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DEFORESTATION IN BRAZILIAN AMAZONIA

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ABSTRACT:

The extent and rate of rainforest clearing in Brazilian Amazonia provide ample cause for concern about the forest's future. While clearings are still small relative to the region's total area, the explosive surge of clearing in recent years has followed a pattern that would lead to disappearance of the forest within a few years if continued unchanged. Deforestation is concentrated in certain parts of the region, especially Mato Grosso, Rondônia, Acre and southern Pará.

Reasons dominating the deforestation process vary in different parts of Amazonia. Migration of small farmers is most important in Rond^nia and eastern Acre; large cattle ranchers are the principal agents elsewhere. Deforestation for cattle pasture is used by speculators to secure their claims to the land. Positive feedback relationships linking roadbuilding to population increase, profitability of agriculture, and speculative land values all lead to increased deforestation. Deforestation for low-yielding cattle pasture has also been a contributer to Brazil's high inflation, adding to the motivation for land speculation. These vicious circles fuel accelerating deforestation.

Very little stands in the way of continued rapid clearing in the region. Lack of sufficient capital and labor can temporarily slow the rate at which deforesters can realize their plans, but the deforestation process will run to completion despite any such slowing unless fundamental changes are made in the structure of the system underlying forest clearing. While many of the events in Amazonian deforestation are beyond the government's control, key points within the government's domain include the system of granting land titles on the basis of deforestation, programs of special loans and tax incentives for land uses requiring deforestation, and the construction and improvement of highways. The frenzied rate of deforestation in the region today indicates the need for speedy government action to contain the process.

DEFORESTATION PATTERNS AND TRENDS

Brazil's Amazon forest is being destroyed at a galloping rate. The seemingly endless expanse of trees that still exists can not delay the forest's destruction by more than a brief moment in historical terms. It is of little importance whether twenty or sixty years pass by before we come to the last tree. The essential point is the decision about what kind of world future generations will inherit: Will the Amazon forest survive?

The sharp disagreements concerning the area currently deforested in the Brazilian Amazon are partly rooted in the limitations of existing data and, more importantly, in interpretation of these data. The most widely-used data applying to the entire Brazilian "Legal Amazon" are taken from LANDSAT satellite images. Information from these images, however, is not up-to-date and is not reliable for areas that have been deforested for more than a few years. In addition, it is generally presented to emphasize the least alarming -- but also least important -- aspect of the results.

In 1980, Brazil's National Institute for Space Research (INPE) revealed a study of images of the Amazon taken in 1975 and 1978 (Tardin et al., 1980). This study resulted in the impression becoming widespread that only 1.55% of the Legal Amazon had been cleared, substantially underestimating the deforestation that had occurred up to that time -- a fact one can easily deduce from a comparison between results of the satellite study and what is known from direct ground observation. The *Zona Bragantina* in the state of Pará, is the best example. The 30,000 km^2 surrounding the city of Bragan,a was completely deforested by the first decades of this century by a population of colonists that furnished food, charcoal, and other products to the city of Bel'm (Egler, 1960; Sioli, 1973; Penteado, 1967). This area alone represents almost five times the area indicated as deforested by 1975 in the state of Pará (See Table 1). Disturbed areas that are not completely deforested (such as forests where loggers have removed the more valuable trees) are not easily identified in LANDSAT studies even though more recent reports refer to "altered" instead of "deforested areas." The areas that are disturbed but not yet deforested are at present relatively rare in the Amazon in comparison with other parts of the world, but this situation could change.

Although studies of LANDSAT images have underestimated the extent of deforestation in the Amazon, it is still true that clearings represent only a small fraction of the region's five million square kilometer total area. Despite Amazonia's vastness it is nonetheless finite and therefore can be destroyed. This fact becomes clear when one considers the rate of deforestation indicated by the LANDSAT data, instead of being concerned only with the area deforested at any given time.

The shape of the growth curve of the deforested area is crucial -- the most dangerous tendency is for the areas to increase exponentially. The best illustration of this is inflation. Who in Brazil ten or fifteen years ago would have imagined that prices would be hundreds of times higher today? The difficulty of intuitively understanding exponential change is great, even for we who live daily with a phenomenon such as inflation. Thus, for many people, it seems impossible that the relatively small deforested area of the Amazon today could increase within a few years to the point of encompassing the whole region. This is precisely what would occur if deforestation were to increase in an uninterrupted exponential fashion, as inflation has. The same lack of understanding caused many people to be surprised when the forests in Brazil's Central-South states disappeared in less than a generation.

To evaluate the growth curve of the deforested areas, it is necessary to measure them in successive years. In the case of the Amazon, data of this type are very scarce. One attempt (Fearnside, 1982) uses the information from LANDSAT images for three areas of INCRA (National Institute of Colonization and Agrarian Reform) colonization and one area of large cattle ranches in Rond^nia for the period 1973-1978. The data suggest that the trend is better described as exponential rather than as linear.

After the report in 1980, INPE stopped monitoring deforestation in Amazonia, passing the task to a team in Bras'lia at the Brazilian Institute of Forestry Development (IBDF). The first results for 1980 images were released in an IBDF report compiled in 1982 (for Rond^nia), and in a 1983 bulletin that included five more federative units (states and territories) in Legal Amazonia (Brazil, Minist'rio da Agricultura, IBDF, 1983). The 1980 data for Roraima, Amazonas and Amapá have not yet been released. Data for Rondônia from 1983 images became available in 1985 (Brazil, Ministério da Agricultura, IBDF, 1985; Fearnside and Salati, 1985).

The available information for each state or territory is graphed in Figure 1. To better visualize the trends, the horizontal axis of the graphs begins with the year 1970. We know that the deforested areas were relatively small at that time based on the RADAMBRASIL project's mosaic of radar images taken in 1971-1972 (Brazil, Presidência da República, DNPM, Projeto RADAMBRASIL, 1973-1979). For purposes of comparison with the later LANDSAT data we can consider the open area in 1970 to be negligible, taking into account the method's inability to identify deforested areas under old second growth, as was apparent in the case of Pará's *Zona Bragantina*. The fact that deforested areas really did exist in 1970 only increases the exponential rate implied by the graphs: deforestation actually rose more sharply than indicated by Figure 1, where the open areas in 1970 are considered zero. The axes are presented in the graphs extending to the year 1986, to remind the reader that the data already are out of date due to the extremely rapid pace of events in the region. In fact, the deforested area today could be much larger than what the 1980 data suggest.

The results presented in Figure 1 indicate explosive deforestation -- apparently exponential -- in Rondônia, Mato Grosso and Acre. If this current tendency is maintained, these states would be stripped of forests in 1990, 1989 and 1993 respectively. In two other states, Pará and Maranhão, the increase may not have been exponential, but it appears to be a little more rapid than a linear increase. In only one case, that of Goiás, is there any indication of a small deceleration of deforestation by 1980. Of the three federative units with no 1980 data available, two -- Amazonas and especially Roraima -- have received increasing fluxes of migrants from Rondônia in the last few years. Such migration greatly accelerates deforestation.

