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AN ECOLOGICAL ANALYSIS OF PREDOMINANT LAND USES IN THE BRAZILIAN AMAZON

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ABSTRACT

The land uses that now predominate in Brazil's Amazon Region are unlikely to produce sustainable yields. They also tend to close off potentially sustainable alternative uses. Cattle pasture -- either productive or abandoned -- now occupies most deforested land. Small farmers plant pasture after using the land for a year or two under annual crops, while large cattle ranches plant pasture directly after clearing. The principal motive for planting pasture is often its low cost and high effectiveness as a means of securing speculative land claims -- not beef production.

Pasture and cattle yields are low and, after use for about a decade, the planted grasses are outcompeted by secondary forest species or inedible grasses. Depletion of available phosphorus in the soil is a major cause of yield decline; Brazil's relatively modest phosphorus deposits, virtually all of which are outside of Amazonia, make fertilizer use infeasible for the vast areas now rapidly being converted to pasture. Converting a substantial portion of Amazonia to pasture would have potential climatic effects. Areas that can be planted in annual and perennial crops are restrained by world markets, as well as by soil quality and Brazil's limited stocks of the inputs needed for intensive agriculture.

Recent inititatives for "agricultural-ecological zoning" in Brazil's Amazonian states could be a first step toward more rational land use. Immediate measures are needed to slow deforestation, to discourage unsustainable uses and to make sustainable alternatives profitable.

INTRODUCTION

Ecological characteristics of the predominant land uses in Amazonia indicate the urgent need to redirect the processes now rapidly transforming the region's forests into unsustainable forms of development. Land uses should be promoted that are not only agriculturally sustainable but also socially feasible and relatively unrestrained by the limited commodity markets and input sources that either presently or potentially preclude expansion of any crop to a significant portion of Amazonia. The landscape should be viewed as a patchwork of areas designed to fulfill distinct social and ecological functions, and where different economic and environmental criteria apply. Areas zoned for sustainable forestry management cannot, for example, be expected to justify themselves by producing income at a rate that compares favorably with a discount rate reflecting profits obtainable from alternative investments in unrelated parts of the economy. The landscape must contain both patches of the various crops needed to supply the local population and substantial reserves of natural ecosystems, including those inhabited by indigenous peoples.

The best approach to sustainable use in large areas not selected for preservation in their pristine state or that cannot be allocated to intensive uses is to harvest small quantities of those products that Amazonian forests are unique in their ability to provide. Maintaining the forest structurally intact while exploiting it on an extractive basis guarantees the long-term supply of products that are irreplaceable and, in many cases, not yet even "discovered" as useful to Western society. Greatly expanded investigation of pharmaceutical and other potential forest products is needed: at present little is being done with the time bought by efforts to delay the rush to deforestation. The most efficient approach is to examine species that are used by indigenous peoples and by *caboclos* (the Portuguese-speaking inhabitants raised in the Amazonian interior). The value of extractive areas to environmental stability and to maintaining future options for direct human use needs to be incorporated into the prices paid for the forest's products and into society's investment in the institutional infrastructure that supports the extractive systems and prevents them from being supplanted by competing nonsustainable land uses.

Among the immediate actions needed to slow the present substitution of forest with rapidly-degrading pasture, the government should stop all forms of subsidy for ranching, stop considering pasture as an "improvement" for purposes of documenting land claims, and impose taxes and other measures to remove the profit from speculating in Amazonian lands.

EVALUATING DEVELOPMENTS

Evaluations of Amazonian developments are usually limited to financial analyses of an undertaking's profitability from the point of view of individual or corporate investors participating in the scheme. Economic analyses, including returns on the full value of the investment (or at least on a greater portion of it) are sometimes done for the plans benefitting from government subsidies. Environmental impact statements (RIMAs) and "forestry management plans" also exist as required by Brazilian legislation. With the exception of the financial analyses, it is rare for any type of evaluation to affect development decisions. Environmental reports, such as RIMAS, are frequently viewed as mere bureaucratic formalities; they are written long after the real decisions on project implementation have been made (Fearnside, 1985a). Projects often go forward even when their folly is evident from information available beforehand, as in the case of planned settlement areas in Rondônia (Fearnside, 1986a).

An ecological evaluation has been made elsewhere (Fearnside, 1983a) of fourteen classes of development options in use or under consideration in Amazonia: 1) untouched forest, 2) forest products extraction, 3) shelterwood forestry, 4) highgrading with replanting, 5) highgrading without replanting or regulation, 6) enrichment and/or selective poisoning, 7) silvicultural plantations, 8) clearcutting without replanting, 9) perennial crop plantations, 10) taungya, 11) annuals in shifting cultivation, 12) annuals in continuous cultivation, 13) pasture with fertilizer, and 14) pasture without fertilizer. Each is rated on the basis of nine criteria: 1) agronomic sustainability, 2) social sustainability, 3) unsubsidized economic competitiveness, 4) maximum self-sufficiency, 5) fulfillment of social goals, 6) consistency with maintenance of areas for other uses, 7) retention of development options, 8) minimal effects on other resources 9) minimal macro-ecological effects. The selection of these criteria is discussed elsewhere (Fearnside, 1984a, 1986b).

PRESENT PATTERNS OF DEVELOPMENT

1.) Pasture

The dominant types of development today vary greatly among different parts of the Amazon region (Figure 1). The most widespread is cattle ranching, which has taken over the majority of the cleared land in areas like Mato Grosso, southern Par' and the Manaus Free Zone Superintendency (SUFRAMA) Agriculture and Cattle Ranching District in the state of Amazonas. Satellite imagery indicates these areas are centers of deforestation (Fearnside, 1986c; Tardin *et al*., 1980).

