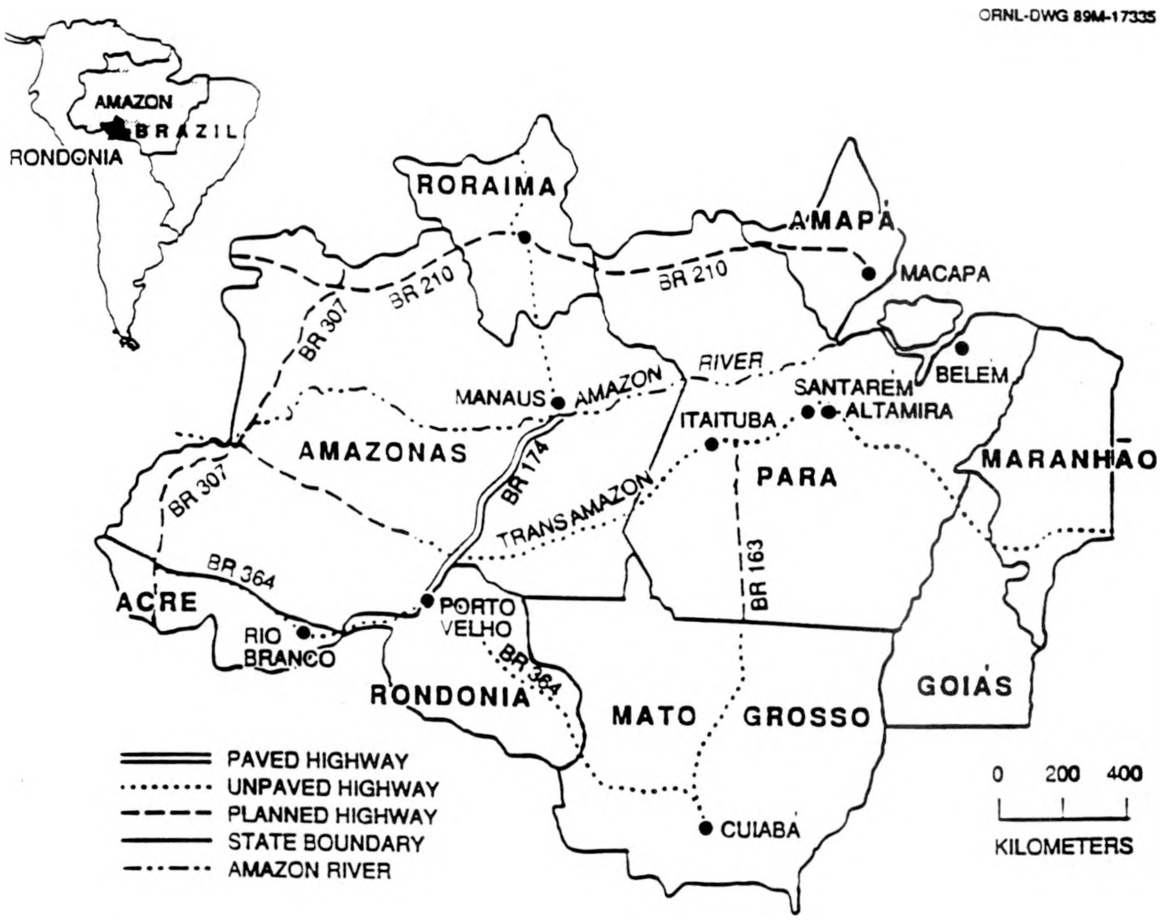

Figure 1. The Brazilian Amazon highway system in 1977. Source: Smith 1978.

goal of INCRA was to colonize different areas in the Brazilian Amazon by establishing integrated-colonization and direct-settlement projects. INCRA was in charge of surveying, selling, and distributing land for settlement; controlling conflict between segments of the rural population; and regulating the ownership and use of land in ways that would enhance agricultural and economic growth (Bunker 1980).

INCRA divided two 20 km strips of land (along each side of the Transamazon Highway) into 100-ha lots. Each lot extended 500 m along the highway and 2000 m from the highway. Every 5 km along the highway, roads were cut that extended the range of small colonies to 10 to 20 km from each side of the highway (Figure 2) (Jordan 1987, Smith 1982). Land adjacent to these secondary roads was segmented into 100 ha lots that extended 400 m along the road and 2500 m back from the road. Lots were grouped into units of 10 to 70, called glebas, which occupied about 5 km on one side of the highway (Fearnside 1986a).

INCRA sold each lot to a selected family usually for a $700 fee that was payable over 20 years and had a four-year grace period. Some families were also provided with a house for an additional $100. During the first three years of colonization, families received six payments which averaged $30 per month with which they could purchase agricultural supplies (Jordan 1987).

INCRA designed two types of colonization projects, the

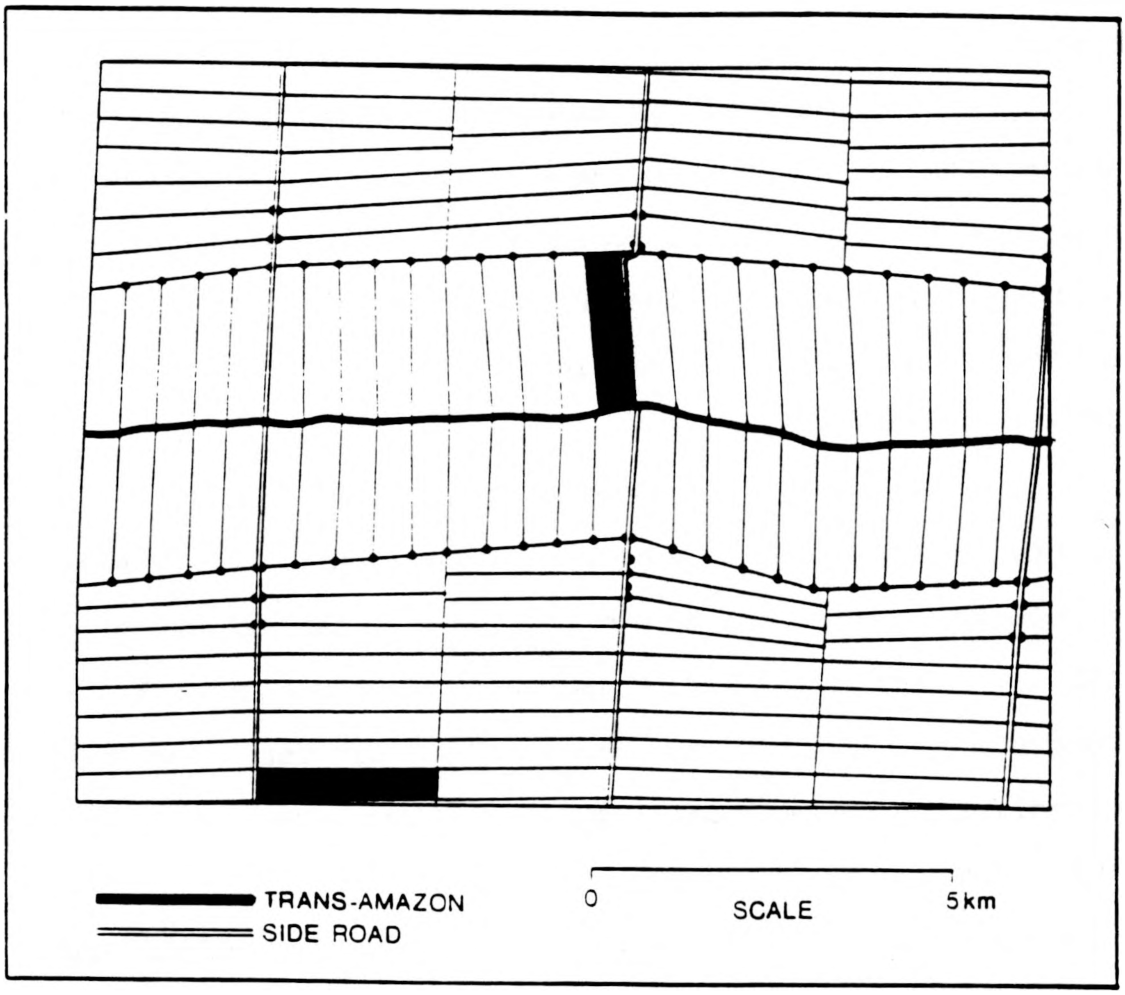

Figure 2. The pattern of lots along the Transamazon highway. Source: Smith 1982.

largest and most complex of which were the integrated colonization projects (PICs). These projects included a variety of government-provided services (post offices, police stations, medical services, etc.) in settlement areas. Colonization along the Transamazon Highway was divided into three PICs (all of which were in the state of Para) in the settlement areas of Altamira, Maraba, and Itaituba (see Figure 1 for locations). Five PIC's were also established in southern and central Rondonia in the early 1970s (Fearnside 1986a).

The direct settlement projects (PADs), planned colonization projects with nominal government assistance, were developed in Rondonia after PICs were established (Fearnside 1986a). The shift to this type of project with limited government services was the result of the high cost of establishing and maintaining PICs, along with the realization that immigrants needed little governmental incentive to colonize areas of Rondonia. Two PADs were established in Rondonia in 1974 and 1975.

The regional plan involved a hierarchical network of colonization centers (Figure 3). The smallest area of settlement was to be a village that consisted of 48 to 66 houses spaced every 10 km along the main highway and along each lateral road. These villages were to be known as agrovilas and were to include such services as a medical post, school, general store, and government offices. Most colonists