Deforestation is highly concentrated in a few foci of human activity. These foci are strongly affected, while many other areas are not significantly altered. The data indicating that only a tiny fraction of the region was deforested by 1980 are therefore quite deceptive as an indication of the impact of deforestation in the most affected zones. The deforestation foci are concentrated along the Bel'm-Bras'lia Highway (which cuts through Pará, Maranh~o and Goi's) in the states of Mato Grosso, Rond^nia and Acre, in smaller areas along the Transamazon Highway in Pará, and in the SUFRAMA (Manaus Free Zone Superintendency) Agriculture and Cattle Ranching Zone in Amazonas.

The spatial distribution of deforestation, when mapped in quadrats of one degree of latitude by one degree of longitude, shows clearly the concentration of deforestation in the areas mentioned above (Fearnside, 1986a). The routes of the principal highways in the region appear outlined in deforestation. The close association of deforestation with roads is a reflection of some of the principal causes of the current explosive trends, and also is an indication of what governmental actions would be most effective in reducing these rates.

MOTIVES FOR DEFORESTATION

The process of deforestation in Amazonia has two distinct components: the appearence of new deforestation foci, and the expansion of open areas inside already-existing foci. Within these foci there are distinct influences from establishment of more properties and from the pattern of deforestation within already-occupied properties. The kind of increase in deforested areas, therefore, depends on the history of any given place as a focus of deforestation and on the dominant forces affecting clearing in the area.

The formation of new foci has been strongly influenced by governmental decisions over the past decades. Construction of the Bel'm-Bras'lia Highway (BR-010) in 1960, its improvement for year-round traffic in 1967, and its paving in 1974 were significant milestones in creating the Amazon's largest deforestation nucleus. This focus increased significantly in recent years, especially in southern Pará and in northern Mato Grosso. Construction of the Cuiabá-Porto Velho Highway (BR-364) in 1967 initiated another focus, and its paving in 1984 has brought even more rapid expansion to the affected area.

Deforestation has been indirectly stimulated by the government in various locations through programs to attract new migrants from other parts of the country, along with the establishment of settlements and the improvement of access roads. These programs have multiplied as a result of the increase in the number of federative units in Amazonia and the elevation of old territories to the status of states. The proliferation of new political units results from interior areas of the Amazon having almost always lent their support to incumbent governments, making it advantageous for any party in power to increase the political representation of these areas. The principal criterion for creating new territories and states is increase in population, a factor leading directly to deforestation. In the early 1980's, for example, the government of Rondônia launched a campaign in the national communications media to promote the "fertile land" there (which, in reality, represents only 10% of the area, almost all in already-occupied zones). The campaign was strongest during the time just preceding transformation of that territory into a state in 1982. In April 1983, the government of Roraima published paid advertizements in Brazilian newsmagazines stating: "thanks to its very rapid growth in the last four years, Roraima is almost ready to become the twenty-fourth state of Brazil." The text explained: "this dizzying expansion is due to the policy of attracting colonists. In four years -- 1979 to today -- the government of Roraima distributed no less than one million hectares of land to ten thousand families. With this, the population has more than doubled in this period" (*Veja*, 13 April 1983).

In recent years the press has reported various government plans to create new federal territories in the southern, central and western parts of Pará and in the southwestern and western portion of

Amazonas. The most active expansion front, which seems to be passing from Rond^nia to Roraima, could easily provoke new foci in areas that have thus far hardly been touched by deforestation. The paving of the Marechal Rondon or Cuiabá-Porto Velho Highway (BR-364) in 1984, with financing from the World Bank, removed a great impediment to population flow to western Amazonia, thus increasing the probability that heretofore untouched areas in the upper Rio Solim~es (Upper Amazon) and Rio Negro drainage basins will be felled. Reconstruction and paving the BR-364 from Porto Velho (Rond^nia) to Rio Branco (Acre) began in 1986, with financing from the Interamerican Development Bank. The spread of deforestation foci to areas far removed from the current zones of most intense cutting, located on the southern and eastern edges of the Amazon region, would bring the Amazon as a whole into an accelerated phase of deforestation.

Within these foci, the pattern of deforestation depends on the prevaling type of economic exploitation. In the Brazilian Amazon, the activities of small farmers planting subsistence crops are currently small relative to the clearing of large cattle ranches. In other countries in the Amazon basin, such as Peru, the activity of small colonists has greater impact relative to that of the large landowners. Nevertheless, the small agriculturalists of the Brazilian Amazon have a strong impact on deforestation rates where these farmers are concentrated. Migration to the Amazon has elevated the rate of population increase to a level far above the national average, reaching the highest values in the places that receive the largest fluxes, such as Rond^nia. The population of Brazil's Northern Region grew at 4.9% per year (continuous exponential rate) between the censuses of 1970 and 1980, compared with 2.5% per year in Brazil and 14.9% in Rondônia! In this state the deforested area increased at a rate of 37% per year between 1975 and 1980 (Table 1), indicating that deforestation reached rates even higher than the growth of the population. This suggests that the arrival of migrants explains only a part of the phenomenon of explosive deforestation.

Even so, the arrival of more inhabitants is fundamental. Deforestation patterns in 100-hectare lots in the Ouro Preto Integrated Colonization Project (PIC) in Rond^nia are being observed as a part of INPA's "Carrying Capacity Estimation of Amazonian Agro-Ecosystems Project." In eighteen lots that had only one owner over a 10-year period, the cumulative area deforested, on the average, increased linearly until the sixth year of occupation, after which it increased much more slowly (Fig. 2; Fearnside, 1984a). The replacement of original INCRA-settled colonists by new owners who bought lots second hand has a great impact on deforestation -- the new owners increase the pace of deforestation in the years following the purchase of the lot. A comparison between 23 original colonists and 97 new colonists in the Ouro Preto PIC indicated that in the first four years after purchasing a lot, the new owner deforests, on the average, at an annual rate almost twice as great as the original colonist (Fig. 2; Fearnside, 1984a). Therefore, the process of replacing original colonists with new owners, already well on its way both in Rond^nia and on the Transamazon Highway, contributes to accelerated deforestation in these areas.

Pasture's role in the phenomenon of accelerated deforestation is central, both for small colonists and for large land owners and speculators. Even in INCRA areas in Rondônia -- where almost all of the official effort in agricultural extension, credit, and advertising is focused on promoting perennial crops -- it is pasture that occupies the greatest area. For the small colonist, planting pasture is both a cause and a result of rapid deforestation. The colonist who cuts forest for an annual crop can expect only one or two harvests before the decline in yields makes continued planting of these crops on the site less attractive than the option of cutting a new area. When annual crop production is halted in

any given field, the colonist is usually forced to choose between planting grass and temporarily abandoning the area to secondary forest. Other options, such as planting perennial crops, demand a much larger investment of labor and capital. Pasture offers the advantage, in comparison with secondary forest, of producing some income, even if only a small amount, from the cattle raised by the colonist or from leasing the pasture. Much more important is the value that pasture grass adds to a lot's price when the land is sold. A large part of the money that colonists receive as the fruit of their labors in the colonization areas comes not from the agricultural production from one year to the next, but from the eventual sale of the lot for a higher price.