Ranching dominates the region not because it produces beef, but rather because of the attraction of fiscal incentives and especially because it is the cheapest way to secure land claims for speculative purposes (Fearnside, 1979a, 1983b, 1987a; Hecht, 1985; Mahar, 1979). Incentives have allowed companies and individual investors from southern Brazil to apply to the ranching schemes a portion of the income tax owed to the government on profits made elsewhere in the country. Generous financing terms give loans at rates below those of Brazilian inflation, thus creating a powerful motive to initiate the schemes even if beef production is negligible.

The Superintendency for Development of the Amazon (SUDAM), the agency responsible for the largest incentives program, altered its policies in 1979 to grant "new" incentives only to projects outside of Amazonia's "high forest" area. Three major loopholes allow continued clearing with incentives: the substantial areas of forest still being felled in "old" projects already approved for the subsidies (Hecht, 1985), the wide zone classified as "transition forest" where clearing is preferentially directed at high forest interdigitated with *cerrado* (scrubland) vegetation (Dicks, 1981), and a very restrictive definition of what constitutes "high forest" (Fearnside, 1985a). Brazil's economic crisis in the late 1980s has meant that less government money has been available than previously for cash contributions to the ranching schemes, although subidies through foregone tax revenues continue. The consequent slowing of subsidized clearing in such areas as the SUFRAMA Agriculture and Ranching District near Manaus must be viewed as a temporary phenomenon. In the absence of fundamental policy changes regarding pasture subsidies one can expect the flow of government funds to resume its former level once Brazil's economy recovers. Despite minimal economic returns on the government largesse directed to the ranches, exacerbation of social tensions, and the opportunity costs and environmental impacts of massive forest loss, Brazil's president is quoted as saying that he doesn't "even want to hear" any suggestion to discontinue the incentives *Isto É,* 15 July 1987: 65).

Important as incentives are, pasture expands rapidly even in the absence of these windfalls. A LANDSAT satellite survey of 445,843 ha cleared along the Belém-Brasília Highway indicated that 45.4% of this deforestation was done without incentives even in this highly subsidized ranching area (Tardin *et al.*, 1978: 19, see Fearnside, 1979a). Land speculation provides ample motive for replacing the forest with pasture even when little or no beef is produced. The prices of Amazonian ranchland have consistently risen at rates exceeding inflation (Mahar, 1979; Hecht, 1985), motivating speculators to plant pasture so that the land will not be taken by squatters or by other ranchers. In the case of the vast areas without legal documentation pasture has the powerful additional attraction of being considered a\benfeitoria\ ("betterment") that qualifies the rancher for title to the land.

Pasture has pernicious effects on Amazonian society. Ranching drives small farmers off the land, either by violence (Martins, 1980; Schmink, 1982; Valverde and Dias, 1967) or by tempting smallholders to sell their plots to more wealthy newcomers (Coy, 1987; Fearnside, 1984b). Land tenure distribution becomes highly skewed toward large holdings with absentee owners. Only a minimal amount of employment is generated after the initial clearing phase is over. The beef produced is often exported from the area, bringing little benefit to local residents. The low productivity of the pastures fuels inflation since money is invested without a corresponding return of products to the marketplace; this creates a vicious cycle leading to greater speculative motive for pasture expansion (Fearnside, 1987a).

Pasture is not sustainable in the region without heavy and antieconomic inputs. The pasture grass grows progressively more slowly following the first two or three years of use. Measurements of dry weight production over a full annual cycle in Ouro Preto do Oeste, Rond^nia, indicate that a twelve-year-old pasture produces at about half the rate of a three-year-old pasture (Fearnside *et al.*, in preparation). Yields decline due to invasion by inedible weeds, soil compaction, and decrease in available phosphorus in the soil (Fearnside, 1979b, 1980a; Hecht, 1981, 1983). Over the long term, erosion can be expected to further exhaust soil fertility: measurements under various land uses at Ouro Preto do Oeste, Rondônia, and near Manaus, Amazonas, indicate that soil erosion rates in grazed pasture are much greater than in intact forest (Fearnside, *et al*., in preparation). Presently used land capability classifications mistakenly assume that pasture protects the soil from erosion *e.g.* Brazil, Ministério das Minas e Energia, Projeto RADAMBRASIL 1973-82).

Prospects are poor for maintaining pasture over large areas in Amazonia. One reason is the necessity of phosphate fertilizers. In the early 1970s when the fiscal incentives program for Amazonian pastures was rapidly expanding,, the agency that is now the Brazilian Enterprise for Agriculture and Cattle Ranching Research (EMBRAPA) maintained that pasture improved the soil (Falesi, 1974, 1976). Unfortunately, available phosphorus declines sharply from the peak caused by ash from the initial burning of the forest; after 10 years the levels of this critical element are at least as low as those under virgin forest and far below the amounts required by the pasture grasses (Fearnside, 1980a; Hecht, 1981, 1983). In 1977 EMBRAPA changed its position that pasture improves the soil, recommending instead that productivity be maintained by applying annually 50 kg/ha of phosphorus, equivalent to about 300 kg/ha of superphosphate (Serrão and Falesi, 1977; Serrão *et al*., 1979). The much greater productivity of pasture when fertilized with phosphate is obvious (Koster *et al*., 1977). The problems are the cost of supplying the phosphate and the absolute limits to mineable stocks of phosphate. A report on Brazil's phosphate deposits published by the Ministry of Mines and Energy indicates that only one small deposit exists in Amazonia, located on the Atlantic coast near the border of Pará and Maranhão (de Lima, 1976). An additional deposit has been reported near Aripuanã, Mato Grosso (dos Santos, 1981). Almost all of Brazil's phosphates are in the state of Minas Gerais, a site very distant from most of Amazonia. Brazil as a whole is not blessed with a particularly large stock of phosphate -- the United States, for example, has deposits about 20 times larger (de Lima, 1976). On a global scale most phosphates are located in Africa (Sheldon, 1982). Continuation of post-World War II trends in phosphate use would exhaust the world's stocks by the middle of the next century (Smith *et al*., 1972; United States, Council of Environmental Quality and Department of State, 1980). Although simple extrapolation of these trends is questionable because of limits to continued human population increase at past rates (Wells, 1976), the conversion of a substantial portion of Amazonia to fertilized pasture would greatly hasten the day when stocks of phosphate are exhausted in Brazil and in the world. Brazil would be wise to ponder carefully whether its remaining stocks of this limited resource should be allocated to

Amazonian pastures.

