ENVIRONMENTAL DESTRUCTION IN THE BRAZILIAN AMAZON

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ABSTRACT

Environmental destruction is rampant in Amazonia. Deforestation for cattle pasture dominates land use in Brazilian Amazonia largely because of its role in securing speculative land claims. Deforestation threatens soil fertility, forest species, development options and tribal peoples. Widespread conversion of forest to pasture would decrease rainfall in the region, especially during the dry season. Burning of standing forest and tree death from desiccation could greatly accelerate forest loss in a drier Amazonia. Converting Brazilian Amazonia to pasture would also release about 50 billion metric tons of carbon, contributing significantly to the global "greenhouse effect". Soil erosion, phosphorus fixation, soil compaction and weed invasion make pasture unsustainable without continual inputs of fertilizer. Brazil's limited phosphate deposits, and the long distances separating the deposits from Amazonia, render plans inviable for sustaining vast areas of fertilized pasture or agriculture. Also contributing to the destruction are agribusiness initiatives, charcoal production for pig-iron smelting, lumbering, slash-and-burn agriculture, hydroelectric dams, military bases and mining. A pattern of environmental misadventures in these projects is an inevitable result of a decision-making process that allows political considerations to override virtually any technical objection.

Highway construction sets in motion a vicious cycle leading to accelerating deforestation. Many highway and settlement projects reflect policy-makers' desire to solve social problems elsewhere in Brazil by diverting to Amazonia the flow of rural population being expelled by land tenure concentration and agriculture mechanization in the southern part of the country. This objective is unattainable through agricultural development in Amazonia--solutions must be provided in the migrant source areas themselves. Government policies are needed to limit roadbuilding and land speculation in Amazonia and to promote industrial development and agrarian reform in migrant source areas. Decisions of multilateral banks can be critical in financing a redirection of development rather than funding the forces of destruction in Amazonia.

I.) EXTENT AND RATE OF ENVIRONMENTAL DESTRUCTION

Environmental destruction in Amazonia takes many forms, such as deforestation, loss of animal and plant populations from the remaining forest, disturbance and pollution from mining, flooding by hydroelectric dams, and elimination of tribal peoples and their cultures. The various types of destruction are all linked to the advance of deforestation. The vast extent and explosive rate of deforestation hastens the demise of natural ecosystems, closes the door to the most promising human uses of the region and provokes impacts that are regional and in some cases global in scope.

The extent of deforestation remains poorly known despite the existence of remote sensing tools capable of monitoring land surface changes rapidly were sufficient funds and effort allocated to the task. The last LANDSAT analysis covering all of the Brazilian Amazon is for imagery from 1978 (Tardin et al., 1980, see Fearnside, 1982). Of the region's nine states and territories, 1980 LANDSAT data are available for only six: Acre, Goiás, Maranhão, Mato Grosso, Pará and Rondônia (Brazil, IBDF, 1983; see Fearnside, 1984a, 1986a). For Rondônia and half of Mato Grosso, 1983 LANDSAT data are available (Brazil, IBDF, 1985; see Fearnside and Salati, 1985). Data for 1985 from the AVHRR sensor on the NOAA weather satellite are available for Rondônia and the eastern part of Acre (Malingreau and Tucker, 1987, 1988; see Leopoldo and Salati, 1987); 1987 AVHRR data are available only for Rondônia (J.P. Malingreau, personal communication, 1988).

In addition to many of these data being out of date, other deficiencies contributing to underestimates of deforestation include the sensors' inability to (1) distinguish secondary from primary forest, (2) register small clearings and (3) identify disturbances less than full clearcutting. Underestimation also results from the practice adopted by the agency responsible for monitoring deforestation (the Brazilian Institute for Forestry Development: IBDF) as a means of countering the problem of cloud cover: using some images from years previous to the nominal year for the estimate. Both the absolute area cleared and the rate of increase are underestimated by the decrease in the resolution of the sensors used for the most recent data: AVHRR's coarser resolution as compared to the earlier LANDSAT data increases the area of unregistered small clearings. Despite these limitations one must draw the best conclusions possible.