Real estate speculation is one of the principal forces driving the deforestation process in the Brazilian Amazon and pasture has a central role in this system: besides increasing the value of the land of legalized lots, deforestation followed by planting pasture is the method most often used to secure land claims (Fearnside, 1983a). The system is used both by small *posseiros* (squatters), who are not always thinking of speculation afterwards, and by the large *grileiros* (land grabbers) who are attracted primarily by speculative opportunities. The centuries-old legal practice in the Brazilian Amazon is to grant the right of possession to whoever deforests a piece of land (Fearnside, 1979a). Such rights of possession are eventually transformed into full rights of ownership. Pasture represents the easiest way to occupy an extensive area, thus considerably increasing the impact of a small population on deforestation.

Land speculation in the Amazon has yielded spectacular profits in recent years, far surpassing the income obtainable from agricultural production (Mahar, 1979). The increase in land prices is linked to the function of real estate as a reserve value serving to protect the investor from inflation. The prospect of reselling the land in the future makes land buyers willing to pay prices far above those that expected production could justify. Land becomes something similar to gold or rare stamps, whose value is not based on utility as an input to production. Could it be that, in the future, the speculative values of land in the Amazon might crash, as sometimes happens with the prices of stocks? This is an important question, since the outlook for sustained production is very doubtful. The pastures being planted in Amazonia have dismal prospects for sustaining cattle production because of decline in the level of phosphorus in the soil, soil compaction, and the invasion of non-edible secondary vegetation (Fearnside, 1979b, 1980, 1985a; Hecht, 1981, 1984).

The very small reserves of mineable phosphate in the Amazon make it unlikely that the hopes of the Brazilian Enterprise for Research on Agriculture and Cattle Ranching (EMBRAPA) will be realized by improving productivity in degraded pastures in a significant portion of the region (the total area of Brazil's Legal Amazon is 5×10^6 km^2). The possibility of this vast area being planted in perennial crops, such as cacao, is also doubtful, since the capacity of world markets to absorb production is limited. Nonetheless, speculation continues without a firm basis in terms of the probable value of future production. Furthermore, the best hope of obtaining truely sustainable yields, which is the forest itself, is being destroyed in the process.

Financial incentives also continue to contribute to the deforestation of the region, despite the myth that these incentives ceased to be important following the 1979 decision of the Superintendency for the Development of the Amazon (SUDAM) to suspend approval of incentives for new cattle projects in parts of the Amazon classified as "high forest." New projects continue to be approved in the areas of "transition forest," located in the region between the Amazon forest and

the *cerrado* (Central Brazilian scrubland), contributing to intense deforestation in southern Pará and northern Mato Grosso. The old projects in the high forest area continue to receive incentives for deforestation, which in most cases was still small at the time of the policy change. The policy of denying approval to new incentives in high forest areas has not even always been followed: according to Fernando Campano (a member of the Consulting Council of SUDAM's Renewable Resources Department), a large cattle project was approved for implantation in the state of Acre, which is completely within the supposedly-protected high forest zone (F. Campano, statement at the Interciencia Association Symposium on Amazonia, Bel'm, Oct. 1983). The existence of generous governmental incentives makes it possible for many projects to continue clearing to convert forested land into pastures even after the low production of beef would have bankrupted any undertaking whose profits depended on agronomic results.

The concentration of land tenure in Amazonia also contributes to the process of deforestation. Small farmers are continually replaced by large ranchers, either through buying up blocks of contiguous small properties, or by the often violent expulsion of squatters. Deforestation increases, due both to the new owners investing more capital and to the tendency of the large landowners to plant pasture. In addition, displacement of the former occupants leads to initiating or enlarging deforestation foci in the new areas they settle.

Deforestation for subsistence production is currently of little importance in the Brazilian Amazon when compared with other factors, but it may become more significant in the future if the population continues to grow. Because settlement schemes are almost always unsustainable, even more deforestation occurs as farmers and ranchers clear new areas when production in already-cleared areas ceases. This factor is most important for subsistence production, although it also influences commercial agriculture. Increasing the output or the sustainability of agricultural systems would not necessarily decrease deforestation rates, however, because very little of the clearing now occurring in Brazilian Amazonia is the handiwork of traditional farmers who limit their activities when subsistence demands are satisfied (Fearnside, nd). Profits from the sale of agricultural production are often invested in increasing cleared areas.

Felling for commercial crop production occupies a larger area than subsistence agriculture, even in the case of food crops such as rice that are also planted for direct consumption. Loans from special financing programs have encouraged clearing, as happened in the colonization areas of the Transamazon Highway and Rond^nia, for both annual and perennial crops. In assessing the motivation for the crops planted, or of the pasture that often replaces them, the speculative value of the land is inseparable from the value of the commercial production.

Inflation and deforestation for pasture are linked in a viscious cycle of positive feedback. Money invested in establishing and maintaining cattle ranches (including the vast pyramid of support activities) creates demand for products, but low pasture yields mean that little is added to the marketplace for people to buy with the salaries they receive. Raising demand without increasing supply results in rising prices. Like any large investment that does not contribute to the economy of the country, implanting vast areas of low-productivity cattle pasture is an inflationary factor (Fearnside, 1986b). Inflation, in turn, motivates speculation in Amazonian real estate -- investments that are protected by planting more pasture.

How can these processes of Amazon forest destruction be controlled? The miniscule amount of funds and personnel currently allocated to enforce the Forestry Code in the Amazon Region indicates that the Brazilian government is not taking the task of deforestation control seriously. Infringement on parks and reserves is common whenever they stand in the way of new highways or other development projects (See Câmara, 1983; Fearnside and Ferreira, 1984; Werneck, 1983). The deforestation problem must be elevated to a higher position in the hierarchy of national priorities, but a number of obstacles would still remain even after the rationality of such a change is recognized.

One fundamental problem that impedes deforestation control is the current distribution of the costs and benefits of forest destruction. The groups and individuals that profit from deforestation are generally not the same ones that pay the resulting environmental, social and financial costs. Profits are often channeled to beneficiaries outside the Amazon region. Besides this, the benefits are concentrated, while the costs are distributed among many: this is the classic formula of the "tragedy of the commons" (Hardin, 1968). Under these conditions, destruction continues to be completely rational in economic terms even if the total cost were much greater than the benefits. On the other hand, some costs are concentrated, with the benefits accruing to larger and more influential groups, as in the case of land seized from indigenous tribes.

