Chapter 15

PREDOMINANT LAND USES IN BRAZILIAN AMAZONIA

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Abstract

The land uses that now predominate in Brazilian Amazonia are unlikely to produce sustainable yields, and they also tend to close off potentially sustainable alternative uses. Cattle pastures -- either functional or abandoned -- now occupy most deforested land. Rather than beef production, the principal motive for planting pasture is often its low cost and high effectiveness as a means of securing speculative land claims. 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 unfeasible 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 research on land-use alternatives could be a first step toward changing predominant forms of land use in Brazilian Amazonia. Policies are urgently needed to slow deforestation, to discourage unsustainable uses, and to make sustainable alternatives profitable.

Introduction

An ecological anaylsis of the predominant land uses in Amazonia indicates the urgent need to redirect the processes that are rapidly transforming the region's forests into unsustainable forms of development. Land uses should be promoted that are not only agriculturally sustainable but also economically and socially feasible. 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. In addition to agroecosystems, the landscape must contain substantial reserves of natural ecosystems, including those inhabited by indigenous peoples.

In practice, however, proposed development projects in Amazonia are rarely formulated on the basis of technical information concerning potential sustainability, environmental impacts, or even economic profitability. Instead, projects are often motivated by political factors (Fearnside 1984a, 1986a) and carried forward even in the face of technical evidence indicating their almost certain failure (Fearnside 1986b). For example, the prospects for sustainability, the long-term economic return to society, and the environmental and social impacts of cattle pasture all compare poorly with other land-use options (Fearnside 1983a). Yet it is precisely this most undesirable land use that dominates the occupied landscapes of Amazonia today.

Pasture Conversion

Causes

The dominant types of development 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 and southern Par'. Satellite imagery indicates these areas are centers of deforestation (Tardin et al. 1980; Fearnside 1986c).

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 (Mahar 1979; Fearnside 1979a, 1983b, 1987a; Hecht 1985). Incentives have allowed companies and individual investors from southern Brazil to apply a portion of the income tax owed on profits made elsewhere in the country to ranching schemes in Amazonia. Generous financing terms provide 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 "dense forest" area.

Three major loopholes allow continued clearing with incentives: (i) the substantial areas of forest still being felled in "old" projects already approved for the subsidies (Hecht 1985), (ii) the wide zone classified as "transition forest" where clearing is preferentially directed at dense forest interdigitated with "cerrado" (scrubland) vegetation (Dicks 1982), and (iii) a very restrictive definition of what constitutes "dense forest" (Fearnside 1985a). Brazil's economic crisis in the 1980s has meant that less government money has been available than previously for cash contributions to the ranching schemes, although subidies continue through tax revenues the government forgoes under the fiscal incentives program.

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 Bel'm-Bras'lia 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 forest with pasture even when little or no beef is produced. The value of Amazonian ranchland has 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 vast areas without legal documentation, pasture has the powerful additional attraction of being considered an improvement ("benfeitoria") that qualifies the rancher for title to the land.

Effects

Pasture has pernicious effects on Amazonian society. Ranching drives small farmers off the land, either by violence (Valverde and Dias 1967; Martins 1980; Schmink 1982) or by tempting smallholders to sell their plots to more wealthy newcomers (Fearnside 1984b; Coy 1987). 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 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).

The most worrisome characteristic of pasture conversion is that there is no immediate limit to its continuation. 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 available. Nor does labor availability restrain pasture as it does other crops, because of low labor demands of the extensive systems used in Amazonia (Fearnside 1980a, 1986a). Pasture's dominance among land-use choices allows a small human population to exert maximum impact on regional forest ecosystems (Fearnside 1983b).

Soil fertility. Pasture is not sustainable in the region without heavy and antieconomic inputs. Pasture grasses grow 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 (Rondônia) indicate that a twelve-year-old pasture produces at about half the rate of a three-year-old pasture (Fearnside, unpublished data). Yields decline due to invasion by inedible weeds, soil compaction, and decreasing levels of available phosphorus in the soil (Fearnside 1979b, 1980b; 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 (Rond^nia) and near Manaus (Amazonas) indicate that soil erosion rates in grazed pasture are much greater than in intact forest (Fearnside, unpublished data).