The satellite data indicate that deforestation has been following an exponential trend in many parts of the region. As will be discussed later, this reflects some of the underlying forces driving the deforestation process. The exponential nature of deforestation means that the cleared area could rapidly expand to encompass the entire region if the trend were to continue unopposed by some restraining force. Notwithstanding a number of constraints on the speed with which the forest can be dispatched, the process will continue to its endpoint of total destruction unless positive steps are taken to restrain deforestation and to redirect development to less destructive alternatives.

Each year a larger area of forest is cut than in the year before. If one makes the conservative assumption of a linear trend since the last two data points available for each state or territory, the area cleared annually as of 1988 is over 25,000 km^2--a tract about the size of Belgium. The limitations of satellite data mentioned earlier also make this an underestimate of deforestation. Assuming a linear trend up to 1988 within each state or territory implies that the total classified as "cleared" is 322,000 km^2 or 6.5% of Brazil's 4,975,567 km^2 Legal Amazonia. Assuming exponential trends to 1988 since the last available data would imply about 17% of the region cleared, which is probably too high. The actual amount probably lies between these bounds; the linear assumption value of about 6-7% represents a safely conservative estimate.

Deforestation is highly concentrated in certain parts of the region, especially those nearer to the source of population flows from Brazil's Central South and Northeast Regions. When the Legal Amazon is viewed as a whole, however, the amount cleared is still small relative to the total area of the region. This fact frequently lulls policy makers and others into dismissing concerns about deforestation as "alarmist." Environmental destruction is seen as too far removed in space and time to warrant concern when more immediate economic and social pressures are clamouring for attention. Such a stance is sadly mistaken. The explosive rate of deforestation is far more important than the absolute area cleared so far. The exponential form of the curve is highly deceptive to most people, even to those who have lived their lives in daily contact with such exponential trends as inflation. An exponential trend can cause a seemingly insignificant area of clearing to expand to the size of Amazonia within a few years.

Making projections into the future can be useful as an illustration of the logical consequences of the trends. However, <u>projections</u> should not be confused with <u>predictions</u>, which are <u>prophesies</u> about how the future will actually unfold. The system of forces that drives deforestation is too complex for long term predictions using simple linear or exponential equations. Nevertheless, simple projections make it obvious that speedy and firm government actions are needed to strike at the forces behind deforestation's present exponential trend.

In 1982 I published a projection of deforestation that has been widely quoted, and more widely misquoted. Based on data through 1978, continuation of an unrestrained exponential trend throughout Amazonia would lead to complete deforestation of the region by 1991 (Fearnside, 1982). More recent data are now available indicating that deforestation has proceeded at a somewhat slower pace than that implied by the trend observed through 1978. A number of factors explain the downward shift of the curve, including the limitation Brazil's economic crisis has imposed on the funds available for clearing as fast as Amazonian landholders might like. Many such restraints are temporary. The reasoning behind the 1982 projection remains as valid as ever: policy makers would be well advised to consider carefully the power of exponential trends such as those produced by positive feedback processes underlying deforestation (Fearnside, 1987a). Deforestation is not a problem that will "take care of itself" without conscious decisions by national leaders (Fearnside, 1985a). The trends are the result of identifiable forces that are subject to government control in many ways. Deforestation is not a foreordained process that plays itself out like a Greek tragedy: it is subject to human will.

II.) IMPACTS OF DEFORESTATION

Deforestation provokes many serious consequences that rob Amazonia's residents of a potentially sustainable future. The ecological functions and potential economic uses of the forest are being traded for rapidly-degrading cattle pastures. Some of the potential impacts of this massive transformation can be expected to extend far beyond Amazonia. While planners often mistakenly associate deforestation with such positive terms as "development" or "progress", an examination of the deforestation's impacts provides ample basis for bearing the financial and political price of containing forest clearing.