Another factor that impedes controling deforestation is that the benefits are monetary, while many of the costs, being environmental and human, are more difficult to quantify and translate in terms of money. The non-monetary costs, unfortunately, are no less real than the monetary ones (For a review of environmental impacts of deforestation, see Fearnside, 1985b).

The fact that felling forest brings immediate profits -- while many of the costs will only be paid by future generations -- is one of the most fundamental aspects of the problem. In the middle of the economic crisis that Brazil faced in July 1983, Rond^nia, Mato Grosso and Roraima were the only federative units whose monthly income from the Tax on Circulation of Merchandise (ICM) grew more than inflation. It is probably not a coincidence that the ICM, which is considered one of the best indices of economic activity, has increased most in areas where deforestation is most explosive. This encouraging picture of immediate profits, however, should be evaluated taking into account the heavy costs that follow massive deforestation. Use of the discount rate in economic decision-making insures that the future weighs very little when compared with any immediate profits.

The discount rate problem is part of the very structure of decision-making that renders inviable many potentially renewable systems of resource management. The discount rate -- the speed with which profits and future costs have their weight diminished in calculating the net present value of each option -- is an index that depends on the income that can potentially be earned on money in alternative investments in other locations or other sectors of the economy. No logical connection exists between the discount rate and the biological rates (such is the rate of growth of a tree in the forest) that limit the rate of return from sustained exploitation of biological resources (Clark, 1973, 1976; Fife, 1971). Rational use of the Amazon forest would generate only a slow return (Fearnside, 1983b).

Growth of the human population in the Amazon region could also frustrate any policy designed to control deforestation. Population growth is attributed to two causes: reproduction above the

mortality rate, and the entrance of new migrants. At the moment, the flow of new migrants greatly surpasses the impact of reproduction, but in the long term both must reach an equilibrium. The capacity of Amazonia to absorb population in a sustainable manner is very limited: the social problems that motivate the rush of migrants to the region must be solved in the source areas themselves (Fearnside, 1986c).

The expulsion of small agriculturalists by land concentration both in the Amazon and in other parts of the country, together with the existence of a large landless rural population, makes finding a definitive solution to the deforestation problem extremely difficult. The land tenure system in Amazonia, which is based on deforestation, would have to be modified to make using the forest possible without clearing it. Since the tradition of legalizing land claims established by means of deforestation is an important factor in alleviating the impact of extreme social inequalities and the expulsion of rural population, solutions for these problems would have to be implemented at the same time.

FUTURE PRESSURES FOR DEFORESTATION

What forces, besides the current ones, could influence Amazonian deforestation in the future? Commercial logging, which currently affects a relatively small fraction of the region, could become a substantial source of disturbance. At the moment, world markets for tropical woods are being supplied principally by destruction of forests in southeast Asia (Myers, 1980a,b; Ranjitsinh, 1979).

The Asian tropical forests are dominated by a single family of trees, Dipterocarpaceae, and almost all produce high-quality lumber. Due to their more homogeneous character, the Asian forests are much more easily used for industrial purposes than is the Amazon forest. At the current pace, the Asian tropical forests will be extinct before the end of the century, and, according to tropical wood merchants, commercial volumes of hardwood coming from Asia could be reduced to insignificant levels by the end of the current decade. This means that the large lumber firms, currently much more active in Asia than in tropical America, are likely to transfer their attention to Amazonia. Many forests intensively exploited by these firms are left in a heavily altered state with little chance of recuperation, even without having been cut down by clearcutting or burning. It is probable that this form of destruction will increase substantially in the Amazon. More advanced methods use a larger number of species to make plywood, paper pulp or other wood products would also increase the areas clearcut.

Another potential cause of large-scale destruction in the Amazon forest is the making of charcoal. This would be the case, for example, if plans are implemented to collect wood from the native forest to supply a pig-iron industry in conjunction with the Grande Caraj's Program. The charcoal plans associated with Grande Caraj's have oscillated widely. The initial scheme called for 2.4 million hectares of silvicultural plantations plus a vast network of collection points for obtaining wood from the natural forest (see Fearnside and Rankin, 1982). This was reduced to a much more modest plan sufficient to supply two pig iron plants (Brazil, Minist'rio da Agricultura, 1983; Fearnside, 1986d). In late 1985, 8 pig iron plants were approved for financial incentives from the Grande Carajás Program, with a combined capacity of 670 m tons year^{-1} for iron output and approximately the same demand for charcoal. In addition, 3 iron alloy plants and one metalurgical manganese plant, requiring lesser amounts of charcoal, were approved at the same time. According

to the head of the Grande Carajás Program, proposals awaiting approval would bring the total to 20 pig iron plants, with a combined annual demand of 1 - 1.5 million metric tons of charcoal (Francisco Sales Batista Ferreira, Personal communication, 1986). It has not yet been decided how much charcoal would be produced from silviculture and how much harvested from native forest.

In the future, deforestation due to the population concentrations associated with mining centers should increase considerably. Plans for hydroelectric projects also imply the elimination of substantial areas of forest. The hydroelectric plans seem to have given little value to the destroyed forest. For example, in the case of the Samuel dam in Rond^nia and the Balbina dam in Amazonas, the extremely shallow reservoirs will produce only about a twelfth as many kilowatts per square kilometer of forest sacrificed as in the case of the more productive Tucuru' dam in Pará.

CONCLUSION

It is clear that the range of problems that need to be solved to slow deforestation in the Amazon is enormous. Brazil must face all of these problems both present and future if destruction of the Amazon forest is to be avoided. Underlying motives for deforestation must be addressed, rather than restricting action to the more superficial symptoms.

Very little now stands in the way of massive increases in deforested areas. Limited amounts of capital, especially in Brazil's current economic crisis, can temporarily slow the rate at which deforesters are able to realize their plans, but the deforestation process will run to completion despite any such slowing unless fundamental changes are made in the structure of the system underlying forest clearing.

Many of the events in the process of Amazonian deforestation are beyond the control of the government. Decrees prohibiting deforestation would have minimal effect on land clearing decisions made by farmers or ranchers who live many kilometers from major roads and cities, and who are spread over a region as vast as Amazonia. Some key points in the system, however, are subject to government control. The granting of land titles, with its associated criteria of land "improvement" through deforestation, is entirely a government activity. The government also is responsible for the programs granting special loans and tax incentives for agriculture and ranching activities requiring felling. Above all, only the government builds highways. Were the government to build and improve less highways in Amazonia, the vicious circle of highway construction, population immigration, and deforestation would be broken.

Current deforestation rates indicate that such changes would have to be made without delay. In the face of such a daunting array of problems, paralysis is frequent: either accepting destruction as inevitable, or considering as useless any action less extreme than a complete restructuring of society. Paralysis, whatever its rationalization, is the most certain path to a future without an Amazon forest.