The necessity of phosphate fertilizers dampens the prospects for maintaining pasture over large areas of Amazonia. 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 initial burning of the forest; after 10 years, levels of this critical element are at least as low as those under virgin forest and far below the amounts required by pasture grasses (Fearnside 1980b; Hecht 1981, 1983). In 1977 EMBRAPA changed its position that pasture improves the soil, recommending instead that productivity be maintained through annaual applications of 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 phosphate and the absolute limits to mineable stocks of phosphate. 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), Brazil would be wise to ponder carefully whether its remaining stocks of this limited resource should be allocated to Amazonian pastures.

Pests and weeds. 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 such changes are likely to increase.

Brachiaria decumbens Stapf. ("braquiária"), a pasture grass formerly common on the Belém-Brasília Highway, was devastated in the early 1970s by outbreaks of the pasture spittlebug, known as "cigarrinha" *Deois incompleta* Ceropidae). Guinea grass or "colonião" (*Panicum maximum* Jacq.) subsequently became a favorite in the area, and its performance was described by EMBRAPA as "magnificent" (Falesi 1974). Yield declines later became apparent with depletion of available phosphorus depletion and increased invasion of weeds. Weed invasion in planted pastures of\Panicum maximum is facilitated by the bunchy growth habit of this species, which leaves bare spaces between the tussocks of grass, and by poor germination of seeds produced by grass in the field. By the 1980s, the spittlebug 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* (Rendle) Schweickt.). This species was at first tolerant of spittlebug attack, but the insects have become increasingly well adapted to feeding on this species. EMBRAPA now recommends *Andropogon guianensis* Kunth pasture grass. The continual changing of species and fertilizer recommendations does not alter the basic characteristics of pasture that ultimately undermine its sustainability.

Climate. 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 1985b, 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 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 drier, 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. Various lines of evidence indicate that 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 (Molion 1975; Villa Nova *et al*. 1976; Marques *et al*. 1977; Salati *et al*. 1978). 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 a handful of leaves: in only a few minutes the inside of the bag is covered with water droplets condensed from evapotranspiration. Summing 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 forest is much greater than that recycled through pasture, especially in the dry season when the pasture is dry while the forest remains evergreen. This difference is accentuated 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, unpublished data). Soil under pasture quickly becomes highly compacted, inhibiting infiltration of rainwater into the soil (Schubart *et al*. 1976; Dantas 1979). 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 variations in water vapor found by Salati et al. (1978, 1979). The relative contribution of recycled water to rainfall is greatest in the dry season, and increases as one moves farther away from the Atlantic Ocean. This means that in the western states of Rond^nia and Acre, where rapid deforestation is taking place, the proportion of rainfall derived from forest could be much higher than the roughly 50% average for Amazonia as a whole. The greater dependence in the dry season means that conversion to pasture may 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 (Nepstad *et al*. 1989). In patches of forest isolated by cattle pasture 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 these 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 to 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 1985c).

If a substantial portion of the region were converted to pasture, the severe droughts provoked by deforestation could threaten the remaining tracts of forest. In Amazonia at present, burning is almost entirely restricted to areas where trees have been felled and allowed to dry before being set alight. The fire stops burning when it reaches the clearing edge rather than continuing into unfelled forest. This fortuitous situation, however, could change. In forested areas that have been disturbed by logging along the Belém-Bras'lia Highway, fires from neighboring pastures have already been observed to continue substantial distances into 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 kmD2Uof the 35,000 km^2 burned in the Indonesian province of East Kalimantan was primary forest, while 12,000 kmD2U 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 deforestation.

Other Regional Land Uses

Pioneer Agriculture

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, infectious diseases, and 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 already occupied, if not by Luso-Brazilians, then by indigenous peoples.

Colonization by small farmers is concentrated in certain parts of the region, with modes of organization that vary from place to place. Colonists were installed in government projects on the Transamazon Highway in the state of Pará and in colonization areas in Rond^nia (Fearnside 1986b; Moran 1981; Smith 1982). In the Grande Caraj's 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 practiced by 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 converted to cattle pasture. Unlike indigenous peoples, pioneer farmers do not have the cultural tradition of leaving their previously cultivated fields in secondary forest for a sufficient time to restore soil quality. The fallow periods used are usually too short to make the system sustainable as a form of shifting cultivation (Fearnside 1984b). Soil degradation through erosion occurs during the cropping phase (Fearnside 1980c). A variety of problems associated with soil fertility, insects, vertebrate pests, weeds, weather, transportation and marketing make returns to the farmers highly uncertain (Smith 1978; Fearnside 1986a). 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 Par' (Egler 1961; Ackermann 1966; Penteado 1967; Sioli 1973).