IMPACTS ON SOIL

Soil erosion results in loss of nutrient capital and agricultural productive potential that is permanent on the scale of human planning. Although erosion losses can be compensated through use of fertilizers, Amazonia's vastness and lack of deposits of key elements such as phosphates makes this impractical on any significant scale. Although erosion may seem to many planners to be too slow a process to worry about, it can cause substantial damage within a few years.

When the forest is removed, the soil becomes compacted upon simple exposure to sun and rain (Cunningham, 1963). Increased soil temperature shifts the equilibrium between oxidation and formation of organic matter such that less of this critical material is present to maintain soil structure (Greenland and Nye, 1959). In the case of the pasture that dominates land use in deforested areas in Brazilian Amazonia, the trampling of cattle further speeds the process of soil compaction. Infiltration of rainwater into the soil is decreased by an order of magnitude in Amazonian pastures as compared to adjacent forest (Dantas, 1979; Schubart et al., 1976). The result is that rainwater runs off over the surface rather than sinking into the soil. The runoff causes both sheet erosion and gulleying.

Annual crops such as rice and maize are well known to be subject to serious erosion, especially in Amazonia, where much of the rain falls in torrential downpours rather than in slow drizzles that can sink into the soil. Measurements of the lowering of the soil surface on the Transamazon Highway indicate that the level commonly falls at a rate of about one centimeter per year; most of this surface lowering is the result of erosion rather than compaction since the rate is significantly correlated with slope (Fearnside, 1980a; 1986b). Recent direct measurements of erosion under various land uses confirm the rapid loss of soil when either bare or under annual crops (in preparation).

Perennial crops and tree plantations are often seen as a solution to erosion. Although most such land uses are far better than annual crops, the protection they provide can be less than one might think. Some perennials with clear areas between the plants, such as black pepper, have erosion rates similar to annual crops (Fearnside, 1980a). Much ground is maintained bare under coffee, which has been expanding in Rondônia and northern Mato Grosso. The spectre of exhausted coffee lands abandoned earlier in this century in the state of São Paulo provides a reminder of the power of erosion.

In silvicultural plantations that require replanting every few years severe erosion often occurs when the ground is exposed between crops and when the planted trees are still young. This is evident in the more steeply-sloping portion of the Jari estate (Fearnside and Rankin, 1982a). Rubber and oil palm in Malaysia (Br"nig, 1977: 189) and teak in Trinidad (Bell, 1973) provide examples of erosion under tree plantations. Nevertheless, trees are undoubtedly much to be preferred over annual crops or cattle pastures.

Cattle pasture is the most important factor in soil degradation in Amazonia because of the wide extent and relatively long time that this land use remains in place. A mythology has developed in Brazil concerning the powers of cattle pasture to protect and improve the soil--a mistaken view that had significant effects on incentives programs and official planning. In 1974 the government agricultural research organ (EMBRAPA) announced that pasture improved the soil, thus making it a "rational means to occupy and increase the value of these extensive areas" (Falesi, 1974). Unfortunately, available phosphorus (P_2O_5) declines under pasture following the initial peak caused by the ash deposited from burning the forest: after ten years P_2O_5 is insufficient to maintain pasture growth (Fearnside, 1980b; see also Hecht, 1981, 1983). Reasonably high levels of pH or soil cations can not compensate for lack of phosphorus (Fearnside, 1980b), which is the limiting factor for pasture growth in much of Amazonia (Koster et al., 1977).

Pasture has also been mistakenly viewed as protecting the soil from erosion. "Protection from erosion" is pointed out in EMBRAPA recommendations for pasture use on poor soils (e.g. Brazil, EMBRAPA/IPEAN, 1974: 43). The RADAMBRASIL land capability mapping, which is widely used for land use planning in Amazonia, classifies land as suitable for pasture if it is "susceptible to erosion" and "inappropriate for use of agricultural machinery"--that is, too steep for tractors (Brazil, Projeto RADAMBRASIL, 1978: Vol. 16, p. 383). Recent direct measurements of erosion under pasture at Manaus (Amazonas) and Ouro Preto do Oeste (Rondônia) indicate much higher erosion under pasture than under forest (in preparation).