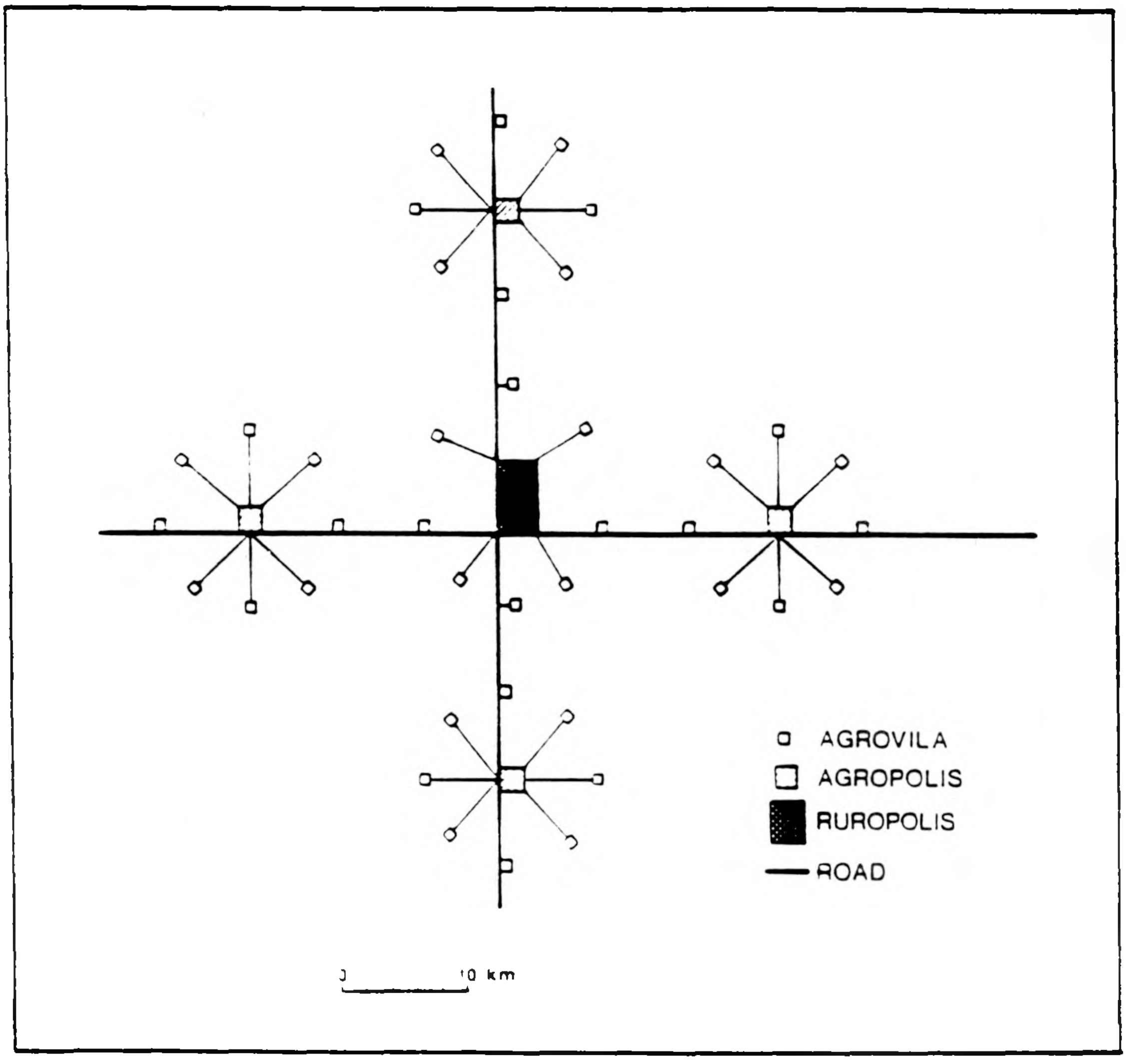

Figure 3. The regional plan for colonization along the Transamazon highway. See text for definitions. Source: Smith (1982).

living along the main road would have houses built by INCRA, but those living along lateral roads would have houses in agrovilas (Fearnside 1986a). The next largest urban center was to be the agropolis, a town composed of as many as 600 families and expected to service 8 to 10 agrovilas. According to INCRA, an agropolis was to be built every 20 km along the main highway, and each was to include a small hospital, a dental office, stores, administrative offices, and a police station (Jordan 1987). The largest urban center was to be the ruropolis, a city of as many as 20,000 people, which would serve as an administrative center to colonists living within a 140-km radius. The ruropolis was to include trade schools, banks, hotels, restaurants, a post office, telephones, and an airport (Jordan 1987, Smith 1982).

2.2 FAILURE OF TRANSAMAZON COLONIZATION

The goal of the PIN was to settle 100,000 families in three colonization areas along the Transamazon Highway by 1974. Actually, only 5717 families, a little more than 5% of the goal, were settled by December 1974 [of these families 3120 (59%) settled in Altamira] (Fearnside 1986a). Fewer than 2000 more families settled in the colonization areas by 1977 (Jordan 1987), and only 511 more families settled in the areas by 1978 (World Bank 1981). Thus, by 1978, four years after the plans were originated, fewer than 7700 families (less than 8% of the anticipated number) were settled. Only 29 agrovilas, 2 agropoli, and 1 ruropolis were constructed (Fearnside 1986a).

It had been estimated that 75% of the families settling along the Transamazon would come from the Northeast of Brazil, where a lack of available land for settling had resulted from an unequal land tenure situation. However, in Altamira, which is the largest colonization area along the Transamazon Highway, only 30% of the colonists had come from the Northeast as of 1974 (Fearnside 1986a). By December of 1978 only 41% of the colonists in all three settlement areas had come from the Northeast (Table 1). The PIN was a major disappointment to the Brazilian government.

Several factors contributed to the failure of Transamazonian colonization. The PIN program was governed by a weak administration and involved too many aspects and very little planning time. INCRA failed to provide land titles necessary for farmers to secure loans for agricultural provisions. And the quality and availability of loans decreased rapidly. For example, loans granted in 1972, compared with those granted in 1973, had grace periods of three years as opposed to none, 7% annual interest rates as opposed to 10% rates, and terms of 8 years as opposed to one year (Fearnside 1984). Governmental support, such as storage facilities and technical assistance, was inadequate. The maintenance of feeder roads necessary for transporting

Table 1. Origin of families settled by INCRA along the Transamazon, December 1978

Region	Settlement areas: Maraba	Altamira	Itaituba	Total	% total families
Northeast	1195	1520	410	3125	41
North	416	725	260	1401	18
Center-West	888	267	66	1221	16
South	46	766	234	1046	14
Southeast	490	317	74	881	11
Totals	3035	3595	1044	7674	100

Source: Smith 1982.

products and supplies was also poor (World Bank 1981, Bunker 1980).

The inability of the underlying forest soils to sustain agriculture probably slowed colonization most. The most fertile soil along the Transamazon was Terra Roxa, which accounted for only 3% of the colonization areas (Smith 1982). The remaining soils along the Transamazon were very infertile and would sustain agriculture for only 1 to 4 years. Although the availability of soil nutrients increases immediately after an area of forest is cut and burned, within a few years a rapid depletion of nutrients occurs because of erosion, leaching, and fixation of phosphorus (Jordan 1985, 1987; Moran 1981). The pattern by which the 100-ha lots were laid out did not account for such variables as soil fertility, topographic relief, soil drainage characteristics, and the availability of water (Bunker 1980). Also, many of the colonists had either no or very little agricultural experience or farm management skills. Consequently, agricultural productivity was low (Smith 1978, 1982). By 1978, 19% of the lots in Maraba and 30% of the lots in Altamira were abandoned by their original owners (Smith 1982).

2.3 SHIFT TO CATTLE RANCHING IN THE BRAZILIAN AMAZON

Because the PIN project was not achieving its objectives, the government was faced with strong recommendations to divert funding from colonization. The Superintendency for the

Development of the Amazon (SUDAM) and ranching and mining investors criticized the PIN, which received 30% of income-tax revenues, and urged the government to reallocate funds to large-scale ranching and mining operations (Bunker 1980). Large ranching companies described colonization projects as detrimental to the environment and maintained that rational practices by their companies would prevent environmental degradation. As a result, in 1974, the government published a second plan for the development of the Amazon, which established large cattle-ranching and mining corporations instead of the colonization of 100-ha lots (Fearnside 1986a, Bunker 1980).

Although more than 50% of the budget for the first plan for the development of the Amazon (PDAM I) was allocated for transportation, only 19% of the budget for the second plan (PDAM II) was allocated for transportation (Table 2). The amount of funds directed to colonization decreased from 18% of the budget for PDAM I to only 2% of the budget for PDAM II. Most of the money was shifted to supplement large-scale cattle ranching, mining, and industry, which collectively accounted for more than 40% the budget of PDAM II compared with only 2% of the budget of PDAM I (Mahar 1979).

Beginning in 1974, 3000-ha ranches were sold in previously planned colonization areas of Maraba, in areas 150 km west of Altamira, and in Rondonia. By 1977, 500 ha ranches, in strips about 30 km wide, were being sold in an

Table 2. Budget percentages by sector of the first and second plans for the development of the Brazilion Amazon

Sector	PDAM I 1972-1974	PDAM II 1975-1979
Transportation	50.8	19.1
Colonization	17.5	1.8
Agriculture	1.9	12.2
Mining	0.0	15.4
Industry	0.0	13.0
Supply	10.1	0.0
Energy	11.8	15.8
Government and urban development	0.1	1.3
Communications	1.7	2.7
Natural resource management	4.2	2.8
Housing (excl. colonization)	0.0	2.1
Health and sanitation	2.8	3.4
Education	5.1	2.0
Other	3.1	8.6

Source: Mahar 1979.

area beginning 12 km west of Altamira and extending 63 km along the Transamazon Highway (Fearnside 1986a). As fiscal incentives, SUDAM offered to refund as much as 50% of a company's yearly taxes, if that company would conduct large-scale cattle ranching, lumbering, or mining operations in Brazil (Bunker 1980). Tax incentives and other subsidies accounted for 72% of funds invested in cattle-ranching projects. Large corporations took advantage of the very generous subsidies that SUDAM offered and immediately began investing in large ranching operations.

Cattle ranching was not a new concept in the Amazon, cattle had been raised in low-lying, open, grassy areas at the mouth of the Amazon for centuries (Foresta 1990). By the late 1950s, large cattle ranches were established along the Belem-Brasilia Highway in Para and northern Mato Grosso. In the late 1960s, the Food and Agriculture Organization, the World Bank, the Inter-American Development Bank, and other institutions were involved in funding large-cattle ranching operations in tropical America (Foresta 1990). For example, in 1968, the King Ranch of Texas and the Swift Armour Company established a 72,000-ha cattle ranch in Paragominas, Para (Davis 1977, Jordan 1987). Following authorization of that ranch, many other ranchers established operations of similar sizes (Foweraker 1981, Jordan 1987). But the number of ranches established during the early 1950s and 1960s was minuscule compared with the number established during the mid-

1970s with the help of SUDAM and its policies supporting PDAM II.

By 1981, SUDAM had approved funding for 351 livestock projects that covered an area of 7,768,528 ha in the Brazilian Amazon (Table 3). More than 50% (184) of these projects were located in Mato Grosso, and 30% (105 projects) were located in Para. Only one cattle-ranching project, encompassing an area of 30,000 ha, was approved for Rondonia. By law, no investors were allowed to clear more than 50% of their land (Fearnside 1986a). Therefore, a little less than 3,900,000 ha could be cleared legally. Because of the emphasis on investment from colonization, Transamazon settlement continued to decrease. In 1976, private cooperatives made an attempt to colonize 2000 families on 200-ha plots along the Transamazon. The project, known as Cooperativa Triticola Serrana (COTRIJUI) was located 110 km west of Altamira, the largest Transamazon colonization project. However, the project was never implemented because of pressure from local Indians against colonizing the area (Fearnside 1986a).

At the same time, cattle ranchers were faced with a new environmental dilemma, pasture degradation. The soils beneath a cleared forest tract were incapable of sustaining pasture production for an extended period of time. Initial production, during the first three years after pastures were planted, was high, and weed invasion was minimal. After 3 to 5 years, the productivity of grass declined because of a rapid

Table 3. Livestock projects approved for funding by SUDAM through 1981

Political unit	Number of projects	Total ha	% of total projects
Mato Grosso	184	4,825,764	52.4
Para	105	1,780,664	29.9
Goias	23	556,728	6.6
Amazonas	18	186,760	5.1
Maranhao	10	110,873	2.8
Amapa	5	44,739	1.4
Acre	4	220,000	1.1
Rondonia	1	30,000	.3
Roraima	1	13,000	.3
Totals	351	7,768,528	99.9

Source: Foresta 1990.

decrease in soil fertility. Subsequently, weeds comprised 50% of the vegetation cover. After 5 to 10 years, the pasture was severely degraded, heavily weed infested, and no longer productive (Bushbacher 1986).