Under shifting cultivation, fallow plots are usually dominated by woody secondary forest species such as\Cecropia and\Vismia. This may not always remain the case. In southeast Asia, for example, fallow plots with an area of more than about 100 mD2U are usually dominated by grasses such as the very aggressive *Imperata cylindrica* L. (Richards 1964). In the Gran Pajonal of Peru, the less-aggressive neotropical relative *Imperata brasiliensis* Trin. dominates fallows for an extended period (Scott 1978). On heavily degraded sites in Amazonia, succession could 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. Even in pioneer areas, cattle pasture soon becomes the predominant land use (Fearnside 1983b; Leite and Furley 1985; Léna 1986; Coy 1987). The relative importance of pioneer farmers could increase greatly if the Brazilian government's agrarian reform program goes forward on a large scale. Agrarian reform usually implies redistributing large landholdings, but 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 forest and indigenous reserves, parks, and privately owned land would yield only one half square kilometer, or 50 ha, per family. This is half the size of lots distributed in 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.

Logging

Logging has been rapidly increasing in areas of Amazonia relatively accessible to Brazilian markets and ports. Southern and eastern Pará, northern Mato Grosso, and Rondônia are presently experiencing an unprecedented explosion in the number of sawmills. This exploitation has been taking place without any attempts to manage the forests for sustainable production of timber.

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 markets, the list of species exploited lengthens. The rapid spread of highways has opened up vast new lands to logging, including those on the previously inaccessible borders of Brazil and Peru. Logging is one of the principal 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; the first began operation on 8 January 1988. 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. Although official statements often mention silvicultural plantations as a future wood source for charcoal, the native forest appears to be the most likely source. At least in theory, firms are required to obtain the wood used for charcoal from sustainable sources after a given period. At present, their principal source is wood from lands being clearcut 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 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.

Extraction of Forest Products

Extraction of forest products such as rubber and Brazilnuts has supported 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 in comparison with short-term profits derived from deforestation (especially profits from real estate speculation), and the inability of the extractivists to secure their claims to the land in the face of appropriation by ranchers or squatters.

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; Allegretti 1989). 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 \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: 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 above that of international commodity markets. The difference represents a subsidy that is being paid by Brazilian consumers when buying 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 which are now expanding in the Northeast and Center-South regions of the country.

The great advantage of the extractive reserve system is that it maintains the forest's environmental functions and its genetic resources. It also serves an important social function for the traditional extractivists that have so far been the victims of expulsion and economic marginalization. If designed to abut Amerindian reserves, 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 urgently needed, as a basis for determining policies in relation to this land use.

Silviculture

Silviculture has been implanted in the Jari Project, where yields have been lower than those expected by the project's designers, as well as 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 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 1988a). 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).

Perennial Crops

Despite government research, financing, and extension programs, plantations of cacao, coffee, rubber, black pepper, oil palm and other perennial crops occupy only a very small fraction of the region. Official interest in these crops is high because of their perceived potential for sustained production, and because they produce goods for export for foreign exchange. Perennial crops that cover the soil, such as cacao and rubber, offer better prospects of avoiding soil erosion and other forms of degradation in already deforested areas. However, expansion of these crops on a large scale 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 of perennial crops. 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. Diseases in perennial crops include the South American Leaf Blight or SALB (*Microcyclus ulei* (P. Henn.) v. Aix) in rubber, witches' broom (*Crinipellis perniciosa* (Stahel) Singer) in cacao, and Margarita disease (*Fusarium solani* f. *piperi* (Mart.) App. & Wr.) in black pepper. Establishment of a perennial crop on a new continent often provides effective but temporary protection against disease. This protection is absent for crops native to Amazonia such as rubber and cacao, but has helped protect recent arrivals like black pepper and oil palm. The honeymoon period for black pepper ended, however, 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 Belém 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).