Pasture yields decline steadily as the combined result of soil nutrient depletion, compaction and invasion by inedible weed species. Measurements of dry matter production in Ouro Preto do Oeste (Rondônia) indicate that 12-year-old pasture produces only half as much as 3-year-old pasture (in preparation). The strong seasonal cycle of grass production severely limits the fraction of this production that can be effectively converted into beef. Reduced dry matter productivity leads to reduction of beef yields to virtually zero within about eight years (Fearnside, 1979b).

In addition to the immobilization of phosphorus in forms that plants are unable to utilize, as occurs in pasture, other forms of degradation include the removal of cations such as calcium and magnesium ions through leaching when the soil is exposed to the region's heavy rains. In addition, the availability of sites for holding cations in the soil is reduced by depletion of soil organic matter and by the migration of clay particles to lower layers in the soil profile. Cycling of nutrients through the cattle concentrates them in the unevenly dispersed dung, thus reducing their availability for pasture grass growth. Soil nutrients are also removed in the beef exported from the system.

The stock of nutrients in the system represents an equilibrium between inflows and outflows. The increases in outflows described above shift nutrient equilibria to lower levels. Nutrient inflows are largely through contributions dissolved in rainwater and from atmospheric particulates. In the case of phosphorus, a significant source is believed to be Saharan dust transported across the Atlantic Ocean by wind (see Talbot et al., 1986). These inputs may have increased slightly over historical levels because of increased aeolean erosion in Africa provoked by human impact on the vegetation there. Further inputs of nutrients come from smoke from burning within the Amazon Region, a phenomenon that has increased dramatically in recent years. A small input may also come from industrial pollution. Although these added inflows act to partially compensate for losses, the greatly increased outflows in pasture as compared with forest lead to a steady degradation of the nutrient capital.

IMPACTS ON RIVERS

Deforestation increases runoff as the combined result of soil compaction causing decreased infiltration of rainwater and reduced leaf area causing decreased evapotranspiration. An order of magnitude increase in runoff under pasture as compared to forest has been observed in Manaus (Amazonas) and Ouro Preto do Oeste (Rondônia) for measurements over a one year period (in preparation). As deforestation in Amazonia proceeds, rivers in the region can be expected to have reduced water flows in the low water period and higher and more irregular floods in the high water period. The changes in the flood cycle will be particularly damaging to agriculture in the _várzea_ (floodplain), where farming depends on precise timing of agricultural activities in accord with the river's annual cycle.

Hydroelectric schemes in Amazonia might appear to be benefitted by the increased runoff, but the schemes would suffer negative impacts that more than outweigh the gains from increased stream flow. The flow increases would be concentrated at the height of the flood season, when most dams would be obliged to pass the bulk of the flow over their spillways anyway. The runoff from deforested areas would also contain silt from soil erosion, greatly speeding the sedimentation of the reservoirs.

IMPACTS ON CLIMATE

Rainfall in Amazonia is closely tied to the presence of forest. As in other areas, the forest plays a role in inducing the water vapor present in the air to fall as precipitation. Another link to rainfall has perhaps greater importance in Amazonia than in other areas because of the region's vastness. This is the input from evapotranspiration to the stock of water vapor in the atmosphere over Amazonia and neighbouring regions. Several lines of evidence indicate the importance of water recycled through the forest. One is the simple comparison of the water flow from the Amazon River with the amount of rain falling in the catchment basin. The flow at Óbidos is only about half (46%) of the rainfall in the basin above that point, indicating that the other half is returned to the atmosphere as evapotranspiration (Villa Nova _et al_., 1976).