Large expanses of pasture can be expected to be subject to disease and insect outbreaks in the same way as other large monocultures. Switching the grass varieties planted can counter such problems to some extent, but the cost and frequency of the changes can be expected to increase. *Brachiaria decumbens* ("braqui'ria"), a pasture grass formerly common on the Belém-Brasília Highway, was devastated in the early 1970s by outbreaks of the homopteran known as "cigarrinha" *Deois incompleta*, Ceropidae). Guinea grass or "colonião" *Panicum maximum*) became a favorite in the area, and its performance was described by EMBRAPA as "magnificent" (Falesi, 1974). Yield declines later became apparent as available phosphorus depletion and invasion of weeds proceeded. Weed invasion in *Panicum maximum* is facilitated by the bunchy growth habit of this species leaving bare spaces between the tussocks of grass and by poor germination of the seeds produced by the grass in the field. By the 1980s "cigarrinha" had adapted to *Panicum maximum* as well, but not yet at the devastating levels reached in *Brachiaria decumbens*. Despite its disadvantages, *Panicum maximum* remains the most common pasture grass in Brazilian Amazonia today. In the late 1970s EMBRAPA began recommending creeping signal grass or "braquiária da Amazônia" *Brachiaria humidicola*). This species was at first tolerant of cigarrinha attack, but the insects have become increasingly well adapted to feeding on this species. EMBRAPA now recommends *Andropogon guianensis* pasture grass. The continual changing of species and fertilizer recommendations does not change the basic characteristics of pasture that make its sustainability doubtful.

The sustainability of pasture, as well as its social and environmental impacts, are closely tied to the size that these areas are allowed to attain. A small area of pasture can be maintained on imported nutrient inputs while a large one cannot. A small area would cause climatic impacts that are within the capabilities of natural systems to correct or absorb, whereas a large area would at some point cross thresholds triggering processes that lead these equilibria to degenerate (Fearnside, 1985b; Salati and Vose, 1984). The most worrisome characteristic of pasture is that there is no immediate limit to thwart its continued expansion. Unlike annual and especially perennial crops, market limits for the system's products are unlikely to halt its expansion: the demand for beef is tremendous and would be even greater if more meat were to become available. The availability of labor also does not restrain pasture as it does other crops because of the low labor demands of the extensive systems used in Amazonia (Fearnside, 1980b). Pasture's dominance among land use choices allows a small human population to have maximum impact on deforestation (Fearnside, 1983b).

Conversion of a substantial fraction of Amazonia to pasture would have severe impacts on regional and global climate. Global warming from the "greenhouse effect" caused by increasing COU2D in the atmosphere would have its greatest effect in temperate and arctic latitudes rather than in Amazonia itself. Were all of the five million square kilometers of Brazilian Amazonia converted from its original vegetation to cattle pasture, 50 billion metric tons (50 gigatons) of carbon would be released (Fearnside, 1985c, 1986d, 1987b). Were the conversion to pasture to take place over a span of 50 years, which is conservative considering the pace of conversion in the past two decades (Fearnside, 1982, 1986c; Fearnside and Salati, 1985), carbon would be released at a rate of one gigaton per year over the coming decades. Since the global release of carbon from all sources has been taking place at the rate of about five gigatons per year (Bolin *et al.*, 1979), the release from conversion to pasture in the Brazilian portion of Amazonia alone could contribute on the order of one fifth of the total to this serious global problem. Potential consequences include a redistribution of rainfall patterns around the world with the result that many of the earth's present agricultural breadbaskets would become dryer, and a rise in mean sea level by up to five meters (thereby flooding both a portion of Amazonia and many centers of human population).

A second climatic consequence of massive conversion to pasture would be a decrease in rainfall in Amazonia and in neighboring regions. Half of the rainfall in Amazonia is derived from water that recycles through the forest as evapotranspiration, rather than from water vapor in clouds originating over the Atlantic Ocean. Four independent lines of evidence lead to this conclusion. First, water and energy balances derived from average charts of temperature and humidity indicate 56% of the precipitation as derived from evaptranspiration (Molion, 1975). Second, calculations of precipitable water and water vapor flux for a transect from Bel'm to Manaus indicate a contribution from evapotranspiration of 48% (Marques *et al*., 1977). Third, isotope ratioing of water vapor samples in the same area indicates up to 50% as recycled through the forest, depending on the month (Salati *et al*., 1978). Fourth, the volume of water flowing out of the Amazon River can be compared with the volume of water falling as rain in the catchment basin. River flow is 5.5×10^{12} m^3/year measured at the Amazon's narrow point at 'bidos, and rainfall is 12.0×10^{12} m^3/year estimated from the network of pluviometers around the region (Vila Nova *et al*., 1976). The volume of water in the rain is slightly more than double the amount leaving through the river, meaning that the approximately half (54%) that does not drain out through the river has been returned to the atmosphere as evapotranspiration.