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LITERATURE CITED

Brazil, Ministério da Agricultura, 1983. Programa Grande Carajás, Versão Preliminar. Ministério da Agricultura, Brasília. 6 vols.

Brazil, Ministério da Agricultura, Instituto Brasileiro de Desenvolvimento Florestal (IBDF). 1983. Desenvolvimento Florestal no Brasil, Proj. PNUD/FAO/BRA-82-008. Folha Informativa No. 5.

Brazil, Ministério da Agricultura, Instituto Brasileiro de Desenvolvimento Florestal (IBDF). 1985. Alteração da cobertura vegetal natural do Estado de Rondônia. Map scale: 1: 1,000,000. IBDF, Brasília.

Brazil, Ministério das Minas e Energia, Departamento Nacional de Produção Mineral (DNPM), Projeto RADAMBRASIL. 1973-79. Levantamento de Recursos Naturais. DNPM, Rio de Janeiro. 23 vols.

Câmara, I. de G. 1983. Araguaia: Uma estrada contra o parque. Ciência Hoje 1(4): 67-68.

Clark, C.W. 1973. The economics of overexploitation, Science 181, 630-634.

Clark, C.W. 1976. \Mathematical Bioeconomics: the Optimal Management of Renewable Resources, Wiley-Interscience, New York, 352 pp.

Egler, E.G. 1961. A Zona Bragantina do Estado do Pará, Revista Brasileira de Geografia 23(3): 527-555.

Fearnside, P.M. 1979a. The development of the Amazon rain forest: Priority problems for the formulation of guidelines. Interciencia 4(6): 338-343.

Fearnside, P.M. 1979b. Cattle yield prediction for the Transamazon Highway of Brazil. Interciencia 4(4): 220-225.

Fearnside, P.M. 1980. The effects of cattle pastures on soil fertility in the Brazilian Amazon: Consequences for beef production sustainability. Tropical Ecology 21(1): 125-137.

Fearnside, P.M. 1982. Deforestation in the Brazilian Amazon: How fast is it occurring? Interciencia 7(2): 82-88.

Fearnside, P.M. 1983a. Land use trends in the Brazilian Amazon Region as factors in accelerating deforestation. Environmental Conservation 10(2): 141-148.

Fearnside, P.M. 1983b. Development Alternatives in the Brazilian Amazon: An Ecological Evaluation. Interciencia 8(2): 65-78.

Fearnside, P.M. 1984a. Land clearing behaviour in small farmer settlement schemes in the Brazilian Amazon and its relation to human carrying capacity. pp. 255-271 In: A.C. Chadwick and S.L. Sutton (eds.) Tropical Rain Forest: The Leeds Symposium. Leeds Philosophical and Literary Society, Leeds, U.K. 335 pp.

Fearnside, P.M. 1984b. A floresta vai acabar? Ciência Hoje 2(10): 42-52.

Fearnside, P.M. 1985a. Agriculture in Amazonia. pp. 393-418 In: G.T. Prance and T.E. Lovejoy (eds.) Key Environments: Amazonia. Pergamon Press, Oxford, U.K. 442 pp.

Fearnside, P.M. 1985b. Environmental Change and Deforestation in the Brazilian Amazon. pp. 70-89 In: J. Hemming (ed.) Change in the Amazon Basin: Man's Impact on Forests and Rivers. Manchester University Press, Manchester, U.K. 222 pp.

earnside, P.M. 1986a. Spatial concentration of deforestation in the Brazilian Amazon. Ambio 15(2): 81-74.

Fearnside, P.M. 1986b. Causes of deforestation in the Brazilian Amazon. In: R.F. Dickinson (ed.) Geophysiology of Amazonia: Vegetation and Climate Interactions. John Wiley and Sons, New York. (In press).

Fearnside, P.M. 1986c. Human Carrying Capacity of the Brazilian Rainforest. Columbia University Press, New York. 293 pp.

Fearnside, P.M. 1986d. Agricultural plans for Brazil's Grande Carajás Program: Lost opportunity for sustainable development? World Development 14(3): 385-409.

Fearnside, P.M. nd. Continuous cultivation in Amazonia: Rethinking the "Yurimaguas Technology." BioScience (in press).

Fearnside, P.M. and G. de L. Ferreira. 1984. Roads in Rondonia: Highway construction and the farce of unprotected forest reserves in Brazil's Amazonian forest. Environmental Conservation 11(4): 358-360.

Fearnside, P.M. and J.M. Rankin. 1982. Jari and Caraj's: The uncertain future of large silvicultural plantations in the Amazon. Interciencia 7(6): 326-328.

Fearnside, P.M. and E. Salati. 1985. Explosive deforestation in Rond^nia, Brazil. Environmental Conservation 12(4): 355-356.

Fife, D. 1971. Killing the goose. Environment 13(3): 20-27.

Hardin, G. 1968. The tragedy of the commons, \Science\ 162, 1243-1248.

Hecht, S.B. 1981. Deforestation in the Amazon basin: Practice, theory and soil resource effects.

Studies in Third World Societies 13, 61-108.

Hecht, S.B. 1984. Cattle ranching in Amazonia: Political and ecological implications. pp. 366-398. In: M. Schmink and C.H. Wood (eds.) Frontier Expansion in Amazonia. University Presses of Florida, Gainesville. 502 pp.

Mahar, D.J. 1979. Frontier Development Policy in Brazil: A Study of Amazonia. Praeger, New York, 182 pp.

Myers, N. 1980a. Conversion of Tropical Moist Forests. National Academy of Sciences Press, Washington, D.C., 205 pp.

Myers, N. 1980b. The present status and future prospects of tropical moist forests. Environmental Conservation 7(2): 101-114.

Penteado, A.R. 1967. Problemas de Colonização e de Uso da Terra na Região Bragantina do Estado do Pará. Universidade Federal do Pará, Belém. 488 pp.

Ranjitsinh, M.K. 1979. Forest destruction in Asia and the South Pacific. Ambio 8(5): 192-201.

Sioli, H. 1973. Recent human activities in the Brazilian Amazon Region and their ecological effects. pp. 321-334 In: B.J Meggers, E.S. Ayensu and W.D. Duckworth (eds.) The Tropical Forest Ecosystem in Africa and South America: A Comparative Review. Smithsonian Institution Press, Washington, D.C., 350 pp.

Tardin, A.T., D.C.L. Lee, R.J.R. Santos, O.R. de Assis, M.P. dos Santos Barbosa, M. de Lourdes Moreira, M.T. Pereira, D. Silva and C.P. dos Santos Filho. 1980. Sub projeto Desmatamento, Convênio IBDF/CNPq-INPE 1979. Instituto Nacional de Pesquisas Espaciais-INPE, Relatorio INPE-1649-RPE/103, São Paulo, São José dos Campos, 44 pp.

Werneck, H.F. 1983. A quem serve a nova estrada? Ciência Hoje 1(4): 68-69.