Floodplain Settlement

The "v'rzea" (whitewater floodplain), which covers approximately 2% of the Amazon Basin, is occupied in large measure by small-holders raising subsistence crops and fiber crops such as jute (*Corchorus* spp.) and malva (*Malva rotundifolia* L.). Mechanized cultivation of irrigated rice is presently limited to the Jari Project plantations (see Fearnside and Rankin 1980, 1982b, 1985). In areas such as Maraj' Island and in the Jari Project, water buffalo raising is increasing. This activity -- which generates income for absentee investors more readily than does the small-scale agriculture it frequently replaces -- is being encouraged through government programs in the state of Amazonas.

The principal advantage of the floodplain is its annual renewal of soil fertility by the deposition of silt during the high water period. Its principal disadvantage is the necessity of vacating extensive areas 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 low water will expose more land. Despite these limitations, the floodplain has far greater potential than the unflooded uplands for cultivation for short-cycle crops.

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 careful not to allow extended discussion of experimental or "model" systems to obscure the fact that degraded pasture is 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. 1977; Serr~o and Falesi 1977; Serrão *et al*. 1979). Although production on a per-area basis is much higher than in pasture without 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). More recent experimental approaches to pasture recuperation are still under analysis (see Nepsted *et al*. 1989; Serrão and Toledo 1989), but none have been shown to be economically viable.

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 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 according to results from analysis of soil samples. The infrastructure that would be necessary to analyze these samples and communicate the results would greatly impede widespread use of the system. Even with the subsidized inputs in the experimental program at Yurimaguas, the system has not proved economically attractive (Fearnside 1987d).

Other systems under testing include different forms of agroforestry (reviewed by Hecht 1982). These systems frequently mimic the natural succession by substituting secondary forests that occupy the fields during the fallow period with plantations of economically valuable trees. A number of interplanting combinations have been devised to make the best use of the light and nutrients. These include intercropping with nitrogen-fixing legumes and alley cropping, in which rows of annual crops alternate with rows deep-rooted perennial shrubs that minimize the losses of nutrients to leaching (Dickinson 1972; Kass 1978; Fearnside 1988b). Other regional systems utilize diversified plantings of fruit trees and other arboreal species (Alcorn 1989; Subler and Uhl 1989). Agroforestry systems appear to be especially suited land-use alternatives for areas that have already been deforested in Amazonia. For areas still covered with primary forest, however, land uses that maintain this cover would be preferable.

Research on the management of Amazonian forest for sustained production is still in its infancy. Systems under testing 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 (de Carvalho 1980, 1984, 1985; de Graaf and Poels 1989). Other systems include the poisoning of low-value trees in order to accelerate the growth of the remaining commercially valuable species (e.g. Jonkers and Schmidt 1984; Sarrailh and Schmitt 1984), removal of vines or other undesirable components, and enrichment of the forest through planting seeds or seedlings of commercial species. One system for producing charcoal removes the smaller trees to permit recolonization by 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 latter practice is far from proven (Fearnside 1989). Finally, a system under testing in Peru for hardwood timber production involves cutting the forest in strips to permit recolonization by native species coming from strips that are left in forest (Hartshorn 1989).

Alternative Policies

So far no system has been developed that is attractive for the bulk of lowland Amazonia under present economic conditions. Accelerated research -- along with increased preservation -- are necessary to guarantee future implementation of forest management when economic conditions provide greater value to products that the forest can produce sustainably. Policy changes are required both within and outside the region (Sawyer 1989).

The first questions that need to be addressed when delineating plans for regional development are: "for whom?" and "for how long?" is this development to serve. Although not usually the case, I suggest that "for whom" should refer to the residents of the region and to their descendants, and "for how long" should mean for an indefinite period. Even though Amazonia is geographically immense, it is not capable of solving the problems of other regions, such as lack of effective land reform, which is the cause of much of the current wave of migration to Amazonia. Such problems can only be solved in the areas where they originate.

Deforestation can be slowed by implementing major policy changes including: (i) halting road building in Amazonia; (ii) ending subsidies to the region from country-wide price standardization for petroleum products, electricity, and other items; (iii) abolishing all direct and indirect subsidies for pasture and other nonsustainable land uses; (iv) levying heavy taxes on speculative profits from land sales; (v) ceasing to recognize pasture establishment as a basis for legitimizing land claims; (vi) carrying out agrarian reform by redistribution of large private landholdings; (vii) slowing population growth, and (viii) 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.

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