Only by seeing the Amazon River at flood season can one fully appreciate the immense volume of water involved: what one sees in the river is the same volume that is returning unseen to the atmosphere through the leaves of the forest. That the leaves of the forest are constantly giving off water is evident to anyone who has tied a plastic bag over handful of leaves: in only a few minutes the inside of the bag is covered with water droplets condensed from evapotranspiration. Summed over the several hundred billion trees in Amazonia a vast amount of water is returned to the atmosphere. Since evapotranspiration is proportional to leaf area, the water recycled through the forest is much less than that recycled through the pasture, especially in the dry season when the pasture is dry while the forest remains evergreen. This is aggravated by the much higher runoff under pasture. Increases in runoff by one order of magnitude have been measured near Manaus (Amazonas), Altamira (Pará) and Ouro Preto do Oeste (Rondônia) (Fearnside *et al*., in preparation). Soil under pasture quickly becomes highly compacted, inhibiting infiltration of rainwater into the soil (Dantas, 1979; Schubart *et al*., 1976). Rain falling on the compacted soil runs off quickly, becoming unavailable for later release to the atmosphere through transpiration.

The potential damage of lowered rainfall for the remaining natural ecosystems is indicated by the seasonal and spatial patterns in water vapor sources found by Salati *et al.* (1978, 1979). The importance of recycled water is greatest in the dry season, and increases as one moves farther away from the Atlantic Ocean. This means that in Rondônia and Acre, where rapid deforestation is taking place, the proportion of rainfall derived from the forest could be much higher than the roughly 50% found in the Belém-Manaus transect. The greater dependence in the dry season means that conversion to pasture would cause this period to become longer and more severe, a change that could wreak havoc on the forest even if the annual precipitation total were to remain unchanged. Many rainforest trees are already at their limits of tolerance for drought stress. In patches of forest isolated by cattle pasture in the INPA/WWF "Biological Dynamics of Forest Fragments" project near Manaus, the trees on the edges of forest patches die at a much greater rate than do those in continuous forest (Lovejoy *et al*., 1984). Since many of the trees die "on their feet" rather than being toppled by wind, the dry conditions in the air or soil near the reserve edges is a likely explanation for the mortality. Precipitation in Amazonia is characterized by tremendous variability from one year to the next, even in the absence of massive deforestation (Fearnside, 1984c). Were the forest's contribution to dry season rainfall to decrease, the result would probably be a very severe drought once in, say, 20 or 50 years that would kill many trees of susceptible species. Since Amazonian forest trees live upwards of 200 years, the probability would be much higher that they would encounter an intolerably dry year sometime during their lifespan. The result would be replacement of the tropical moist forest with more drought-tolerant forms of scrubby, open vegetation resembling the\cerrado of central Brazil (Fearnside, 1979c). Such a change could set in motion a positive feedback process leading to less dense forests that transpire less, increasing the severity of droughts, thereby causing even more tree mortality and forest thinning (Fearnside, 1985b).

The severe droughts provoked by deforestation could lead to a surprisingly rapid demise for the remainder of the forest once a substantial portion of the region had been converted to pasture. In Amazonia at present, burning is almost entirely restricted to areas where the trees have been felled and allowed to dry before being set alight. The fire stops burning when it reaches the edge of the clearing rather than continuing into the unfelled forest. This lucky situation need not necessarily continue unchanged. In forested areas that have been disturbed by logging along the Belém-Brasília Highway, fires from neighboring pastures have already been observed to continue substantial distances into the standing forest (Uhl and Buschbacher, 1985). During 1982-83 (an unusually dry year because of the El Niño phenomenon) approximately 45,000 km^2 of tropical forest on the island of Borneo burned when fires escaped from shifting cultivators' fields (Malingreau *et al.*, 1985). At least 8,000 of the 35,000 km^2 of this area in the Indonesian province of East Kalimantan was primary forest, while 12,000 km^2 was selectively logged forest (Malingreau *et al.*, 1985). Devastation would be catastrophic should fires such as this occur in Amazonia during one of the droughts aggravated by drying from deforestation.

2.) Pioneer Agriculture

Colonization by small farmers is concentrated in certain parts of the region, with different modes of organization depending on the place. Colonists were installed in government projects on the Transamazon Highway in the state of Pará and in the colonization areas in Rondônia (Fearnside, 1986b; Moran, 1981; Smith, 1982). In the Grande Carajás Program area various government projects settled farmers at an accelerated pace in an attempt to reduce land conflicts (Fearnside, 1986e). In northern Mato Grosso colonization is organized by private enterprises that sell parcels of land to farmers and provide them with roads and other infrastructure. Spontaneous settlement is important in areas receiving intense influxes of migrants, such as Rondônia, Acre, and southern Pará. These are all centers of intense deforestation.

The pioneer agriculture installed by the settlers is usually based on annual crops such as rice. These crops are planted for one or two years before the field is either allowed to revert to secondary forest or is converted to cattle pasture. Unlike indigenous peoples, pioneer farmers do not have the cultural tradition of leaving their former fields in secondary forest for a sufficient time to regenerate soil quality. Reuse of the fallow plots may occur, but the fallows used are usually too short to make the system sustainable as a form of shifting cultivation (Fearnside, 1984b). Soil degradation occurs through erosion during the cropping phase (Fearnside, 1980c). A variety of problems with soil fertility, insects, vertebrate pests, weeds, weather, transportation and marketing make returns to the farmers highly uncertain (Fearnside, 1986b; Smith, 1978).

Prolonged use in shifting cultivation-like agriculture can lead to soil degradation and replacement of the area by unproductive secondary forests, as has occurred in the Zona Bragantina in Pará (Ackermann, 1966; Egler, 1961; Penteado, 1967; Sioli, 1973).

Ecological succession in the fallow plots has so far been through woody secondary forest species such as *Cecropia* and *Vismia*. This need not always remain the case. In southeast Asia, for example, fallow plots of more than about 100 m^2 in area are usually dominated by grasses such as the very aggressive *Imperata cylindrica* (Richards, 1964). In the Gran Pajonal of Peru the less-aggressive new world relative *Imperata brasiliensis* dominates fallows for an extended period (Scott, 1980). One of the possible future changes in sites heavily degraded through annual crops or pasture is that succession in Amazonia would come to resemble more closely that of southeast Asia. Diversion to a grass dysclimax would both diminish the regeneration of site quality for agriculture and increase the climatic and other impacts of deforestation.