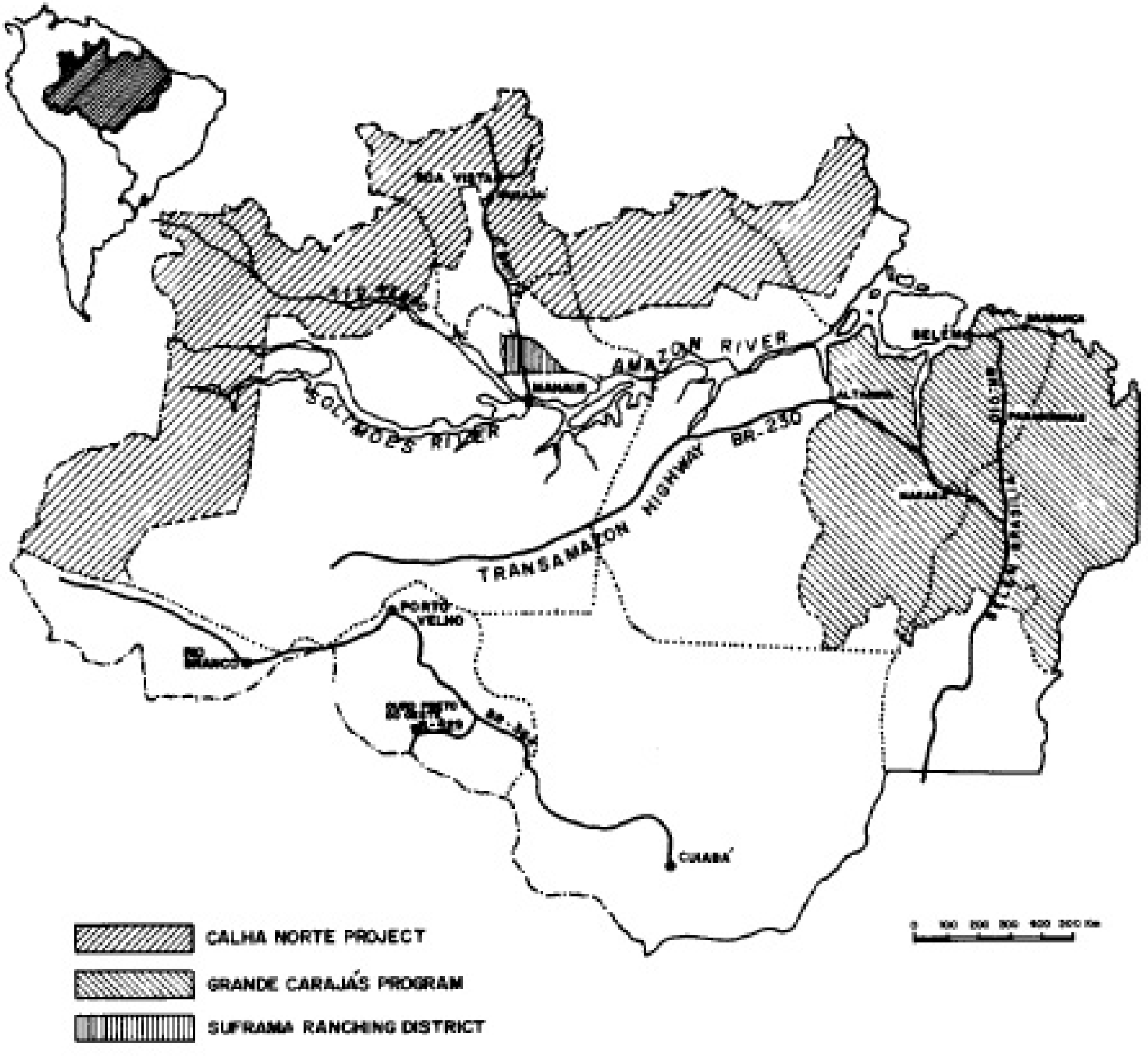
Veja (Rio de Janeiro). 13 April 1983. "A fronteira do futuro." Advertisement from the Government of Roraima. pp. 95-97.