The impact of widespread deforestation on the water cycle is a serious concern because of its potential negative effects on forest survival in Amazonia and on agriculture both in the region and in the neighbouring Central-West Region where rich farmlands produce much of the country's crops (Eagleson, 1986; Salati and Vose, 1984). A feedback to forest survival is expected, where increased drying provoked by deforestation would kill the more sensitive trees in dry years, thereby opening up the forest canopy and further drying the microclimate within the forest, leading to still more tree deaths (Fearnside, 1985b). Eventually rainforest species would be replaced by more drought-tolerant trees, such as those characterizing the *cerrado* vegetation of Brazil's central plateau. The length and severity of the dry season varies tremendously from one year to the next in Amazonia even without the impact of large-scale deforestation (Fearnside, 1984b). Since trees in mature Amazonian forests are believed to live 200 years or more, a very severe drought once every fifty years or so could have a tremendous impact on the forest. Radioisotope ratioing of atmospheric water vapor samples indicates that rainfall is most dependent on water recycled through the forest precisely in the dry season (Salati *et al*., 1979). Increased probability of a very long dry seasons could be disastrous even if mean annual rainfall were to remain unaffected. Radioisotope ratioing indicates that half of the rainfall between Manaus and Belém derives from the forest, and that the importance of the forest increases with distance from the Atlantic Ocean (Salati *et al*., 1978, 1979). More than 50% of the rainfall would therefore be expected to come from the forest in the western Amazonian states of Rondônia and Acre where cleared areas are now exploding exponentially.

The patterns of ecological succession following forest removal in Amazonia could change in the future in a way that increases the climatic impact and decreases the human use potential of the deforested areas. At present, clearings in Amazonia are colonized by woody secondary forest trees such as *Cecropia* and *Vismia*. This pattern is not fixed by some divine decree--it could give way to a grassy dysclimax as occurs in Southeast Asia. In Asia the notoriously aggressive grass *Imperata cylindrica* prevents return of woody vegetation over wide areas, a barrier to forest recovery that is made virtually impassible by frequent burning of the grass. In South America *Imperata cylindrica* does not now occur, although its congeneric *Imperata brasiliensis* does. In Peru's Gran Pajonal, for example, this species serves to impede colonization by woody second growth (Scott, 1978). In highly degraded pastures in Brazilian Amazonia grasses such as "rabo de cavalo" (*Andropogon* spp.) sometimes play a similar role. Even where some woody species are present, biomass accumulation can be minimal for more than a decade after abandonment of highly degraded pasture (Uhl, 1988). The danger of deflecting succession to a non-woody dysclimax is undoubtedly increased by such abuses of the soil as the now increasingly common practice in Northern Mato Grosso of bulldozing secondary vegetation in degraded pasture.

Serious consequences can be expected should large areas of forest be replaced by grasses, whether they be productive pasture or inedible weeds. The difference between forest biomass and the much lower biomass of grass (or of stunted woody growth) is proportional to the amount of carbon that is released to the atmosphere by the conversion. Carbon, which makes up about half of the dry weight of wood, is converted to carbon dioxide (CO_2) either by burning or by the decomposition of unburned wood. A further release of CO_2 results from oxidation of part of the organic matter stock in the soil--a consequence of higher soil temperature under pasture than under forest. Carbon dioxide is the principal cause of the "greenhouse effect"--the increase in global temperature, especially near the poles, caused by trapping of heat by an atmospheric blanket of gases that impede the passage of infrared radiation to space. Expected consequences include both a rise in sea levels and disruption of the present pattern of agriculture by moving climatic zones toward the poles. Most CO_2 is released by burning fossil fuels, but Amazonian deforestation could be a significant contributor to this wider problem in the coming decades. Conversion of Brazil's Legal Amazon from its original vegetation to pasture would release approximately 50 billion metric tons (gigatons = Gtons) of carbon; if this were to occur over a span of 50 years (an optimistic assumption), one gigaton would be released annually, or 20% of the present global total from all sources (Fearnside, 1985c, 1986c, 1987b).