The shift to large-scale ranching was not only environmentally unsound but also diverged from the original goals of Transamazonian development. Large-scale ranching projects did not address the land-tenure situation or poverty problems of the Northeast, nor did they establish a boundary of Brazilian citizens that would protect the Amazon from its neighboring countries. Furthermore, because of short-term productivity, cattle ranching showed very little promise of improving the economic status of the country. Goodland (1980) maintained that large-scale cattle ranching had no lasting benefits for the people of Amazonia.

By late 1979, SUDAM removed incentives for new large scale ranching projects although it continued to support those already in progress (Fearnside 1985). Consequently, because of the lack of funding from the government, the growth of cattle ranching declined. Between 1978 and 1981, only 16 new ranching projects were subsidized by SUDAM. Between the time periods of 1975—1980 and 1980—1985, the rate of increase in livestock diminished from 250% to 28% in Para and from 250% to 86% in the entire Brazilian Amazon region (Table 4). By 1978, colonization was emphasized again, not along the Transamazon Highway but in the territory of Rondonia.

Table 4. Rate of increase in livestock for the time periods of 1970–1975, 1975–1980, and 1980–1985

	1970-1975 (%)	1975-1980 (%)	1980-1985 (%)
Para	30.8	250	27.6
Rondonia	.03	348	209
Acre	66.4	153	14
Regional rate of increase	32	250	86

Source: Hecht et al. 1988.

3. COLONIZATION IN RONDONIA

Unlike colonization on the Transamazon Highway, colonization in Rondonia was successful during the PIN period. A number of immigrants had moved to Rondonia after the Cuiaba-Porto Velho Road, BR 364, was cut and improved in the mid-1960s (Foresta 1990). The PIN established seven settlement projects (six along highway BR 364 and one along highway BR 425) in Rondonia between 1970 and 1975 (Table 5). The early projects were PICs—Ouro Preto, Sidney Girao, Ji-Parana, Paulo de Assis Ribeiro, and Padre Adolpho Rohl—and the two established later were PADs—Burareiro and Marechal Dutra (see Figure 4 for locations). Together, the seven projects covered more than 2.5 million ha and were equipped to accommodate nearly 23,500 families.

Colonization projects in Rondonia were structured very similarly to the three colonization projects along the Transamazon Highway. Colonization areas were segmented into 100 ha plots along BR 364 and along lateral roads, which were cut every 4 km. Feeder roads were to be built before the arrival of settlers to allow colonists access to nearby facilities such as stores and medical posts.

3.1 SUCCESS OF EARLY (1970-1980) RONDONIAN COLONIZATION

Through 1977, INCRA had settled 12,660 families in the seven colonization areas of Rondonia, compared with only 5000

Table 5. Size and capacity of INCRA settlement projects in Rondonia during the PIN period 1970–1975

Project	Year founded	Size (ha)	Family capacity
Ouro Preto	1970	512,585	5,133
Sidney Girao	1971	76,300	500
Ji-Parana	1972	479,737	4,756
Paulo de Assis Ribeiro	1973	293,560	2,974
Padre Adolpho Rohl	1975	456,366	4,341
Burareiro	1975	304,925	1,215
Marechal Dutra	1975	494,661	4,520
Totals		2,618,134	23,439

Source: World Bank 1981.

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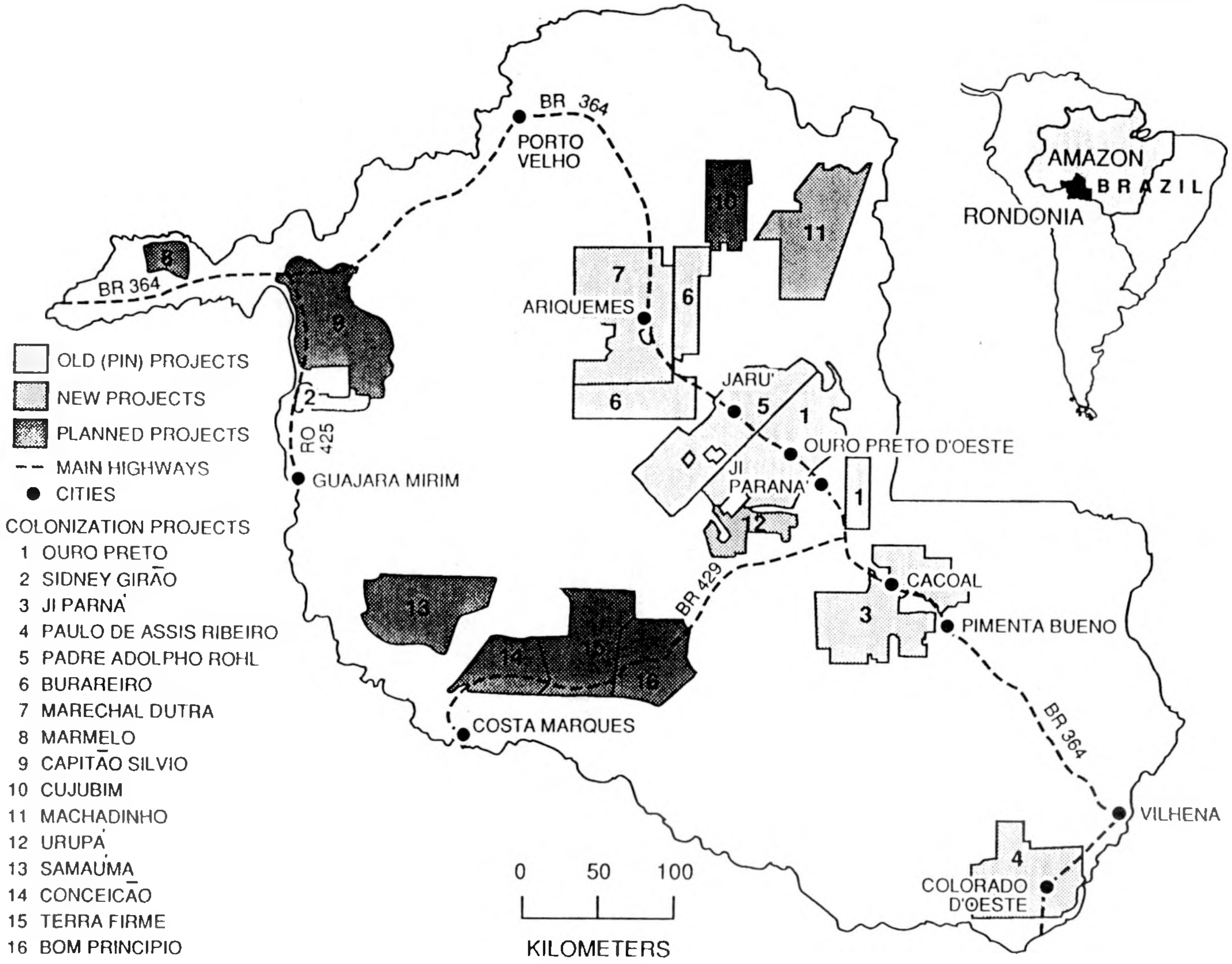

Figure 4. Map showing old, planned, and new colonization projects in Rondonia. Source: Fearnside 1987b.

to 6000 families settled on the Transamazon Highway (Fearnside 1986a). In just two years, 24,000 families had been settled in Rondonia—an amount which was beyond the estimated capacity of the seven projects (World Bank 1981). Official colonization programs could not accommodate the inflow of migrants. In September 1979, at one checkpoint between Mato Grosso and Rondonia, 7000 of the 8000 persons entering Rondonia settled there. Immigration to Rondonia averaged 2000 families per month in 1979 (Fearnside 1986a).

Rondonia attracted so many settlers because the RADAMBRASIL (Radar of Brazilian Amazonia) report had shown that soils in large areas of Rondonia were suitable for agriculture, unlike the poor soils along the Transamazon Highway (Foresta 1990). This information, along with the fact that land was cheap (or, in some cases, free), attracted a large number of migrants from the highly mechanized and consolidated South (especially from the state of Parana) who were looking for a place to settle and farm. Colonists who had either failed in farming along the Transamazon or had heard news of the failure of Transamazon colonization were also attracted to Rondonia. Foresta (1990) maintains that for every family INCRA colonized, another five families came on their own during the PIN era, and additional families came because of private colonization schemes.

Because immigration had surpassed the capacity of Rondonian official colonization projects, incoming migrants settled in areas outside of INCRA projects: along roads, on abandoned lots, or on any accessible piece of land. The increasing number of colonists caused a great deal of conflict among squatters trying to claim places to settle. Thus, titling became an important and extremely difficult task for INCRA. The area of definitive titling, which gave a person legal claim to a lot, extended 20 km along each side of the highway. Colonists who possessed a title on lots extending 20 to 40 km on either side of the highway usually had only a provisional title, which meant they had the right to work and settle the land but had no legal ownership. After a two-year period and a visit by INCRA officials, who checked the settler's progress, a family could obtain a definitive title (World Bank 1981).

If a settling family did not obtain or purchase an official title from INCRA, they could easily be driven off their land by a hostile squatter. Although INCRA had settled 24,000 families by 1979, it had issued only 14,393 titles (Table 6). Because the inflow of newcomers into the state was expected to increase, INCRA realized that the issuing of titles and settling of colonists needed to be controlled more efficiently. By 1980, the government had drafted a new colonization plan for Rondonia known as the Northwest Regional Development Pole or POLONOROESTE.

Table 6. Titles issued by INCRA in Rondonia settlement projects, 1973–1980

	Target	Total	% of Target
Ouro Preto	5,133	4,060	79
Sidney Girao	500	569	114
Ji-Parana	4,725	3,444	73
Paulo de Assis Ribeiro	2,974	2,300	77
Padre Adolpho Rohl	4,341	1,983	46
Burareiro	1,594	616	39
Marechal Dutra	4,649	1,421	31
Totals	23,916	14,393	60

Source: World Bank 1981.

environment and of indigenous populations that might be affected by the first three components of POLONOROESTE.

The investment budget for the POLONOROESTE for the years 1981 to 1985 totalled 77.3 billion cruzeiros or approximately $1.1 U.S. billion. The World Bank loaned one third of this money to the Brazilian government [$346.4 million according to Fearnside (1987a), $432 million according to Ellis (1988), over $500 million according to Foresta (1990)]. A large portion of the funding was taken from the regular budgets of federal agencies, and the rest came from allocations of the PIN, domestic loans, and other foreign loans.

3.2.1 Transportation

More than half of the POLONOROESTE budget was devoted to transportation (Table 7). The paving of BR 364 was proposed in the mid-1970s, but by 1981, only 50 km at Cuiaba, Mato Grosso and 100 km at Porto Velho, Rondonia were paved (World Bank 1981). Officially paving the highway was not heavily promoted until the POLONOROESTE, which allocated nearly $500 million to the improvement of the highway. The paving of BR 364 from Porto Velho to Cuiaba was completed by September 1984 under POLONOROESTE (Malingreau and Tucker 1988, Foresta 1990).