Pioneer farmers have been overshadowed by large ranchers and speculators in many parts of Brazilian Amazonia, but their relative importance is increasing as improved road access to the region facilitates migration. Even in pioneer areas, cattle pasture soon becomes the predominant land use (Coy, 1987; Fearnside, 1983b; Leite and Furley, 1985; Léna, 1986). Massive transformation of forest to pioneer agriculture and subsequently to cattle pasture could be the path of least resistance for the Brazilian government in trying to meet the hopes raised by its agrarian reform program. Agrarian reform usually implies redistributing large landholdings, but the owners of these properties understandably exert strong pressure to have the program redirected to a distribution of public lands. Since virtally all of Brazil's public land is located in Amazonia, such a redefinition of "agrarian reform" would equate the term with what in past decades has been known as "colonization." Brazil has an estimated ten million landless rural families; since the Legal Amazon has an area of five million square kilometers, a complete distribution of the region including parks, reserves and privately owned land would yield only one half square kilometer, or 50 ha, per family. This is half the size of the lots that were distributed in the colonization schemes of the 1970s and is equal to the size of lots distributed in recent projects in Rondônia -- all of which have severe agricultural problems. It therefore should be clear that the problems agrarian reform is intended to solve must be addressed in the regions where the population is now located rather than transferring these problems to Amazonia (Fearnside, 1985d). Nevertheless, it is quite possible that substantial areas of Amazonian forest will be allocated to such schemes before this conclusion is reached.

3.) Shifting Cultivation

Indigenous peoples have been supporting themselves for millenia through shifting cultivation and exploitation of animal and plant resources in natural habitats. These systems are vanishing as Luso-Brazilians continue to take lands away from indigenous groups, in addition to the decreases in tribal populations caused by violent conflicts with invadors, by infectious diseases spread by the latter, and by acculturation. The idea that there exist "lands without men" waiting to be occupied in Amazonia is a myth: all of the region's land can be considered to be already occupied, if not by Luso-Brazilians, then by indigenous peoples.

4.) Logging

Logging has been rapidly increasing in the areas accessible to the markets and ports of Brazil's Center-South Region. The north of Mato Grosso and the areas served by the lateral roads of the BR-364 and BR-429 highways in Rond^nia are presently experiencing an unprecedented explosion in the number of sawmills. This exploitation has been taking place without any indication that the forests would be managed to continue the production of timber in a sustainable manner.

Although the area now influenced by logging is unknown, the most valuable species are sought from all accessible forest in the region. In areas nearer to markets the list of species exploited lengthens. The rapid spread of highways has opened up vast new areas to logging, including areas on the previously inaccessible borders of Brazil and Peru. Logging is one of the primary forms of disturbance in indigenous reserves in Rondônia and Acre.

Timber exploitation has so far been limited by competition from logging in southeast Asia, where tropical forests are characterized by a higher density of commercially valuable trees. Southeast Asian forests are dominated by a single plant family (Dipterocarpaceae), making it possible to group the vast number of individual tree species into only six categories for the purposes of sawing and marketing. In addition, most Asian woods are light in color, making them more valuable in Europe and North America where consumers are accustomed to light woods such as oak and maple. Amazonia's generally dark colored, hard-to-saw, and extremely heterogeneous timber has therefore been spared the pressure of large multinational timber corporations. The approaching end to commercially significant stocks of tropical timber in Asia can be expected to change this situation radically.

Wood removal for charcoal is a new addition to major land uses in Amazonia. The Grande Caraj's Program offers incentives to charcoal production for use in pig-iron mills.   So far incentives have been granted for 11 industries planned to function with charcoal: seven for pig-iron, two for iron alloy, and two for cement. At least 20 pig-iron mills are planned. The first pig-iron mill began operation in December 1987. Although official statements often mention silviculture as a future wood source for the charcoal, "forestry management" appears to be the most likely option for the charcoal production firms. The firms are, at least in theory, required to obtain the wood for their charcoal from sustainble sources after a given period. As of now they are making charcoal from wood from land being clearfelled for pasture. As this source becomes exhausted in the area of the mills the charcoal suppliers are supposed to mount "forestry management" schemes. Experiments are underway at Buriticupu, Maranhão, to measure growth after wood removal at a variety of intensities, including clearcutting (de Jesus, 1984; de Jesus *et al.*, 1984; Thibau, 1985). It is possible that charcoal suppliers will clearcut native forest and then allow the areas to regenerate in secondary forest as a form of "forestry management." Such an interpretation of what constitutes "forestry management" would allow firms to avoid the onus of investing in more costly systems. If, after the free wood from native forest has been exhausted it then is suddenly discovered that the "forestry management" plans are uneconomic or unproductive, the firms could scrap or move their equipment, and simply take their profits and leave.

5.) Extraction

Extracting forest products, such as rubber, Brazilnuts, balata and rosewood oil has been important in supporting human populations in the Amazonian interior since long before the present massive migration to the region. These systems can produce indefinitely, so long as the products are extracted with the minimal precautions already known to rubber tappers and Brazilnut gatherers in the region.   At present the principal problems impeding maintenance of the systems are: low economic return on the short term in comparison with the profits coming from deforestation (especially profits from real estate speculation), the inability of the extractivists to secure their claims to the land in the face of appropriation by ranchers or squatters and the relative weakness of poor *caboclos* in the Amazonian interior when matched against other groups competing for possession of the land.