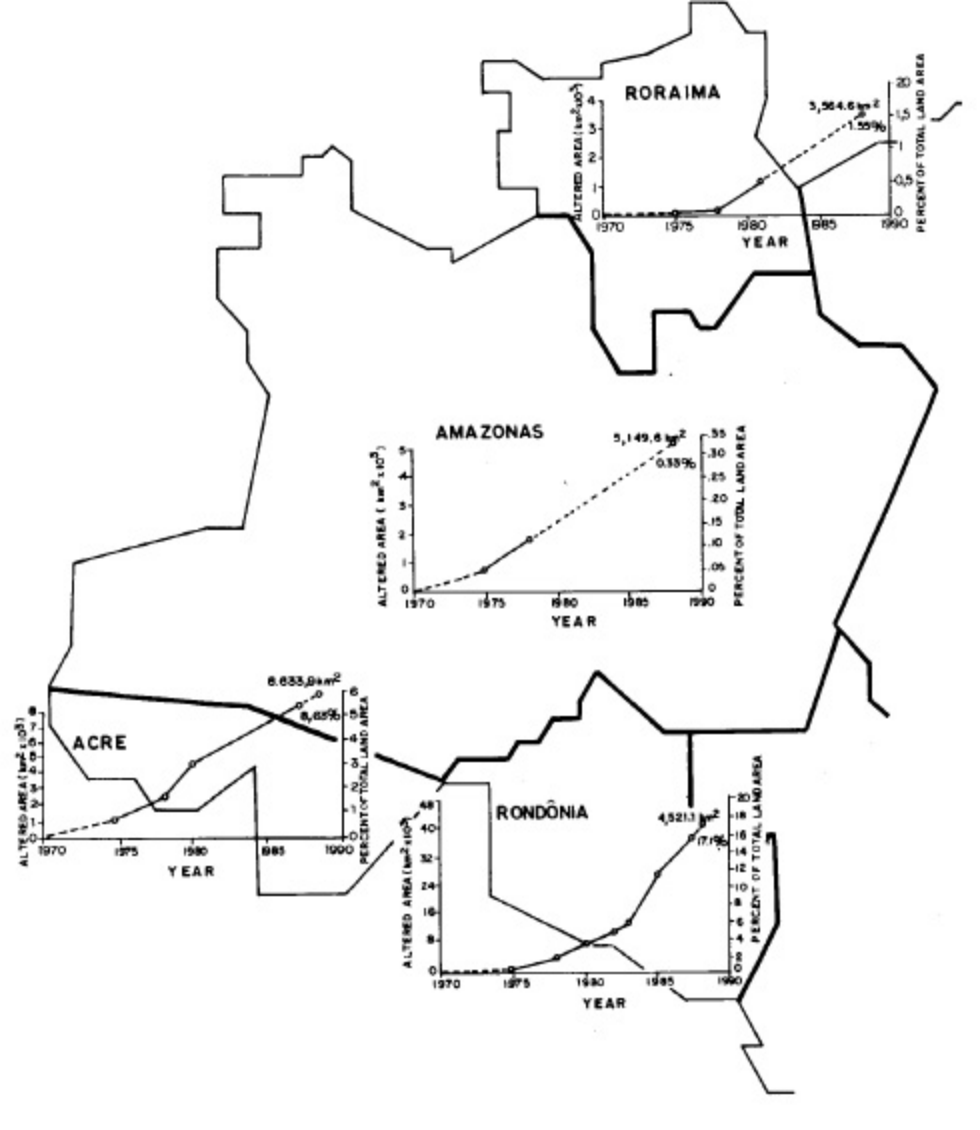
FIGURE LEGENDS

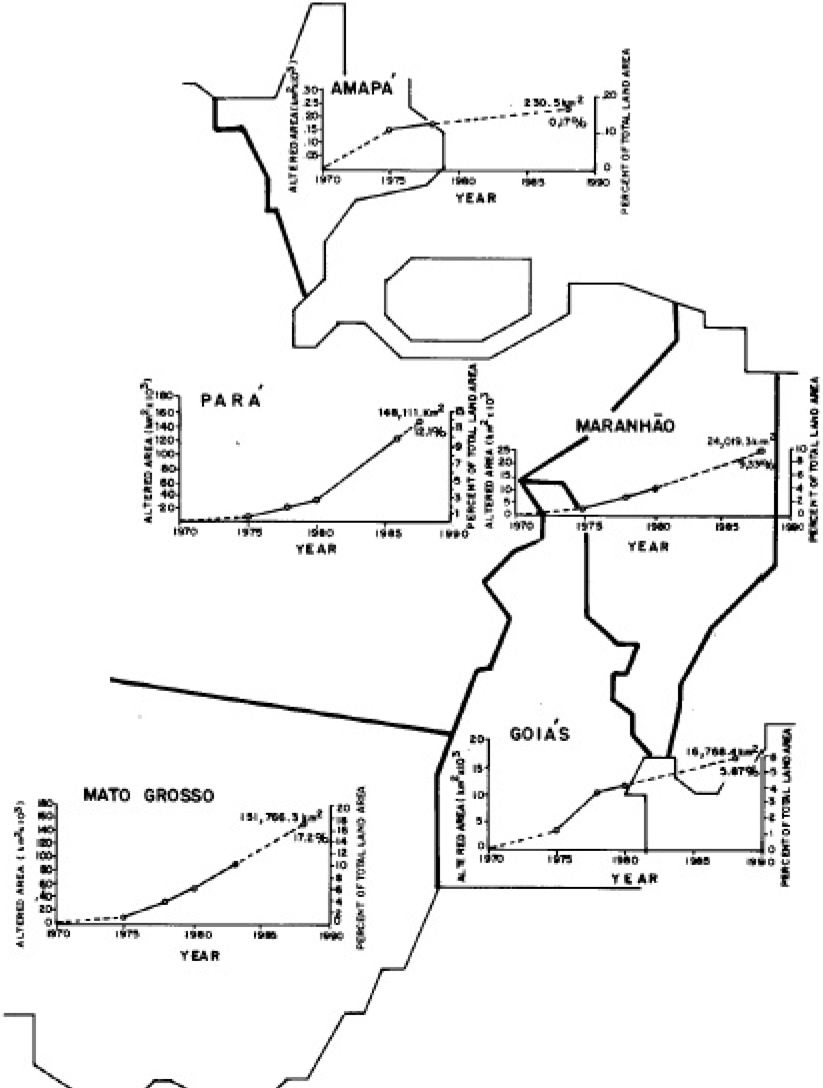
Fig. 1 -- Trends of increase in the areas "altered" (deforested) derived from LANDSAT satellite data (see Table 1). In the states and territories with data complete through 1980, one can see rapid growth in Rondônia, Acre and Mato Grosso. The data for 1980 have not yet been released for Amazonas, Roraima and Amapá. The beginning of the curves is shown as a broken line since LANDSAT data for 1970 do not exist (Source: Fearnside, 1986a).

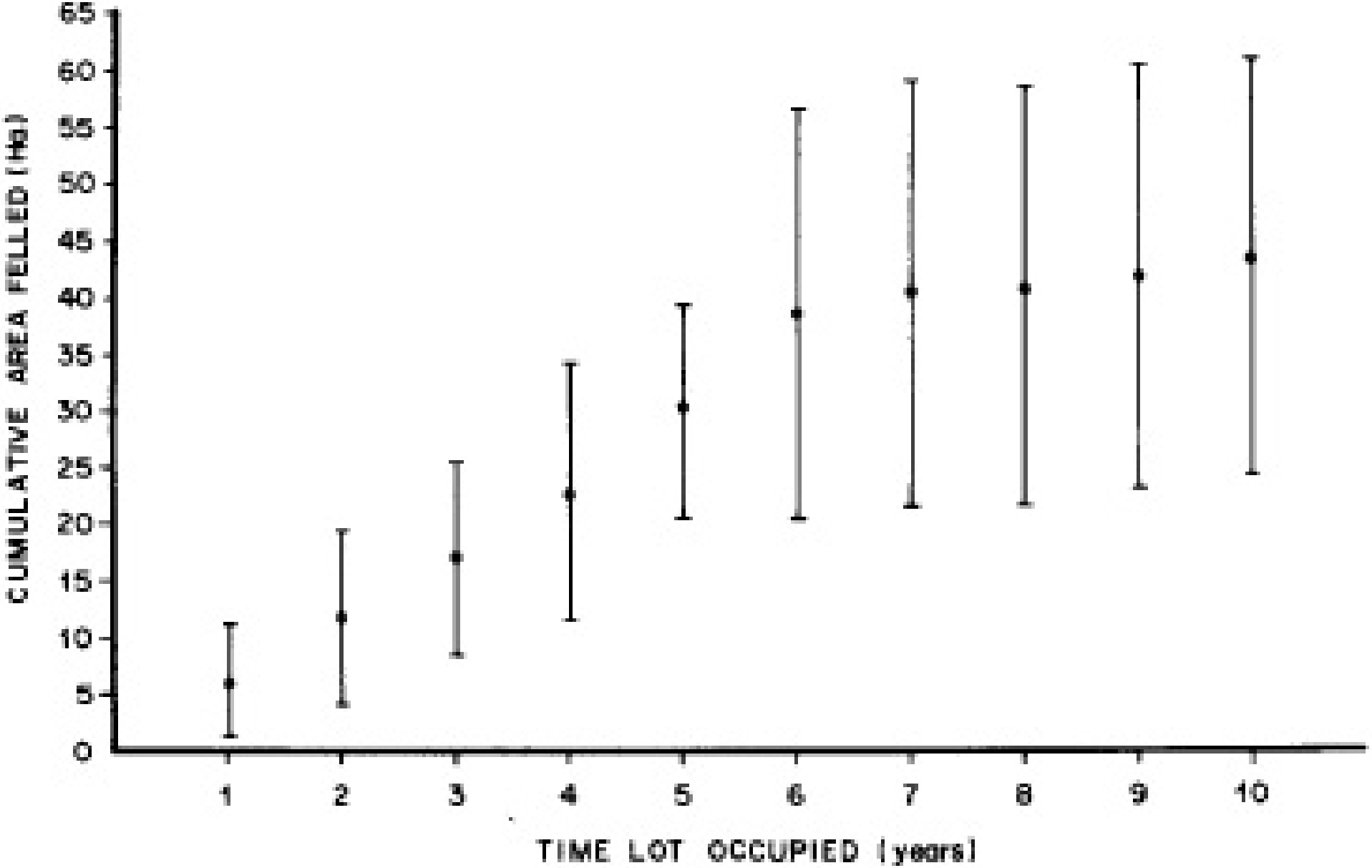
Fig. 2 -- Observed felling in Rondônia in a cohort of lots occupied by their original owners (Source: Fearnside, 1984a).