The construction of new feeder roads and improvement of old feeder roads were also important transportation considerations (7% of the budget). During the rainy season,

3.2 POLONOROESTE: THE 1981-1985 COLONIZATION PROJECTS

Although the success of the Rondonian PIN projects had attracted a large flow of immigrants to the state, the largest increases followed the drafting and implementation of the POLONOROESTE. The goal of the POLONOROESTE project was to "promote orderly human occupation and development (to the Northwest of Brazil) through government support of productive activities and implementation of economic and social infrastructure" (World Bank 1981). First proposed in 1979, then established in 1981, the project can be broken into four major objectives.

• The primary objective was the reconstruction and paving of BR 364, 1450 km from Cuaiba (Mato Grosso) to Porto Velho (Rondonia), along with the improvement of secondary and feeder roads stemming from it.

• The second objective was the consolidation of older settlement projects in Rondonia and establishment of new settlement projects in Rondonia and Mato Grosso.

• The third objective was the improvement of the regional land tenure situation through titling and establishing new projects in unoccupied areas.

• The last objective was the protection of the

Table 7. POLONOROESTE budget, 1981–1985 in millions of January 1981 cruzeiros

Component	Cruzeiros ($x10^6$)	% of total
Transportation	44,305	57.3
- Paving of Br 368	38,690	50.0
- Feeder Roads	5,615	7.3
Settlement of New Areas	17,813	23.0
Development of older areas	9,783	12.7
Land Tenure Services	2,179	2.8
Protection of Amerindians	1,646	2.1
Environmental Protection	791	1.0
Administration	790	1.0
Totals	77,308	100.0

Source: World Bank 1981.

these unpaved roads can become so muddy that they are impassible for as long as six months of the year (Moran 1984).

Only 45% of the targeted 7,743 km of secondary and feeder roads was constructed by 1978 in the seven PIN colonization areas (Table 8). The POLONOROESTE required INCRA to help construct 3,000 km of collector roads (1500 in Rondonia and 1500 in Mato Grosso) between 1981 and 1985. Between 1973 and 1980 the total length of roads in Rondonia increased by 1200%, and by 1986 the total length of roads increased 4100% (Stone et al. 1989).

3.2.2 Colonization

Nearly one quarter of the POLONOROESTE budget was allocated to the establishment of new colonization areas for settlement. INCRA intended to settle 30,000 families by means of the POLONOROESTE (22,000 in Rondonia and 8,000 in Mato Grosso). Colonization projects would be located along BR 364, first in Rondonia and later, in Mato Grosso. Nine projects encompassing 17,429 km^2 of land were planned by POLONOROESTE and the complimentary FINSOCIAL program, which allocated funds to colonization projects along BR 429 (Fearnside and Ferreira 1984). These projects were located along BR 364, BR 429, and BR 425 (see Figure 4 for locations).

3.2.3 Structure of New Settlement Projects

Originally, new settlement areas were to be

Table 8. INCRA Road construction in Rondonia settlement areas, 1971–1978 (km)

	Target	Total built	% of target
Ouro Preto	1770	1120	63
Sidney Girao	224	168	75
Ji-Parana	1427	623	44
Paulo de Assis Ribeiro	1003	556	55
Padre Adolpho Rohl	1300	406	31
Burareiro	896	261	29
Marechal Dutra	1123	375	33
Total	7743	3509	45

Source: World Bank 1981.

compartmentalized into 9 km x 9 km "modules" each having the capacity to settle 120 families on 45-ha plots. Later, INCRA decided the settlement design should be site specific, depending on the agricultural ability of each area and the socioeconomic characteristics of the settler population (World Bank 1981). INCRA definitely wanted to depart from the standard 100 ha plots of PIN settlement plans and decided lot size should be a function of soil fertility, topography, and availability of farm labor. INCRA also sought to enforce the 50% clearing law, which had been violated in older colonization areas, by establishing large blocks of undisturbed forest within colonization areas equal to the total combined area of individual lots.

The structure in which feeder and secondary roads were interconnected changed somewhat from the original PIN colonization plans in both old and new settlement areas. In the original PIN areas, feeder roads were spaced at 5-km intervals extending 10-20 km from the main highway, and lots were delineated along these roads. In the colonization areas specified by POLONOROESTE, road construction was not as organized. For example, in some parts of a colonization area, roads were spaced at 4-km intervals and extended 10–20 km from the main highway. In other parts, however, additional roads were cut at 4-km intervals, branched from these secondary roads, and extended parallel to the main highway. In some cases, roads stemmed from these additional roads at 4-km intervals.

Lots of varying sizes were set up along this complex network of roads. The World Bank continued to reduce the size of lots so that a greater number of families could be accommodated in an area. For instance, in the colonization area of Machadinho, lot sizes were reduced from 100 ha to 60 ha, and in Urupa to 50 ha (Fearnside 1987b) (see Figure 4 for locations). Goodland (1986) stated that lot sizes were gradually reduced to 25 ha during the course of POLONOROESTE.

Almost 13% of the POLONOROESTE budget was devoted to the improvement of conditions in the seven PIN project areas along BR 364 in Rondonia and in the 400,000-ha colonization project area in Mato Grosso. To consolidate older settlement projects, Rondonia developed a plan calling for the extension of network services from 20 to 80 km along either side of BR 364 (World Bank 1981). In the colonization areas of Ariquemes, Ji-Parana, and Conceicao (see Figure 4 for locations), 39 urban support centers (known as NARS) were financed by POLONOROESTE. The size of these support centers varied according to the size and needs of adjacent populations. The smaller centers were to be linked to larger market-oriented centers and were to provide farmers with facilities in which crops could be stored to await fair prices. The larger NARS were to provide colonists with technical assistance as well as schools; health posts; commercial districts; recreation facilities; and police, telephone and postal agencies (World Bank 1981). These larger NARS were to be similar in structure and composition to the ruropoli of the Transamazon colonization plan.

3.2.4 Titling

About three percent of the POLONOROESTE budget was allocated to INCRA to improve the land tenure situation in the region. Because it failed to issue an adequate number of titles during the PIN, INCRA focused on land titling. INCRA also wanted to give settlers who did not have definitive land titles a secure piece of land. Having a land title increased a family's chances of getting bank loans for farming supplies. INCRA also enacted a retroactive possession policy that granted land-tenure rights to established squatters who did not have titles. This policy was intended to prevent untitled farmers from being driven off their lands by more wealthy newcomers (World Bank 1981).

3.2.5 Environment

It is not surprising that the three major criticisms of POLONOROESTE are environmental destruction, disruption of indigenous populations, and project management because these elements were given the least concern. In addition, funds were directed to strengthen associated agencies instead of to develop or to implement plans that would safeguard against potential problems. Only 1.0% of the budget was allocated for environmental protection, and it is likely that this money came from the National Institute for Forestry Development's (IBDF's) regular budget. Only 2.1% of the POLONOROESTE budget was allocated to protect Indian populations. Thus, numerous conflicts emanated from establishing colonization areas and roads next to or in Indian Reserves (See Fearnside and Ferreira 1984, Foresta 1990, Brown and Stone 1989). Finally, only 1.0% of the POLONOROESTE budget was directed to project administration.

3.3 STATUS OF RONDONIAN COLONIZATION PROJECTS

As of 1986, there were sixteen old, new and planned colonization projects covering a total area of 42,427 km^2 in Rondonia (Table 9). Seven of these projects were originally implemented by PIN and encompass nearly 23,000 km^2. Two of the projects are new settlement areas regulated by POLONOROESTE. They are located in Machadinho and Urupa (see Figure 4 for locations) and occupy an area of approximately 4,500 km^2. The remaining seven are more recent or planned projects that are funded by POLONOROESTE and the complimentary FINSOCIAL program, and encompass an area of 13,000 km^2.

3.4 POPULATION CHANGES AS A RESULT COLONIZATION

INCRA colonization projects in Rondonia between 1970 and 1990 have successfully attracted migrants to the state and have caused a dramatic increase in the state's population.

Table 9. Total area and plot size for old, new, and planned colonization projects in Rondonia

Location	Area (km^2)	Plot Size (ha)
Original		
Paulo-Assis Ribeiro	3,497	100
Ji-Parana	4,510	100
Burareiro	2,742	500
Ouro Preto	4,011	100
Padre Adolfo Rohl	3,954	100
Marechal Dutra	3,659	100
Sidney Girao	622	100
Total	22,997	
New and Planned		
Urupa	985	50
Machadinho	3,997	60
Samauma	2,316	100
Capitao Silvio	3,688	100
Bom Principio	2,130	100
Terra Firme	3,137	100
Conceicao	1,617	100
Cujubim	1,427	100
Marmelo	600	40
Total	17,429	

Source: Fearnside, 1987b.

Currently, Rondonia is faced with a rate of increase in human population that shows exponential trends (Figure 5). From 1970 to 1980, there were more than 380,000 newcomers to the state, more than tripling the state's 1970 population of 111,000 (Ludwig 1985). It was estimated that the 1990 population will exceed 1 million (Almanaque Abril 1989), more than doubling the state's 1980 population. It is probable that this estimate is low because Ellis (1988) reported that newcomers are presently moving into the state at a rate of 150,000 per year, a rate that would escalate the population of Rondonia to twice that predicted for the 1990s.

These population increases are beyond the capacity of INCRA settlement schemes. Imagine, for instance, if INCRA were to divide the entire state of Rondonia, including unhabitable land and water, into 100 ha plots and settle one family on each plot. The maximum number of families that could be settled in Rondonia in this case would be 230,100. Assuming an average family size of five persons this would equate to a maximum capacity of 1.15 million people. The projected population of Rondonia should exceed this capacity before 1990.

The rapid increase in the population of Rondonia is a result of unequal distribution of people as opposed to an increase in natural growth rate. From 1970 to 1980, the growth rate of Brazil was 28%, as contrasted with the 344% growth rate of Rondonia. The growth rates of other Brazilian

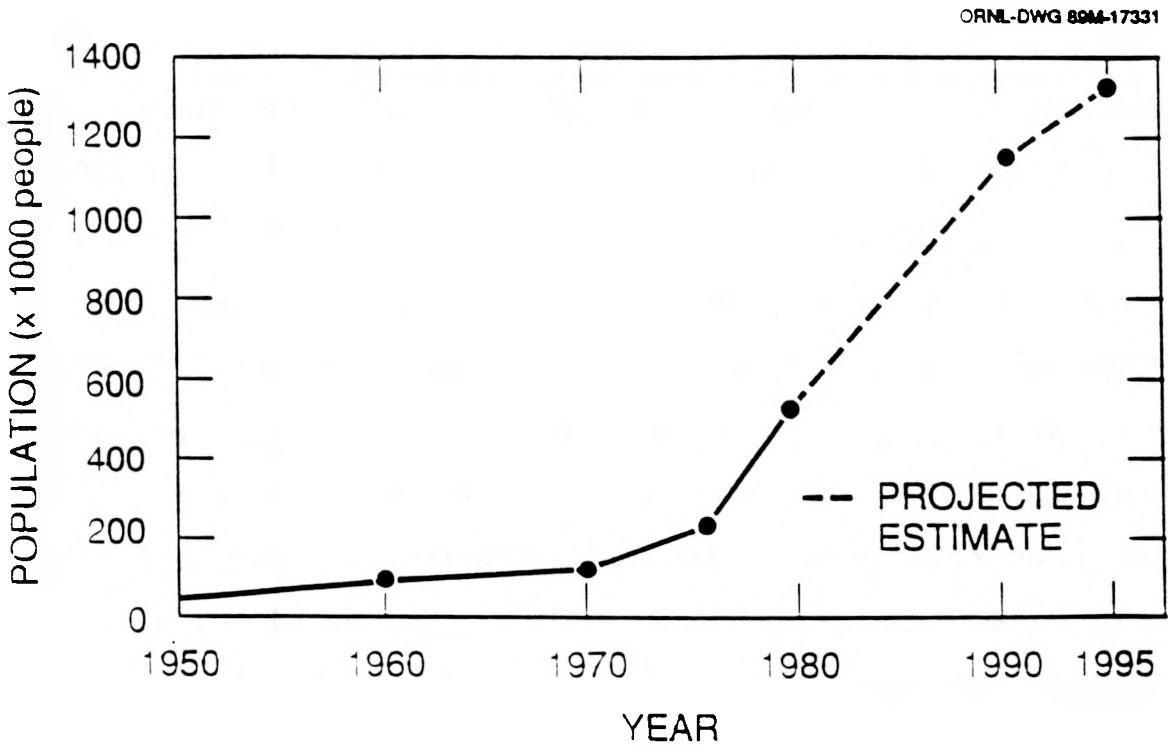

Figure 5. Population growth in Rondonia. Data for 1950, 1960, 1970, and 1980 from Ludwig (1985). Data for 1975 from Mahar (1979). Projected estimates from Almanaque Abril (1989).