The future use of pharmaceutical products and other derivatives of the Amazonian forest species is a strong reason for preserving significant tracts of intact forest (see Oldfield, 1981; Myers, 1984). Many species in the forest are not even known yet, much less the potential uses of the compounds they contain. It is believed, for example, that the loss of the forest would be a significant blow to efforts to find cures for cancer (Myers, 1976, 1979). The most efficient manner to evaluate the uses of these compounds is through the knowledge of the indigenous tribes in the region. The efforts so far, both in the sense of surveying tribal knowledge and in the identification and chemical analysis of the species, has been minimal when compared with the importance of the challenge.

The present trend has been for more and more extractive areas to be appropriated by ranchers, speculators, squatters, and colonization programs. This process is sometimes concentrated in the most productive areas because of the bureaucratic advantage conferred by existing documentation of the claims of rubber and Brazilnut "barons" (Bunker, 1980). The shrinking of extractive areas may not continue unopposed: rubber gatherers have organized themselves to press for legal recognition of "extractive reserves" (Schwartzman and Allegretti, 1987). These areas would be defended against invasion and would be shared by traditional extractivists. Possible improvements include enrichment of the forest with trees producing marketable products and expanding the range of products exploited.

A key factor in making the extractive reserve scheme viable is the price of rubber. Rubber in Brazil is heavily subsidized by government pricing policies. Because the *Microcyclus* fungus does not exist in southeast Asia, plantation rubber is inherently cheaper to produce there than it is in Amazonia. World rubber markets have been depressed in the 1980s to the point where many productive plantations in Indonesia and Malaysia have been cut to replant with other crops. Brazil imports two thirds of its rubber, but the remaining third is produced within the country and bought at a price that, although low from the point of view of rubber tappers, is far higher than it is on international commodity markets. The difference represents a subsidy that is being paid by Brazilian consumers when they buy products made of rubber. A subsidy of this kind can be conceded so long as the amount of rubber produced in Brazil remains relatively small. The same subsidy goes to the owners of rubber plantations (now expanding in the Northeast and Center-South regions of the country).

The great advantage of the extractive reserve system is that it keeps the forest intact, thus maintaining the forest's environmental functions, its genetic resources, and its potential to produce sustainably forest products both known and unknown. It also serves an important a social function for the traditional extractivists that have so far been the victims of expulsion and economic marginalization. If designed to abut Amerindian reserves, the extractive reserves could play an additional role in buffering these against invasion. These factors, which would be labeled by economists as "externalities", implying that they are peripheral benefits, are in this case the principal product while the rubber produced is a mere windfall. Means of assigning values to the long-term and nonmonetary benefits of extractive reserves are needed. The system clearly would require one form or another of subsidy to survive, and this must be approached with great caution. Subsidies can easily lead to self-perpetuating interest groups implanting unsustainable land uses that, without the subsidies, would wither under the competition from more profitable alternatives elsewhere. This has been the case, at least in part, with the heavily subsidized Amazonian pastures. Applying subsidies to extractive reserves must not be perverted to a similar end.

6.) Silviculture

Silviculture has been implanted in the Jari Project, where yields have been lower than those expected by the project's designers and by planners who have suggested it as an appropriate model for larger initiatives in other parts of the region. Based on the yields at Jari, it can be calculated that the plantations of *Eucalyptus* in the Grande Carajás Program would have to total almost ten times the planted area at Jari in order to supply charcoal to the 20 pig-iron plants, plus associated industries, planned for the area (Fearnside, 1988). Biological problems associated with the scale of the plantations, such as pests and diseases, would be likely in these vast stands of\Eucalyptus (Fearnside and Rankin, 1982a).

7.) Perennial Crops

Perennial crops, although they can by no means be considered a predominant land use in Amazonia, are the subjects of government financing and research programs because of their potential for sustained production, and because they produce products that can be exported to obtain foreign exchange. Plantations of cacao, coffee, rubber, black pepper, oil palm and other perennials occupy only a very small fraction of the region in spite of government financing and extension programs. Those perennial crops that cover the soil, especially cacao and rubber, offer better prospects of avoiding soil erosion and other forms of degradation in already deforested areas. However, the spreading on a large scale of these crops is improbable because of losses caused by fungal diseases and the limited capacity of world markets to absorb the increased production (Fearnside, 1984d, 1985d).

Plant diseases are a major limitation on perennial crops because the much longer life cycle of trees relative to disease-causing fungi means that pathogens can evolve means of overcoming disease resistance faster than plant breeders can obtain new varieties (Janzen, 1973). When attacked, the cost of replacing tree crops with new species or varieties is greater than for annuals. Disease limits to perennials include the South American Leaf Blight or SALB *Microcyclus ulei*) in rubber, witches' broom *Crinipellis perniciosa*) in cacao, and Margarita disease *Fusarium solani* f. *piperi*) in black pepper. Recent establishment of a perennial crop on a new continent is often a primary protection against disease. This protection is absent for crops native to the area such as rubber and cacao, but has helped protect recent arrivals like black pepper and oil palm. The honeymoon period for black pepper ended when\Fusarium arrived in Brazil in 1960 and spread rapidly through widely scattered pepper growing areas in the 1970s (Fearnside, 1980d). Oil palm plantations near Bel'm began experiencing an outbreak of shoot rot disease in 1987, but this has not yet reached the larger plantations in Tef', Amazonas (J. Dubois, personal communication, 1987).

8.) *Várzea* settlement

The Amazonian *várzea* (whitewater floodplain) is occupied in large measure by *caboclo* agriculture producing subsistence crops and fiber crops such as jute *Corchorus* spp.), and malva

Malva rotundifolia). Mechanized cultivation of irrigated rice is presently limited to the Jari Project plantations (see Fearnside and Rankin, 1980, 1982b, 1985). Water buffalo raising, for example on the Marajó Island and in the Jari Project, is increasing. This activity, which generates income for absentee investors more readily than does the\caboclo agriculture it replaces, is being encouraged through government programs in\v'rzea areas in the state of Amazonas.