Carbon dioxide is not the only contributor to the greenhouse effect. Trace gases such as methane (CH_4) and nitrous oxide (N_2O), although present in much lower concentrations, have impacts that are now recognized as potentially rivalling those of CO_2 (Dickinson and Cicerone, 1986; Ramanathan et al., 1985). Methane and nitrous oxide are both produced by burning of forest and pasture (Crutzen et al., 1979). Both gases have been increasing in concentration in the atmosphere over the past decades because of emissions from industrial and other sources: CH_4 by 1.1%/year and N_2O by 0.2%/year (Weiss, 1981; Mooney et al., 1987). Unlike carbon dioxide, which is partially reabsorbed by the biosphere through photosynthesis, these trace gases remain in the atmosphere for long periods. Methane is removed very slowly, mainly by reaction with OH in the troposphere although a small amount is consumed by forest soils. Nitrous oxide is only degraded through photolysis in the stratosphere. Although the cycle of reburning pasture or secondary forest makes no net contribution to atmospheric carbon dioxide (except to the extent that average biomass decreases with each succeeding cycle), each reburning makes an addition to the stocks of CH_4 and N_2O with no associated contribution to the removal process.

Methane release increases from conversion to pasture both from the initial burning and because the soil changes from a consumer to a producer of methane, at least in the dry season (Goreau and Mello, 1987). The rumens of the cattle that occupy the pasture are one of the major sources of methane (Ehhalt, 1985: 11). Termites are another potential source of increased methane emission from pasture. Termites are known to produce methane but the amount is a matter of controversy: a factor of ten difference separates high estimates (Zimmerman et al., 1982, 1984) from low estimates (Rasmussen and Khalil, 1983; Collins and Wood, 1984). Pasture, especially degraded pasture, is known to harbor many termites; unfortunately good comparative data on forest termite abundance are lacking.

Nitrous oxide is released by burning, but after this pulse the soil under pasture appears to produce less N_2O than the soil under forest, thereby counteracting some of the initial release (Goreau and Mello, 1987). In the years after the pulse from initial clearing, reburning of pasture or of shifting cultivation fallows continues to release some N_2O through combustion. Deforestation's long-term impact on N_2O is uncertain (Mooney et al., 1987: 928). Over the next few decades, however, the net effect of conversion of Amazonian forest to pasture is expected to be an increase in the flux of this gas to the atmosphere (M. McElroy, personal communication, 1987).

IMPACTS ON FOREST SPECIES

Widespread deforestation presents a serious threat to many species of plants and animals. The diversity of life in Amazonia is legend (Anderson and Benson, 1980; Prance, 1978; Prance et al., 1976). What most exposes this diversity to destruction by deforestation is the highly localized distribution of many species. Because of this endemism, species can be eliminated without deforesting a very large area.

Another characteristic of the forest that magnifies the impact on species of a relatively small amount of deforestation is the requirement of large areas of continuous forest for many species to maintain reproductively viable populations, together with the required sources of food, pollinators, dispersal agents and other ecosystem components. A study being undertaken by the World Wildlife Fund-US (WWF-US) and the National Institute for Research in the Amazon (INPA) near Manaus is investigating some of these interrelationships as a range of sizes of forest fragments degrade following isolation in cattle pasture (see Lovejoy et al., 1984). The need for large areas is already apparent. Climatic changes could make the areas needed to ensure survival even greater. Since climatic zones could shift by hundreds of kilometers, the reserves that would need to be created to buffer against the forced migration of sensitive species may well already be too large to expect in practice.

The question of species extinctions from environmental destruction in Amazonia appears to carry little weight with the decision-makers whose actions most directly affect Brazilian rainforests. Gilberto Mestrinho, then-governor of the state of Amazonas, justified a plan to export the skins of jaguars and other wild species by saying: "the conservationists shouldn't worry. It is not man who decimates species on a wide scale, but rather nature itself, which closes the cycle of life of animals" (A Notícia, 25 June 1983, p. 5). He went on to cite now-extinct life forms that had lived in Amazonia millions of years ago. While extinction is, indeed, the eventual fate of all species, the evolutionary and environmental consequences could be severe from the unprecedented deluge of extinctions expected if present deforestation trends continue (Eckholm, 1978; Ehrlich and Mooney, 1983; Lewin, 1983; Wolf, 1987).