Amazonian states (Table 10) are also much lower than Rondonia's, and average 59% from 1970 to 1980.

3.5 LAND USE CHANGES

Rondonia was once a large tract (208,000 km^2) of undisturbed, moist tropical rainforest. Because of official colonization schemes, building and improvement of roads, and population and economic tension in the south, the state has attracted an enormous number of migrants. These newcomers, who usually have agricultural backgrounds, slash and burn an accessible tract of forest and farm the underlying land for a few years. The result is thousands of abandoned, nutrient-deficient plots of land that cannot sustain any form of agriculture. Consequently, Rondonia has been, and is increasingly becoming, an area of changing land-use patterns and of large scale deforestation.

Because the migrant population of Rondonia is primarily young, male, and from an agricultural background, the major land use pattern in Rondonia involves small-scale farming (World Bank 1981). A government policy enforced by INCRA in Rondonia prohibited the distribution of parcels of public lands larger than 2000 ha, and caused large operators to preclude Rondonia as a potential development site (Fearnside 1983, 1986a). Consequently, the average size of farms in Rondonia is much smaller than those in other Amazonian states such as Para, Mato Grosso, and Acre.

Table 10. Population growth in the Brazilian Amazon, 1970–1980

	Population 1970 (x 1000)	Population 1980 (x 1000)	Growth 1970-1980 (%)
Para	2,167	3,412	57.5
Amazonas	955	1,432	50.0
Acre	215	302	40.5
Amapa	114	176	54.4
Rondonia	111	493	344.1
Roraima	41	79	92.7
Brazil	93,139	119,099	27.8

Source: Ludwig 1985.

Between 1975 and 1979, the number of small farms (less than 200 ha) in Rondonia rose from 4257 to 24,102 as a result of colonization (Foresta 1990). The average size of farms decreased from 230 ha in 1970 to 121 ha in 1980 and then to 75 ha in 1987 (World Bank 1981, IBGE 1987). In contrast, the average farm size in large ranching states such as Paragominas, Para was 620 ha in 1987 (IBGE 1987, Woodwell et al. 1988).

The majority (85%) of farms in Rondonia are run by owner-operators and squatters (World Bank 1981). When a plot is first occupied, a portion of the forest is cut and burned in order to clear a piece of land for farming. Areas adjacent to the road are generally cleared first, and each year the area cleared moves farther back into the lots as agricultural production decreases (Tucker et al. 1984). The most common tool for clearing is the machete, but some farmers use power saws. Small trees, vines, and understory vegetation are cut first. To ensure the area burns completely, farmers wait until the slash is as dry as possible before starting a fire (Jordan 1987). In other cases, farmers simply burn a portion of the forest and clear out bulky debris without cutting first. These burns are very rapid and may last only 15 to 30 minutes in a given area (Setzer, A.W., Instituto Nacional de Pesquizas Espaciais, Brazil, personal communication).

Although site quality influences farming methods and yields, there is a general trend in type and duration of farming on lots. During the first 1 to 4 years of farming, agricultural crops such as rice, corn, coffee, beans, or manioc (Table 11) are planted and harvested. As the soils are depleted of nutrients and crops become more susceptible to pests and disease, agriculture is no longer possible (Tucker et al. 1984, 1986). Following the decline of agriculture, many farmers plant pasture grasses to raise a small number of cattle. Eventually cattle pasture dominates the land use (Fearnside 1983, 1984). In the colonization area of Ouro-Preto in 1980, 40% of 105 lots sampled (Leite and Furley 1985) and 49% of 100 lots sampled (Lena 1982) were cattle pasture (Table 12). Newcomers taking control of abandoned or unoccupied lots are more likely to plant pasture instead of crops because pasture is much easier to farm. Also, newcomers generally have more capital than the original settlers to invest in cattle. Because cattle pastures are larger than agricultural fields, more forest is cleared. Usually land degrades 6—8 years after pasture is planted and will not sustain cattle ranching or any other type of farming. At that time, the farmer either cuts more forest and begins the land-degradation process anew or abandons the land and moves elsewhere. The result is rapid, large-scale deforestation in Rondonia.

Table 11. Key crops in Rondonia, 1978–1979

Crop	Area (x 1000 ha)	Output (x 1000 mt)
Annuals		
Rice	76.2	128.0
Corn	40.9	67.9
Beans	15.9	10.7
Manioc	10.7	144.5
Perennials		
Banana	23.9	92.0
Coffee	25.8	27.0
Cocoa	24.9	0.5
Rubber	1.0	n.a.

Source: World Bank 1981.

Table 12. Land use in the Ouro Preto colonization area of Rondonia in 1980 based on a sample survey of 105 lots

Land use	Area (ha)	% of total area	% of total land cleared
Forest	5,489	49.8	-
Pasture	2,180	19.8	39.5
Perennial crops	1,105	10.0	20.0
Capoeira*	973	8.8	17.6
Annual crops	653	5.9	11.8
Other uses	601	5.7	11.3
Total	1,1003	100.0	100.0

*Indicates secondary growth usually on abandoned lots.
Source: Leite and Furley 1985.

4. DEFORESTATION IN RONDONIA

Deforestation in Rondonia is accelerating at an increasing rate (Figure 6). Recent deforestation estimates indicate that the cumulative area deforested in Rondonia through 1987 was between 37,200 km^2 (Stone et al. 1989) and 45,400 km^2 (Setzer and Pereira 1990). Thus the total area of forest cleared by 1987 was between 15.3% and 19.7% of the total area of the state.

There is some confusion between the estimate made by Setzer and Pereira (1990) and the estimate made by Stone et al. (1989). Setzer and Pereira's (1990) deforestation estimate was based on biomass burnings for 1987, whereas Stone et al.'s (1989) deforestation estimate was cumulative through 1987. In their calculation of recent deforestation (assuming "recent" means 1987) for the entire Amazon basin, Setzer and Pereira estimated that 40% of biomass burnings was attributable to recent deforestation and that this percentage differed among Amazon states from a few percent to 100%. However, Setzer and Pereira gave no specific estimates for any of the states of the Amazon. If 40% of Rondonia's 1987 biomass burnings is associated with 1987 deforestation, then 18,000 km^2 were deforested in the state in 1987 alone, an amount, which combined with cumulative estimates made before 1987, would greatly exceed the cumulative estimate through 1987 made by Stone et al. (1989).

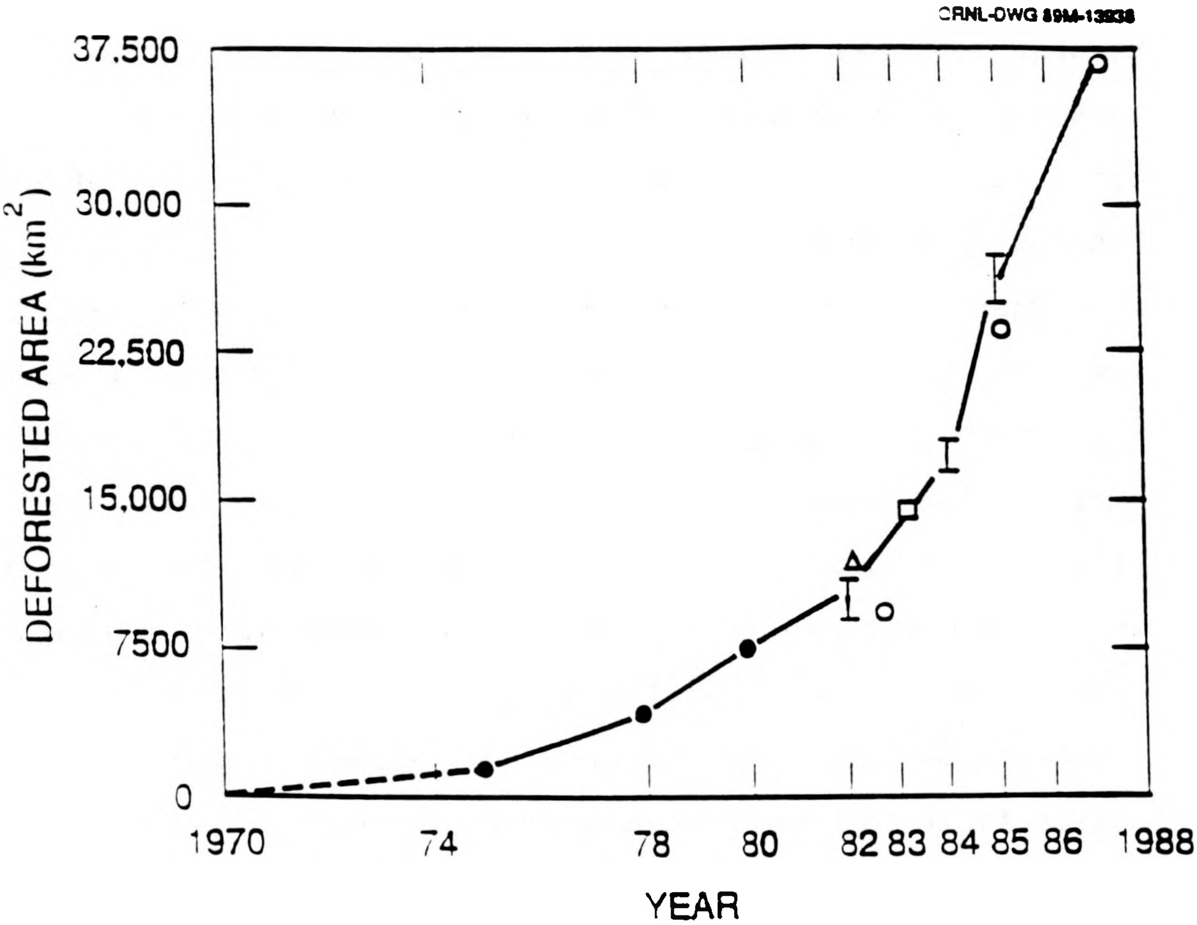

Figure 6. Deforestation in Rondonia from 1970–1987 showing the rapid increase in clearing since 1970. The 1970, 1975, and 1980 values are ground-based estimates from Tardin et al. (1979, 1980). The 1983 estimate is basen on Landsat data (Fearnside 1986b). The triangular 1982 estimate is from combined Landsat and AVHRR data (Woodwell et al. 1987). The 1982, 1984, and 1985 estimates are from AVHRR data (Malingreau and Tucker 1988) and include an error estimate of +/-1000 km^2, based on ground checking the 1985 estimate. The 1987 estimate is from AVHRR data (Stone et al. 1989).