Várzea has the great advantage over\terra firme (unflooded uplands) of annual renewal of soil fertility by the silt deposited during the high water period. Its principal disadvantage is the necessity of vacating the land during the high water period, and the uncertainty of the height and duration of each phase of the river cycle. Increased deforestation will increase this risk by provoking higher and more irregular floods, although the lower river levels at the low water phase will expose more land.

EXPERIMENTAL SYSTEMS

Although experimental systems are not to be confused with predominant land uses, it is important to consider whether any of the systems now under development are likely to expand to a significant extent in the region. One must be cautious of the tendency extended discussion of experimental or "model" systems has to obscure the reality of degraded pasture as the predominant land use (see exchange of views between Revelle, 1987, and Fearnside, 1987c). The existence of systems with "promising prospects" in no way substitutes for effecting structural changes to discourage the rush to convert forest to unsustainable cattle pasture.

Various experiments have been undertaken to develop sustainable systems of production in Amazonia. Fertilized pasture has been tested in Brazil and in Peru (Koster *et al.,* 1978; Serrão and Falesi, 1977; Serrão *et al.*, 1979). Although production on a per-area basis is much higher than in pasture without the treatment, the amount of labor necessary to maintain the pasture free of weeds is uneconomic and the high cost and limited availability of fertilizers would prevent the system's application on the vast scale that would be needed to treat the areas of degraded pasture in the region (Fearnside, 1979b, 1980a, 1985d).

A system to make sustainable the continuous cultivation of annual crops is under testing at Yurimaguas, Peru (Sánchez *et al.,* 1982; Nicholaides *et al.*, 1983, 1984, 1985). Despite the enthusiasm for the results expressed in the publications of the research group responsible for the trials, serious doubts exist regarding the economic viability of the system, its applicability in many areas of the region, and its suitability for use with the shifting cultivators who are identified as the system's intended beneficiaries. The system requires heavy applications of fertilizers, the doses of which are constantly adjusted for each field in accord with the results from analysis of soil samples. The infrastructure that would be necessary to analyze these samples and communicate the results would be a great impediment to widespread use of the system. Even with the inputs subsidized in the experimental program at Yurimaguas, the system has not proved economically attractive (Fearnside, 1987d).

Other systems under testing include different forms of agri-silviculture (reviewed by Hecht, 1982). These imitate shifting cultivation, substituting economically valuable trees for the secondary forests that occupy the fields during the fallow period. A number of interplanting combinations have been devised to make the best use of the nutrient stocks in the soil and of the solar energy entering the system. These include intercropping with nitrogen-fixing legumes and alley cropping, which alters rows of an annual crop with rows of bushes with deep root systems that minimize the losses of nutrients to leaching. Diversified plantings of fruit trees and other arboreal species could produce more sustainably than do the systems that now predominate in the region. These systems merit more research with the objective of obtaining better options for the areas that have already been deforested in Amazonia. For the areas that are still covered with primary forest, however, options would be preferable that maintain this cover intact.

Research on the management of Amazonian forest for sustained production is still in its infancy. Systems under testing in Brazil include the removal of different percentages of the basal area of the forest, leaving the smaller trees for subsequent harvests after they have grown to the requisite minimum size. Other systems include the poisoning of low value trees in order to acclerate the growth of the remaining commercially valuable species *e.g.* Jonkers and Schmidt, 1984; Sarrailh and Schmitt, 1984). Others remove vines or other undesirable components as a part of the treatment. Others try to enrich the forest through planting seeds or seedlings of commercial species. One system for producing charcoal removes the smaller trees to permit the recolonization of fast-growing species (de Jesus *et al.*, 1984; Thibau, 1985); the most extreme treatments, however, are clearcutting or nearly clearcutting of the forest -- the sustainability of this is far from proven. One system under testing in Peru for producing hardwood timber calls for cutting the forest in strips in order to permit recolonization by native species coming from strips that are left in intact forest (Hartshorn\et al., nd). So far no system has been developed that is attractive for the bulk of lowland Amazonia under present economic conditions (Fearnside, nd). Accelerated research, along with preservation of areas of forest, are necessary in order to guarantee that the opportunity to manage the forest on a sustainable basis will not be lost when economic conditions change to give more value to the products that the forest is capable of producing sustainably.

GUIDELINES FOR RATIONAL OCCUPATION AND DEVELOPMENT

The first questions that need to be answered on delineating any plan of occupation and development are: "for whom?" and "for how long?" is this development to serve. Although it is usually not the case, I suggest that "for whom" should always refer to the residents of the region and to their descendants, and "for how long" should be for an indefinite period. Even though Amazonia is big, it is not capable of solving the increasing problems of other regions, such as the states from which the present flood of migrants is now being expelled. The problems of the Center-South, for example, will have to be solved by changes in the Center-South itself.

Deforestation must be slowed by quickly implementing major policy changes including:

1.) Halting road building in Amazonia
2.) Ending subsidies to the region from country-wide price standardization for petroleum products, electricity and other items
3.) Abolishing all direct and indirect subsidies for pasture and other nonsustainable land uses
4.) Levying heavy taxes on speculative profits from land sales
5.) Ceasing to recognize pasture as an "improvement" for establishing land claims
6.) Carrying out agrarian reform by redistribution of large private landholdings
7.) Slowing population growth and
8.) Creating urban employment opportunities in the regions from which migrants are now being forced to leave for Amazonia.

Without these changes the chance will be lost to break the chain of events that inexorably leads to predominant land uses that are unsustainable, unproductive, and economically and socially undesirable.