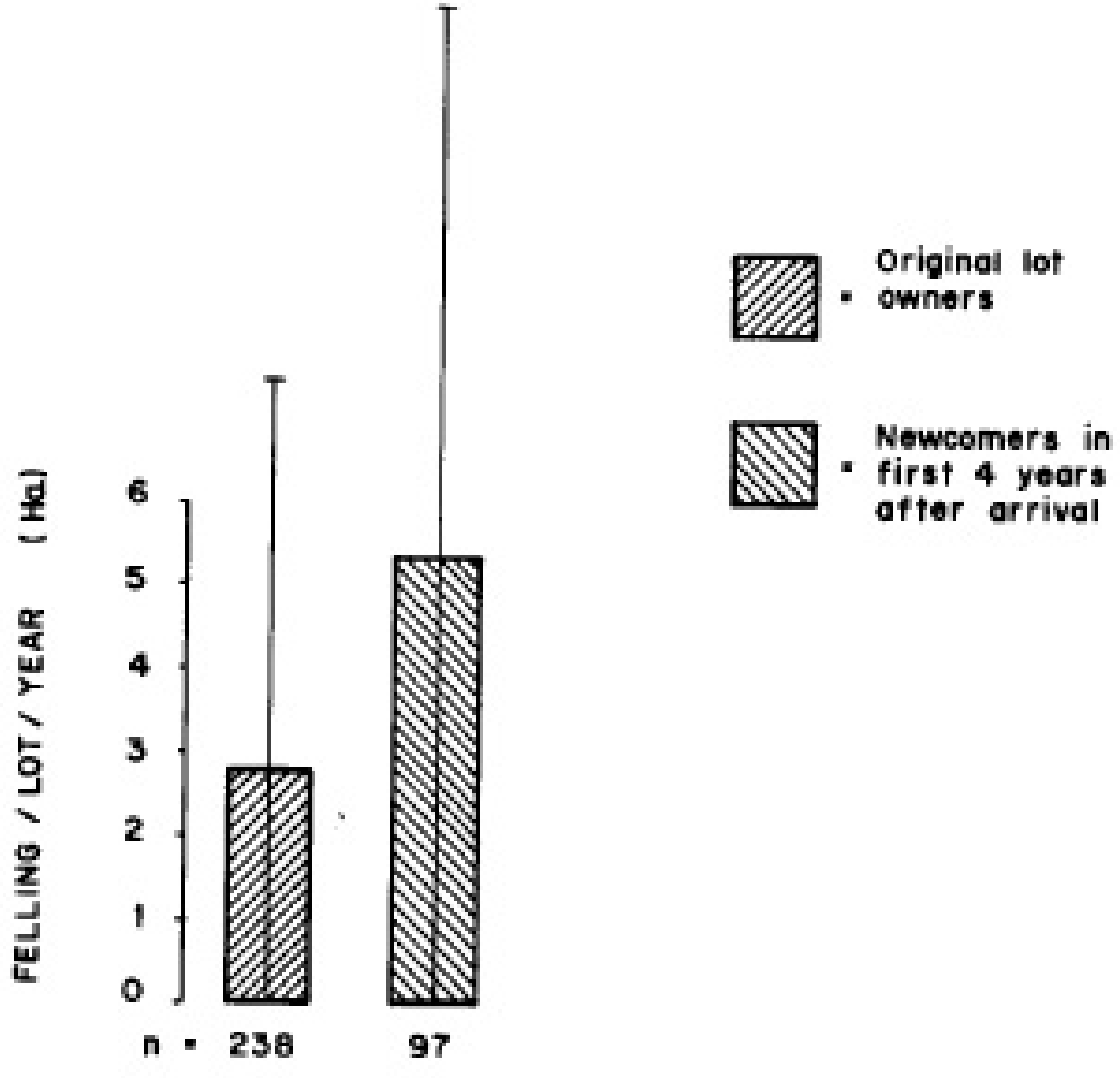
Fig. 3 -- Effect of colonist turnover on felling rates in Rond^nia (Source: Fearnside, 1984a).


BOA VISTA
MANAUS
AMAZON RIVER
SOLIMÕES RIVER
BELÉM
BR-230
TRANSAMAZON HIGHWAY
PORTO VELHO
CUIABÁ
CALHA NORTE PROJECT
GRANDE CARAJÁS PROGRAM
SUFRAMA RANCHING DISTRICT


RORAIMA
3,564.6 km²
1.55%
ALTERED AREA (km² x 10³)
PERCENT OF TOTAL LAND AREA
1970
1975
1980
1985
1990
YEAR
AMAZONAS
5,149.6 km²
0.33%
ALTERED AREA (km² x 10³)
PERCENT OF TOTAL LAND AREA
YEAR
ACRE
8,633.9 km²
8.65%
ALTERED AREA (km² x 10³)
PERCENT OF TOTAL LAND AREA
YEAR
RONDÔNIA
4,521.1 km²
17.1%
ALTERED AREA (km² x 10³)
PERCENT OF TOTAL LAND AREA
YEAR


AMAPÁ
230.5 km²
YEAR
PERCENT OF TOTAL LAND AREA
PARÁ
ALTERED AREA (km² x 10³)
YEAR
PERCENT OF TOTAL LAND AREA
MARANHÃO
YEAR
PERCENT OF TOTAL LAND AREA
GOIÁS
YEAR
PERCENT OF TOTAL LAND AREA
MATO GROSSO
151,766.3 km²
ALTERED AREA (km² x 10³)
YEAR
PERCENT OF TOTAL LAND AREA


CUMULATIVE AREA FELLED (Ha)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
1
2
3
4
5
6
7
8
9
10
TIME LOT OCCUPIED (years)


FELLING / LOT / YEAR (Ha)
0
1
2
3
4
5
6
n = 238
97
Original lot owners
Newcomers in first 4 years after arrival