Malingreau and Tucker (1988) stated that if rates of increase in deforestation during 1975-1985 were maintained, 50% of the forest will be gone by 1990 and all of the forest will be cleared by the year 2000.

The potential for deforestation in official colonization areas is greater than what has actually occurred. For example, in the seven original colonization areas established during the PIN era (1970—1975), 24,000 families were effectively settled by INCRA. If these families had cut 50% of their lots, as allowed by Brazilian law, 12,000 km^2 of land would have been deforested. However, by 1980, only 7600 km^2 had been deforested, which indicates that families were clearing less than 50% of the forest on their plots in the official colonization areas.

However, the largest part of settlement in the Amazon occurs outside of official colonization areas through unplanned colonization by squatters (Bunker 1980, Sawyer 1984). If 50% of all 16 official colonization areas of Rondonia was cleared, 21,200 km^2 would be deforested. Although this figure is inflated because several of the new colonization projects have not been fully initiated, it is considerably less than the most recent estimates of 37,200—45,400 km^2 of deforested land.

4.1 EFFECTS OF POPULATION ON DEFORESTATION

A comparison between the rates of population growth and deforestation suggests that the area cleared each year on a per capita basis is increasing. This difference would be expected for other states of the Amazon for which large ranching companies cause most deforestation. However, there are only a few large ranching operations in Rondonia, and most deforestation is attributed to small-farmer settlements.

In 1975, the population of Rondonia was approximately 200,000 (about 40,000 families), and about 1200 km^2 had been deforested through 1975. Thus, approximately 3 ha were deforested per family by 1975. The cumulative deforested area had increased to about 8 ha per family by 1980 and to about 18 ha per family by 1985. In interpreting these averages, it is important to consider that about 47% of Rondonians lived in the cities in 1980 (Ludwig 1985) and thus were not active in deforestation. However, the proportion of the population likely to clear forest is increasing, as the rural population of Rondonia is growing faster than the urban population (Table 13). These data suggest it is important to examine the increasing rates at which individual family lots are cleared.

4.2 CHANGES IN COLONIST CLEARING RATES

Several reasons account for the increases in clearing rates of settlers. First, clearing patterns are different between new immigrants and settlers who have already

Table 13. Urban and rural population growth in the Brazilian Amazon, 1970–1980

State or territory	Annual percent increase	
	Rural	Urban
Rondonia	17.6	14.6
Para	4.3	5.0
Amapa	3.3	5.2
Roraima	2.6	10.8
Acre	0.8	8.3
Amazonas	0.4	7.8

Source: Wood and Wilson 1984.

established properties (Fearnside 1986b). Early colonists usually practiced agriculture and sometimes switched to cattle ranching. The amount of land cleared by early landowners increased at a linear rate for 6—8 years (Figure 7), then plateaued (Fearnside 1982, 1984, 1986b). Land cleared by new colonists, however, does not follow this pattern. Newcomers often have more capital and thus greater capacities to expand. In many cases, newcomers purchase land from less-wealthy landowners and convert small agricultural fields into much-larger cattle pastures by clearing greater proportions of forest on the lots (Fearnside 1984, 1987a).

Second, an old tradition in the Amazon dictates that anyone who clears an area has possession rights to the underlying land; by clearing more forest, the squatter owns more land (Fearnside 1979). The thousands of squatters who enter Rondonia compete for land. In order to stake a claim, and secure the land from invasion by squatters, a newcomer frequently clears a large tract of forest and plants cattle pasture (Fearnside 1987a). In many cases, a settler occupies an area, clears some of the forest, and sells his squatters rights to the next newcomer, then moves somewhere else to do the same. This practice is known as poor man's speculation (Foresta 1990) and is probably most common in areas outside official colonization. The rapid increase of immigration and poor man's speculation will ensure that the amount of forest cleared on individual lots will continue to increase.

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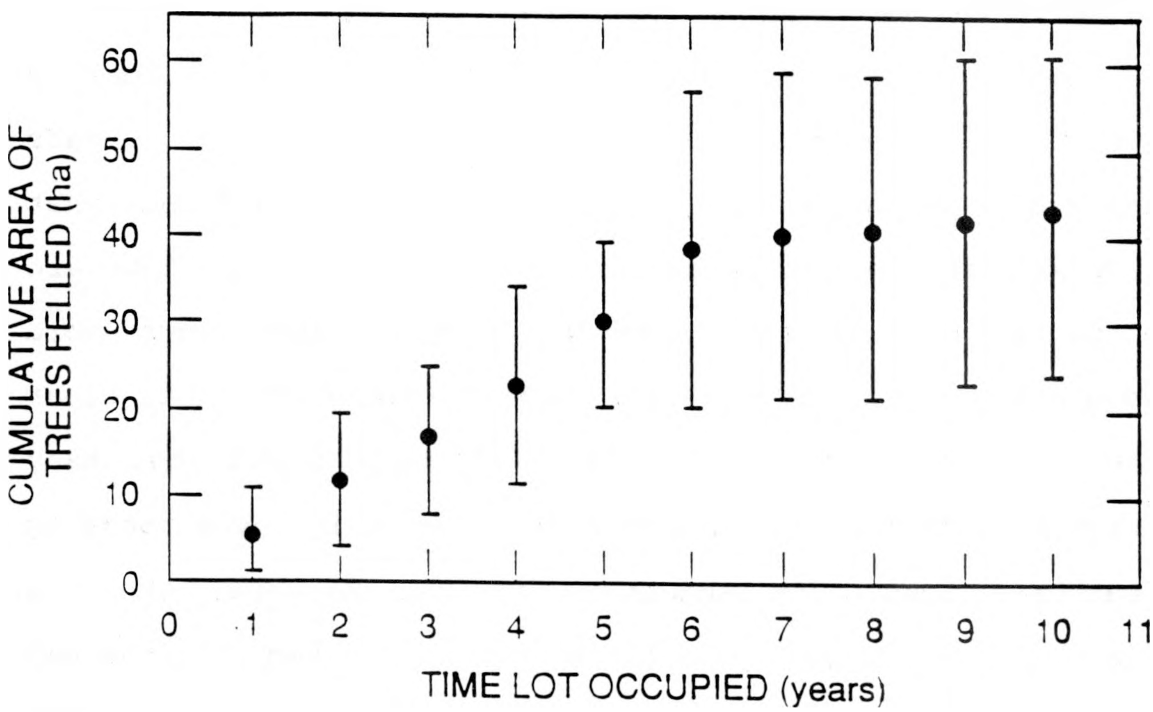

Figure 7. Cumulative tree felling by original settlers in the Ouro Preto colonization area of Rondonia based on a survey by Fearnside (1984a).

Land speculation also brings up a conflict with the 50% law: it is not possible to enforce the law outside official colonization areas and a major loophole exists in regulations pertaining to official INCRA colonization areas. Even if the law were strictly enforced to prevent settlers from clearing more than half their land, nothing in the law prevents a settler from clearing half of the land and selling the rest. Consequently, the buyer clears half of that remaining portion and sells the rest, and so on (Foresta 1990).

Another important factor causing individual clearing rates to increase is the construction and improvement of roads in areas of colonization. Fearnside (1984) pointed out that colonists increase clearing rates if roads near lots are initiated or improved. Better access makes lots more susceptible to invasion by squatters forcing settlers to clear more land to own more. Ellis (1988) maintained that many immigrants frequently cut sideroads from newly paved roads to clear large tracts for land-tenure claims. Moreover, the land value is raised, as agriculture is facilitated by improved transport of goods and supplies, and more land is cleared (Fearnside 1987a).

Regardless of how many newcomers enter Rondonia or how much forest they intend to clear, the major restriction on the extent and rate of deforestation is the accessibility of the forest. Thus, the construction of roads is the most important factor influencing deforestation.

4.3 ROAD CONSTRUCTION AND DEFORESTATION

Deforestation in the Amazon formerly was limited to areas along navigable rivers (Uhl and Bushbacher 1985). The construction of roads, however, made a greater portion of the forest accessible and thus susceptible to deforestation. The parallel between roadbuilding and deforestation in Rondonia over the past decade is shown in Figure 8. In 1979, only 1434 km of permanent roads existed in Rondonia (IBGE 1979a, 1979b). By 1988, 25,324 km of roads existed (DER 1988), an increase of over 1600% in roads. The geographic extent of the increase is shown in Figure 9.

Road construction affects deforestation in two ways, the first of which is the actual clearing of the right of way. At least 45,000 ha of deforestation is attributed directly to road cutting through 1988. Second, and most important, roads make forested land accessible to colonists, who subsequently cut a portion of the forest so they can settle along the road. This relationship between roads and deforestation, as Fearnside (1987c) pointed out, is not one of cause and effect but rather a positive feedback loop (Figure 10). As more roads are built and improved and feeder networks added, more settlers enter a given area. The presence of a larger population justifies the need for the construction of more roads; thus, the process continues and deforestation increases. An increase in road density also increases land values, stimulating colonists to sell land to newcomers, who

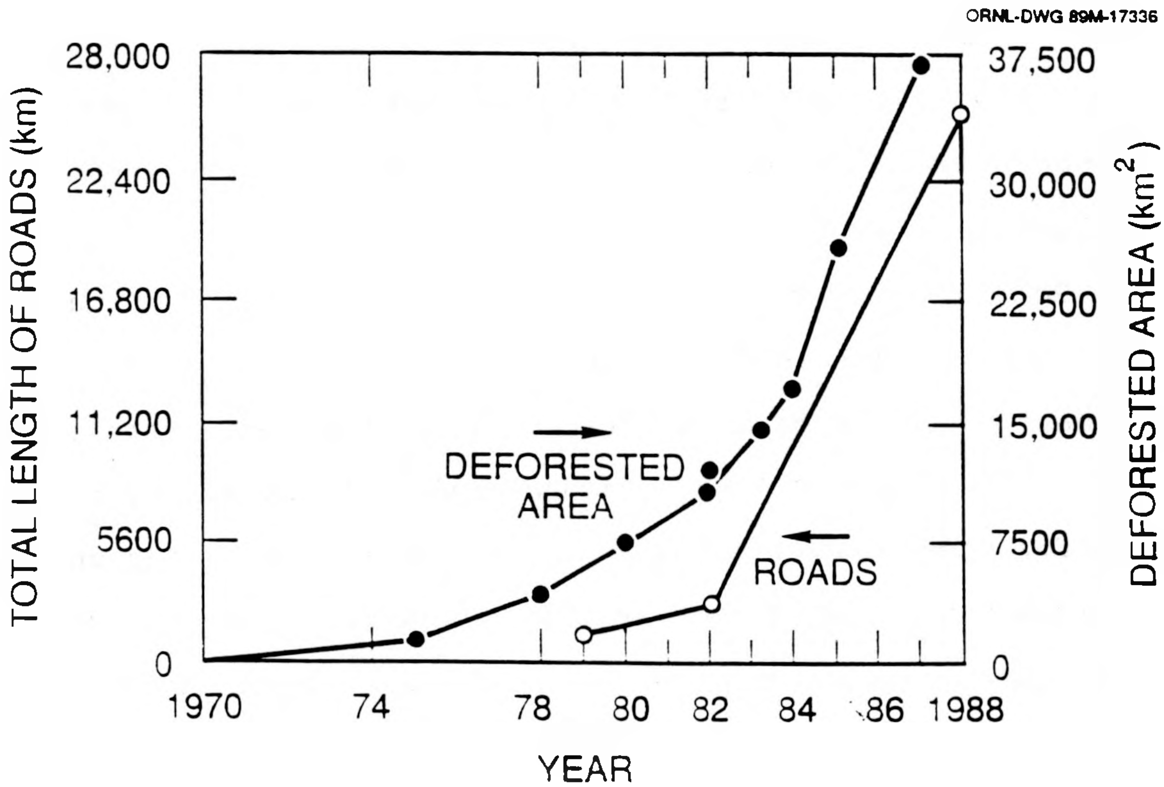

Figure 8. Increases in road construction and deforestation in Rondonia. Data for roads from IBGE (1979a, 1979b, 1982) and DER (1988). Data for deforestated area is from Figure 8.