An economic-ecological zoning of the region is needed based on criteria that reflect the interests of the region's residents and the production limitations of the area. In formulating such a zoning plan it is essential that erroneous assumptions in classifying the aptitude of the soil (such as that pasture improves soil quality and protects the soil from erosion) be replaced by knowledge with a better founding in fact. The economic-ecological zoning of the region should be used to direct development to types of land use that are sustainable over the long term, that are compatible among themselves, and that maintain the environmental functions of the forest as a whole. Classifying an area's soils and other physical characteristics as apt for a given use does not necessarily imply that this use should be implanted, although uses that the capability classification indicates as unsustainable should be prohibited. Interpretation of land capabilities in terms of zoning needs to be based on the concept that no single use should be recommended for the entire area, but rather a patchwork of uses that do not interfere with one another and that attend to the needs of the residents (Eden, 1978, Fearnside, 1983a).

Amazonia has finite limits for sustaining a human population for an indefinite period (Fearnside, 1986b). Although this might appear obvious to many, the very idea that limits exist represents a radical departure from the predominant assumptions of development policy in Brazilian Amazonia today. Population must be adjusted to the ability of the area to support agriculture rather than simply assuming that agriculture will expand and intensify to accomodate population. Together with studies of human carrying capacity the pattern of distribution of resources in the population and limits to total consumption must be defined. Without these fundamentals no plan for occupation and development in Amazonia will meet the needs of future generations in the region.

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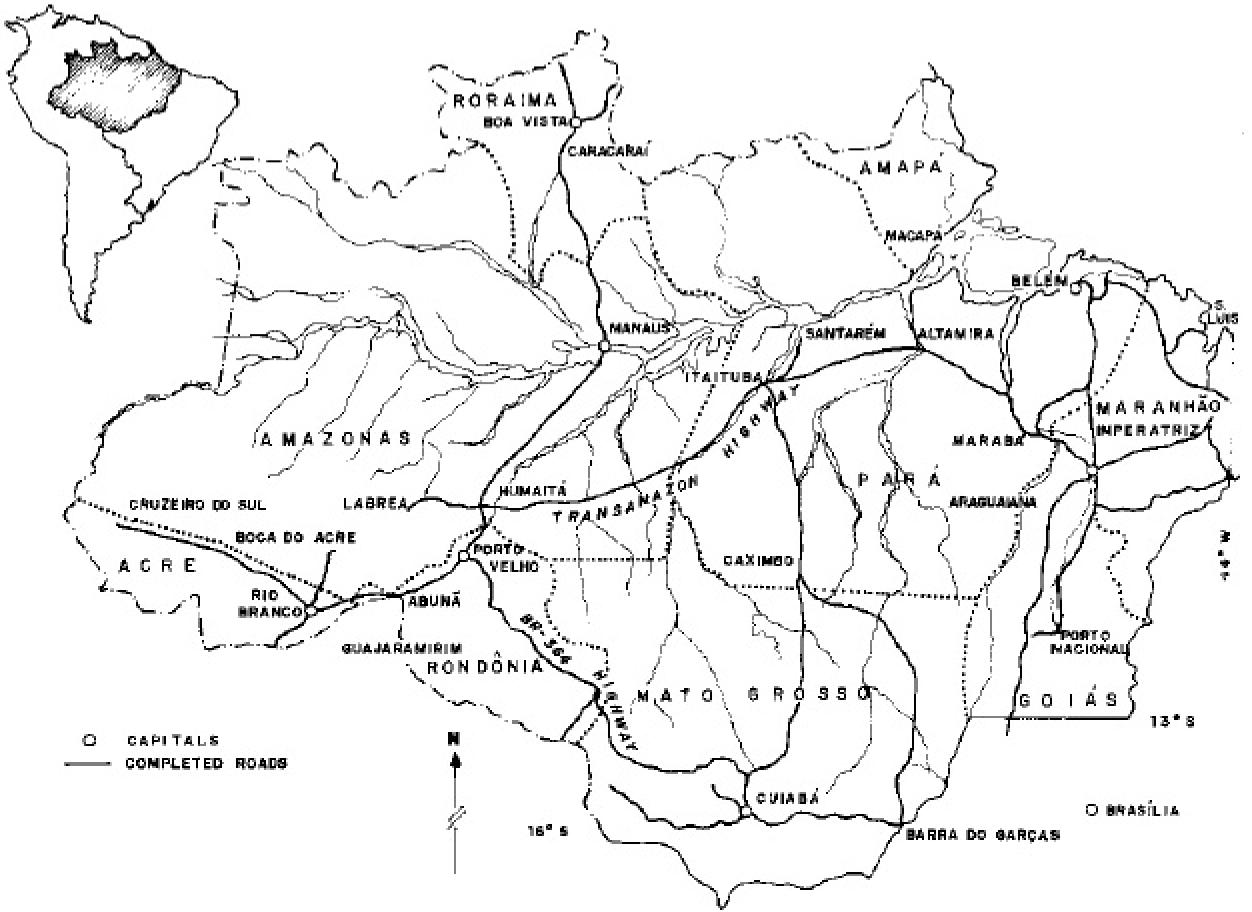
FIGURE LEGEND

Figure 1 -- Brazil's Legal Amazon region.


RORAIMA
BOA VISTA
CARACARAÍ
AMAPÁ
MACAPÁ
BELÉM
S. LUÍS
MANAUS
SANTARÉM
ALTAMIRA
ITAITUBA
MARANHÃO
IMPERATRIZ
AMAZONAS
MARABÁ
PARÁ
HUMAITÁ
LABREA
CRUZEIRO DO SUL
TRANSAMAZON HIGHWAY
ARAGUAIANA
BOCA DO ACRE
PORTO VELHO
CAXIMBO
ACRE
RIO BRANCO
ABUNÃ
BR-364 HIGHWAY
PORTO NACIONAL
GUAJARAMIRIM
RONDÔNIA
MATO GROSSO
GOIÁS
13° S
CAPITALS
COMPLETED ROADS
N
CUIABÁ
BRASÍLIA
16° S
BARRA DO GARÇAS

(Pará) and Ouro Preto do Oeste (Rondônia)