IMPACTS ON OPTIONS FOR FOREST USE

Wood and latex

Deforestation destroys many of the most socially and environmentally attractive options for development in Amazonia. Loss of natural ecosystems directly eliminates economically-valuable species such as trees for hardwood timber, trees now producing about a score of extractive products including rubber and Brazilnuts, and the many medicinal plants whose economic exploitation is presently miniscule.

Pharmaceutical Products

The pharmacological potential of Amazonian forest has scarcely begun to be tapped. It is humbling to realize that almost all of the drugs used in modern medicine were first discovered as products of naturally occurring organisms--from the penicillin mold to the Madagascar periwinkle now used to treat child leukemia (Caufield, 1985: 220-221). Even aspirin was originally derived from willow leaves. Only after the medicinal effectiveness of a compound is recognized is the effort expended to synthesize it without the help of the organisms that produce it naturally. Loss of Amazonian forest is considered a serious potential setback to efforts to find cures for human cancer (see Myers, 1976, 1979, 1984).

Pathogens are continually evolving resistance to drugs used in treatment, making it necessary to have a constant flow of new drugs just to remain in the same place in the battle against disease. The sudden surge to prominence of chloroquine-resistant strains of malaria-causing *Plasmodium* during the 1960s precipitated a rush to tap long-neglected sources of natural quinine in South America (Oldfield, 1981).

In addition to new forms of old diseases, entirely different diseases also continually appear. The recent arrival of Acquired Immune Deficiency Syndrome (AIDS) should provide ample justification for not burning our stocks of potential pharmacological compounds. The notion that the shining achievements of modern medicine permit us to dispense with a major portion of these stocks represents a potentially fatal form of hubris.

Genetic Material

The potential for obtaining valuable genetic material from the forest is another opportunity that is sacrificed by deforestion. Like medicinal plants, genetic resources are irreplaceable--they cannot be bought back with the money earned through deforestation. Germplasm can be valuable both in supplying new crops to agriculture and in providing a store of varieties of already-cultivated species.

A strong popular tendency exists to view agriculture as a technology that has been fundamentally fixed in its basic configuration of crop plants since neolithic times, or at least since the early days of intercontinental travel. In fact, many of agriculture's most fundamental problems remain unsolved, and rely on very temporary technological "fixes" to continue high levels of productivity. One problem is soil erosion under the annual crops that are the mainstay of farming in most of the world. An obvious solution would be to use more perennial crops, thereby reducing both the bare space between crop plants and the fraction of the cropping cycle when the soil is left bare between plantings. Zea diploperennis, a perennial relative of maize became known to the scientific community in 1978 (see Iltis et al., 1979) and was subsequently saved from extinction in Mexico in one of the last vestiges of its threatened habitat (Iltis, 1983: 57).

Another basic limitation on agriculture at present is the inability of almost all major crop species to fix nitrogen. In the tropics as a whole nitrogen is the element that most commonly limits crop production (Webster and Wilson, 1980: 220). Manufacturing and supplying nitrogen fertilizers to farmers depends heavily on petroleum--a nonrenewable resource with rapidly-approaching limits. Green manures and interplanted legumes are a means of alleviating the nitrogen demands of crops, but the dream remains unfulfilled of having an array of crops capable of using directly the vast quantities of nitrogen present in the air. Surveying Amazonian plants and soil bacteria for nitrogen-fixing ability has barely begun (see Sylvester-Bradley et al., 1980).

Another fundamental limit to agriculture is the inability of most plants to solubilize phosphorus when bound in "unavailable" compounds of iron and aluminium in the soil. Were crop plants to gain this ability--either by themselves or through appropriate mycorrhizal symbionts--another impending limit to fertilizer-based agriculture would be less threatening.