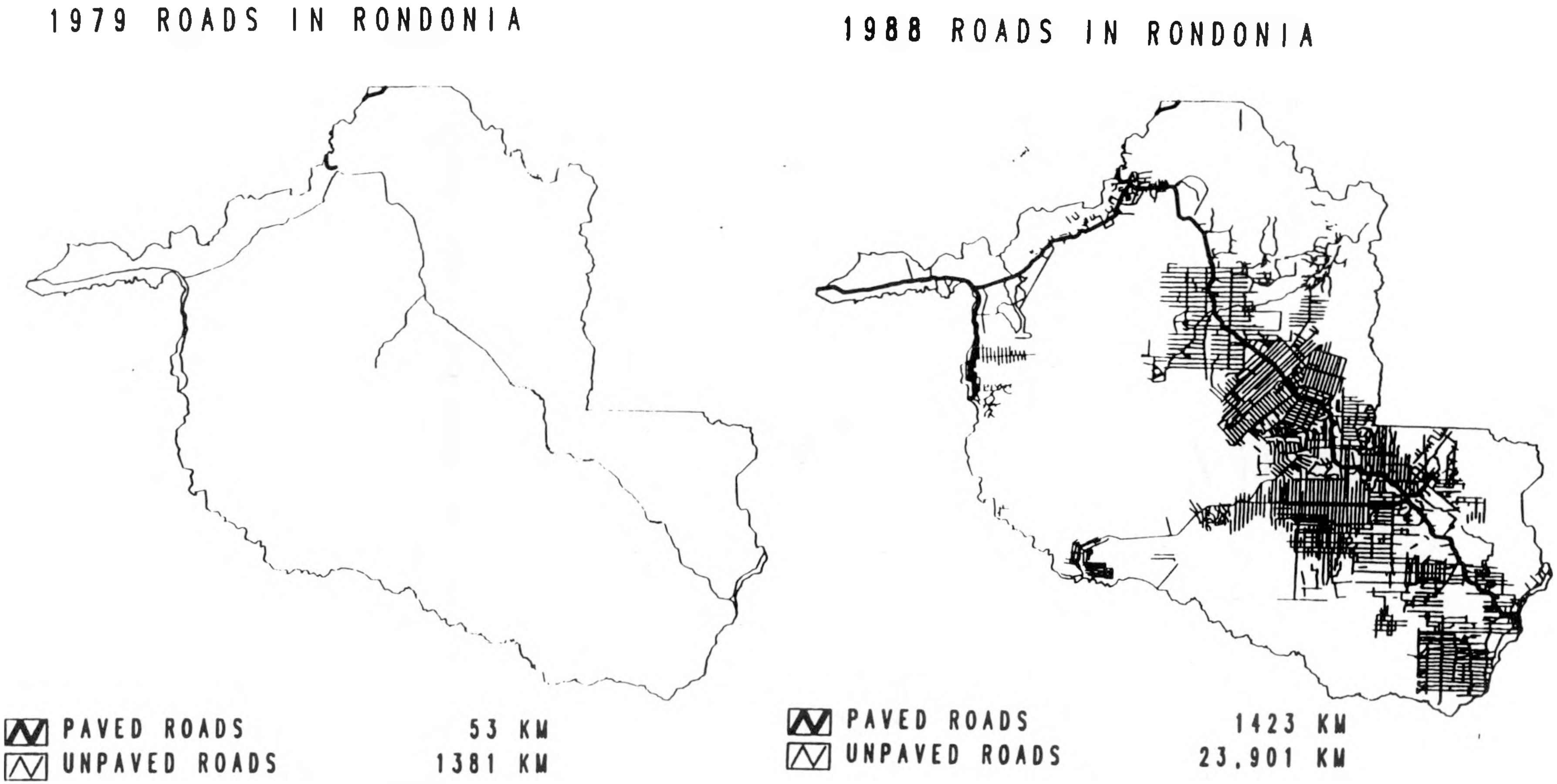

Figure 9. Increase in roads in Rondonia from 1979 to 1988. Data for 1979 from IBGE (1979a, 1979b), for 1988 from DER (1988).

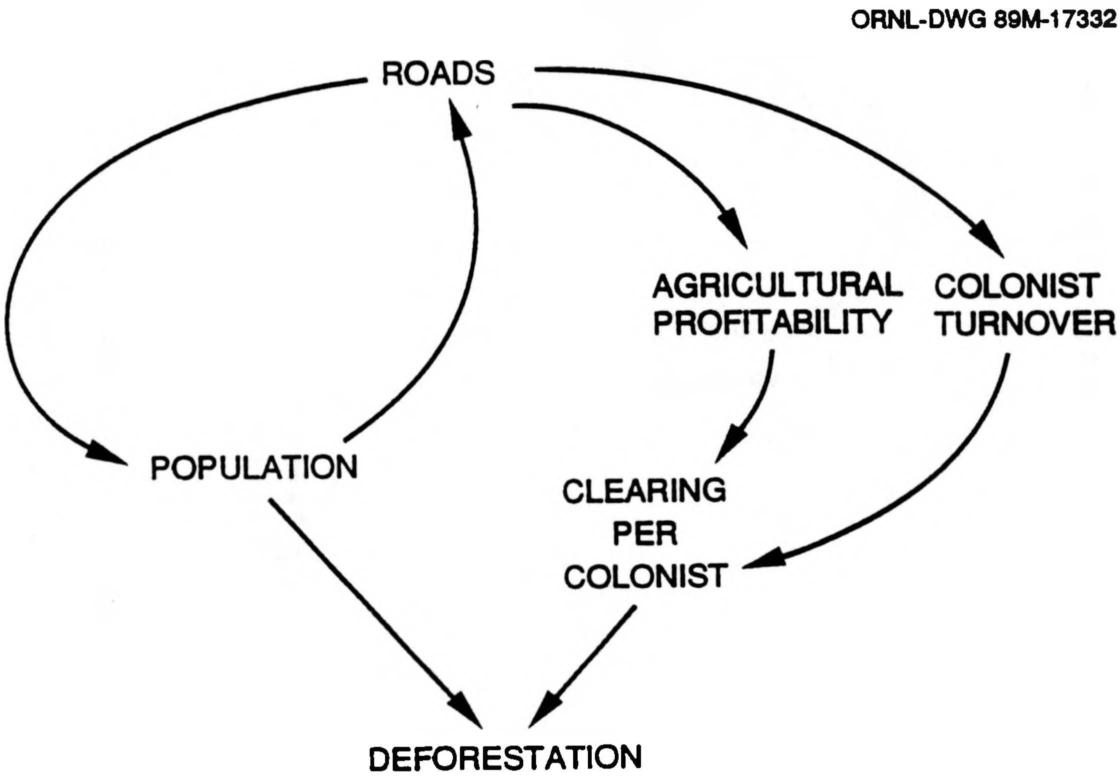

Figure 10. Positive feedback loop diagram of the relationship between road construction and deforestation. Source: Fearnside 1987c.

then clear more land than did the original owners. Moreover, roads enhance agricultural profitability, allowing the colonists to clear and farm larger areas.

A single new road can attract thousands of people to settle in the adjacent area. For instance, the town of Rolim de Moura, founded just 13 years ago has a population of 110,000. The town is accessible by only one partially paved road, which stems from Highway Br 364 (Ellis 1988). Large-scale and rapid deforestation is inevitable with improved access.

The greatest yearly increases in deforestation occurred following the paving of BR 364 from Cuiaba to Porto Velho in 1984. Deforestation in the four years before paving occurred at an average annual rate of 2400 km^2 per year but increased to an average of 6600-9400 km^2 per year in the following three years (Table 14). Before BR 364 was paved, immigration occurred only during the dry season because the highway was too muddy during the rainy season. After BR 364 was paved, however, it served as a corridor for immigration year round. An increase in the number of immigrants, coupled with an increase in the amount of accessible forest, undoubtedly had a multiplicative effect on the amount and rate of deforestation.

Although official colonization schemes and road construction initially attracted immigrants to Rondonia, most of the deforestation has occurred without governmental intent.

Table 14. **Amount and rate of deforestation for the state of Rondonia**

Year	Area Deforested (km^2)	% of total area	Rate of Deforestation (km^2/year)
1975	1200	0.5%	
			1000
1978	4200	1.8%	
			1700
1980	7600	3.3%	
			1250
1982	10,100	4.4%	
			3900
1983	14,000	6.1%	
			3300
1984	17,300	7.5%	
			8800*
1985	26,100	11.3%	
			5500-9650
1987	37,200-45,400	15.3-19.7%	

*Highway BR-364 was paved in 1984.

Source: Data for 1970, 1975, 1978, and 1980 are from Tardin et al. (1979, 1980). Data for 1983 are from Fearnside (1986b). Data for 1982, 1984, and 1985 are from Malingreau and Tucker (1988). Data for 1987 are from Stone et al. (1989) and Setzer and Pereira (1990)

The opening up of new roads has resulted in deforestation by official settlement by farmers, land speculation, settlement by squatters, and conversion of small abandoned agricultural fields into larger cattle pastures.

Regardless of intent, the forest area made accessible by a road is susceptible to numerous types of deforestation. For example, roads in Paragominas, Para that interconnected large abandoned cattle pastures are presently being used as corridors for timber extraction (Uhl and Buschbacher 1985, 1987, Buschbacher et al. 1987). As roads for logging provided continued access to the forest of Para, ranchers and squatters closely followed (Uhl and Vieira 1989). Along the Belem-Brasilia and Transamazon Highways in Para, large ranching companies moved settlers off small lots and converted areas of sporadic deforestation into tracts of large-scale deforestation (Bunker 1980). The potential for such conversion to occur in Rondonia and other settlement areas should not be overlooked. Stone et al. (1989) have reported that commercial organizations already may be clearing large tracts of forest in the Ji-Parana region in Rondonia. In 1980, Stone et al. (1989) observed only one cleared field larger than 6 km^2, but by 1986 there were 11 such fields, 6 of which were 10—20 km^2 in size, 2 of which were greater than 20 km^2.

4.5 PLANNED ROADS IN RONDONIA

The Rondonia Department of Roads and Highways (DER) and the Company for Agriculture and Cattle Ranching in Rondonia (CODARON) have produced government maps showing hundreds of kilometers of planned highways for the state (Figure 11). Many of these roads cut through American Indian and Biological Reserves (Fearnside and Ferreira 1984). These roads are major highways, and the government maps do not include details of feeder roads planned to stem from them. These roads, would provide access to new tracts of forest and attract thousands of additional immigrants, thereby increasing the rate and amount of deforestation in Rondonia.

In other parts of Amazonia as well, road development poses a major threat to the rain forests. A 58 million dollar loan from the Inter-American Development Bank (IADB), which provided for paving the highway from Porto-Velho (Rondonia) to Rio Branco (Acre) was approved on March 14, 1985 (Fearnside 1987a). The subsequent paving of the highway resulted in a dramatic flow of migrants to Acre and a significant increase in deforestation (Malingreau and Tucker 1988). Plans for 1989 include paving and improvement of this highway to the Bolivian border through a reimplemented loan from IADB.

Rondonia not only has become a state of a large population influx and massive deforestation, but now may serve as a center for distribution of people to other Amazonian states. Recently, emigrants from Rondonia have streamed into

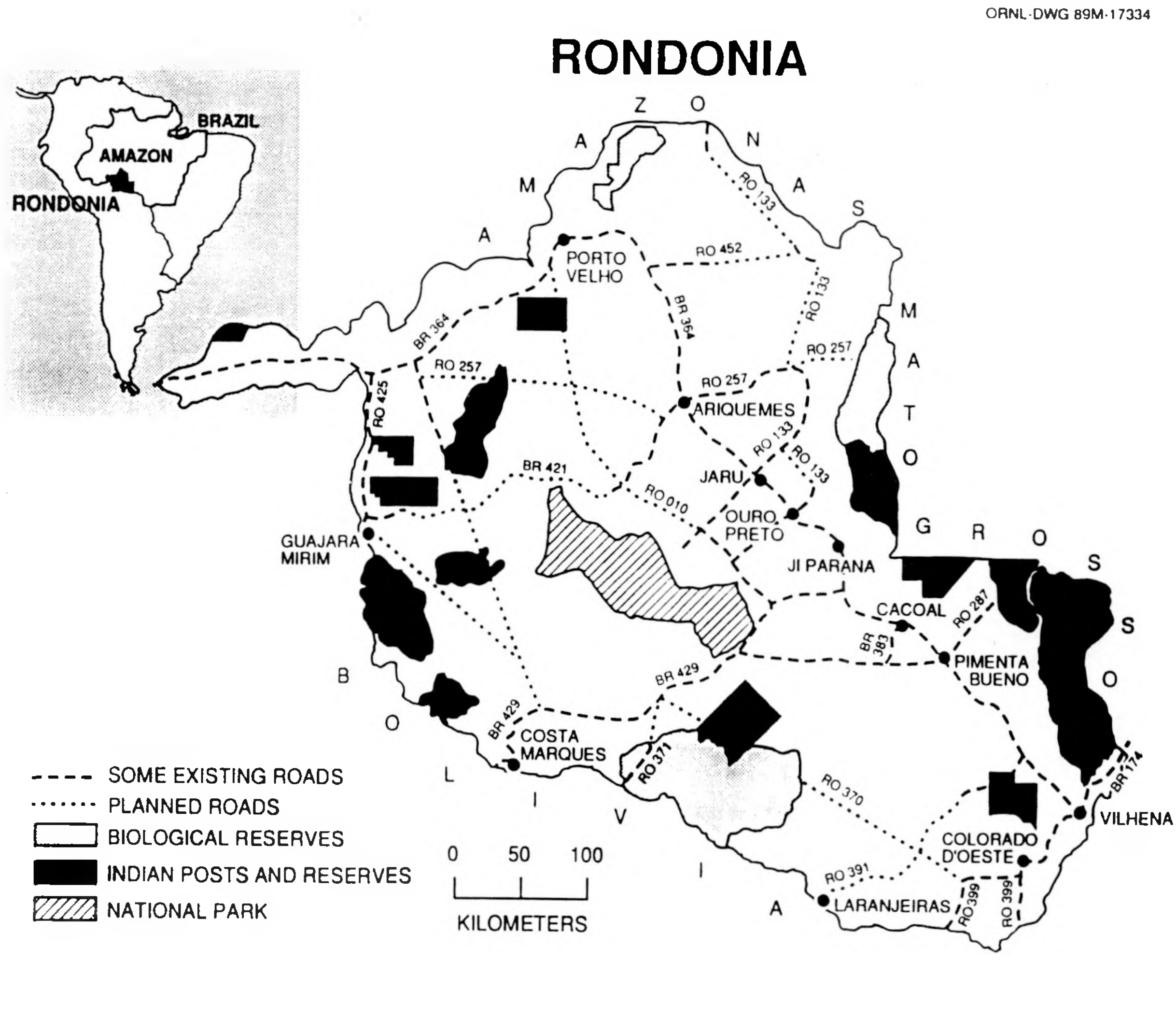

Figure 11. Map showing planned roads of Rondonia as of 1988. Some of these roads would cut through Indian and Biological Reserves. Source: Redrawn from Fearnside and Ferreira (1984) and DER (1988).

the states of Amazonas and Roraima as more land in Rondonia has been fully claimed (Fearnside 1985, 1986b, 1987a). The planned improvement of the Porto Velho-Manaus highway from Rondonia to Roraima should increase migration of landless families to Amazonas and Roraima. Although Roraima has already felt the effects of migration from Rondonia and is undergoing rapid deforestation, the government of Roraima is encouraging immigration (Fearnside 1986b). Patterns of deforestation described for Rondonia are likely to be repeated as long as these roads continue to be constructed and improved.

5. SUMMARY AND CONCLUSION

During the past two decades, official colonization schemes and road construction through the once-undisturbed forests in the Brazilian Amazon have resulted in large-scale deforestation in the region. Plans to colonize the Amazon began in the early 1970s with the construction of the Transamazon Highway from the eastern to western borders. A National Integration Program (PIN) was subsequently developed to motivate landless families from the drought and poverty stricken Northeast to settle and practice agriculture along the highway. Poor planning and implementation and, above all, the inability of soils to sustain agriculture caused the PIN to fail.

By the mid-1970s, the government of Brazil had decided to divert financial support from colonization and to large ranching operations to develop the Amazon. By the late 1970s, as pastures for cattle ranching degraded because of nutrient-deficient soils, cattle production declined and incentives for new ranching operations were removed. The government shifted development policies again, this time from large ranching operations to colonization in the state of Rondonia.

Colonization programs in Rondonia, unlike those along the Transamazon successfully attracted a large number of migrants because soil quality there, although not good, was much better than that along the Transamazon Highway. Because of official colonization plans and subsequent road construction, the population of Rondonia has been growing at an increasing rate, and migrants are settling in the state at a faster pace than the government can manage.

The majority of the migrants who enter Rondonia search for an accessible area of forest along roads or in official colonization areas, clear a tract of that forest, and farm the underlying land by planting agricultural crops. After a few years, the soil is too nutrient deficient to sustain such crops. More land is then cleared to plant pasture for cattle ranching, which is sustainable for 6 to 8 years. By then, the pasture is degraded and the once-forested land is barren and incapable of sustaining any kind of farming.

The result of numerous migrants entering Rondonia and clearing forest for farming is rapid and large-scale deforestation in the state. Current (1987) estimates of cumulative deforested area range from 16 to 19% of the state. If current rates of deforestation were to be maintained, all forested land in Rondonia would be cleared well before the year 2000.

Deforestation in Rondonia is a function of three main parameters: road development, population growth, and individual-farmer clearing rates. The construction and improvement of roads has the most influence on deforestation. As more roads are built or improved, more migrants enter a previously inaccessible area of forest and clear a portion of it for settlement. The presence of a larger population in this area justifies the construction of more roads, and the deforestation process continues. Roads increase the value of land in an area and stimulate colonists to sell land to newcomers who often have more resources than the original landowners and greater capabilities to clear more land. Also, as roads are developed in an area, agricultural profitability increases as the market becomes more available. As a result, colonists have greater incentives to clear and farm larger areas.

The rate of deforestation in Rondonia will continue to increase as more roads are constructed and provide migrants access to the forest. Accessible forest is susceptible to an array of land uses, and deforestation is inevitable. Current maps of Rondonia show hundreds of kilometers of planned highways in the state. If the planned roads were to be constructed, large scale deforestation would continue. Plans to improve highways from Rondonia to other states, such as Acre and Roraima, also would increase deforestation in these states.

There is no single solution for slowing deforestation in Rondonia and other Amazonian states. However, several steps can be taken. First, a critical evaluation of the social, economic, and ecological costs and benefits of promoting colonization in the Amazon is needed. There is more than a decade of proof that large-scale colonization in the Amazon is unsuccessful and provides only a temporary solution to the land-tenure problems of Brazil. However, the latest colonization project, Calha Norte, calls for opening up northern Amazonia for large-scale settlement (Fearnside 1989).

Better ways of addressing the land-tenure situation within the country need to be considered in order to provide landless families with a sustainable life. Environmental impacts of a settlement project must be evaluated before rather than after project implementation. Also, methods of efficient, low impact use of already cleared land need to be developed.

The enormous amount of spontaneous colonization in the Amazon must be controlled. This can be done, as Fearnside (1989) pointed out, by addressing the motives for deforestation. Land speculation is very attractive in the Amazon because anyone who clears a tract of land owns the land and can sell it. Also, pasture is classified by INCRA as an improvement of land over virgin forest, giving squatters a governmental incentive to clear land and plant pasture. Land speculation can be better controlled by taxing land sales, which would reduce the profits of squatters who continuously move from plot to plot, clear the forest, and then sell the underlying land.

Finally, the most direct way of slowing deforestation is by reducing the construction and improvement of roads. Roads attract migrants and subject large areas of undisturbed forest to deforestation. Roads, for settlement purposes, should be built in areas in which soil quality is good and farming is sustainable and should not penetrate Biological or Indian Reserves. Roads are costly to build, are expensive to maintain, and initiate activities detrimental to the environment. Until decision makers are convinced that the economic returns of road building and colonization in the Amazon are far less than the economic and environmental costs, large-scale deforestation in the Amazon will continue.

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CODARON	Company for Agriculture and Cattle Ranching in Rondonia
COTRIJUI	Cooperativa Triticola Serrana
DER	Department of Roads and Highways in Rondonia
FINSOCIAL	Complimentary program to the POLONOROESTE
IADB	Inter-American Development Bank
IBDF	Institute of Forestry Development
INCRA	National Council of Colonization and Agrarian Reform
NARS	Urban Support Centers
PDAM I	First Plan for the Development of the Amazon
PDAM II	Second Plan for the Development of the Amazon
PAD	Direct Settlement Project
PIC	Integrated Settlement Project
PIN	National Integration Program
POLONOROESTE	Northwest Regional Development Pole
SUDAM	Superintendency for the Development of the Amazon

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