The ability of Amazonian plants to make efficient use of scarce nutrients is a feature markedly lacking in the crops favored by present-day agriculture. The dwindling of nutrient and fossil fuel stocks in the world will make this ability more and more valuable as time passes. Great potential value exists in incorporating new capabilities into the repertoire of crop plants, either by adopting new species, breeding wild relatives with present crops, or by genetic engineering techniques.

Pest resistance is another area where germplasm from natural habitats can be indispensible. Most crop plants have been bred to remove the toxic secondary compounds that protect wild plants from devastation by herbivores (Janzen, 1973). The decreasing effectiveness of agrotoxins and the increasing environmental and public health problems they cause provide ample justification for trying to restore to crop plants some of their lost ability to synthesize their own pesticides.

Geographical isolation provides the principal protection against diseases and pests for many crop plants. Rubber, for example, was taken from Brazil to Southeast Asia at the end of the nineteenth century, thereby leaving behind such devastating diseases as the South American Leaf Blight caused by the fungus Microcyclus ulei. Cacao, native to Central and South America, was taken to Africa and Asia where it grows free of witches' broom disease (Crinipellis pernisciosa). Coffee was brought from Arabia and the horn of Africa to the new world, freeing it of coffee rust (Hemileia vastatrix). The protection afforded by geographical isolation is only temporary, and genetic resistance becomes essential when the pests and diseases finally catch up with their far flung host plants. The need to protect the natural sources of resistance was dramatized by the case of coffee when the coffee rust arrived in South America in 1970 and subsequently spread through Central America. In 1964 the last remnants of forest in Ethiopia had provided invaluable genetic material for developing resistant strains; the opportunity might well have disappeared had the germplasm collection expedition been delayed by only a few years (Oldfield, 1981:311).

Maintaining disease resistance in cultivated plants requires continual changes in the plant population's genetic material in order to keep pace with the evolution of pathogens. Because the life cycle of disease causing organisms is much shorter than that of the plants--especially perennials--the disease causing micro-organisms have an inherent advantage in the race. Genetic material conferring resistance to crop diseases is best obtained from wild populations that have been coexisting with the diseases for millennia.

Forestry Management

Destruction of the forest sacrifices the opportunity for sustainable management of this resource. Once the forest ecosystem has been traded for a vast tract of pastureland, reestablishing any kind of forest is costly and difficult, and regaining the original ecosystem can be considered impossible (see Gómez-Pompa et al., 1972). A variety of systems of managing the forest is under testing; the greatest barriers to their use lie in the political decisions necessary to make them economically more attractive than such present money-making activities as planting pasture for land speculation (see Fearnside, nd-a).

IMPACTS ON TRIBAL PEOPLES

For Amazonia's indigenous tribes, forest destruction means either death or loss of cultural identity when acculturation transforms the survivors into the lowest stratum of the dominant society. The process of removing tribes from the forest areas they still occupy has accelerated as new areas are targeted for mining, hydroelectric dams and military bases. The most potent enemy of the indigenous peoples in their ongoing stuggle to maintain their lands and cultures is the tendency of the dominant society to consider disappearance of tribal peoples as either inevitable (and therefore not worth the effort to reverse) or as something that has already occurred. Many people think of the decimation of tribal peoples as a part of history rather than as a process that is still going on today and is, above all, by no means complete.

The litany of affronts to indigenous peoples in the Brazilian Amazon grows longer by the day. The Ecumenical Centre for Documentation and Information (CEDI) publishes a running catalog of these events in the series "Aconteceu" (e.g. CEDI, 1986). Brazil's Legal Amazon has 368 indigenous areas in various stages of documentation, ranging from "unidentified" areas where no measurements of areal extent have been made to "regularized" areas where full legal protection applies (CEDI/Museu Nacional, 1987). Most of the land area and tribal population do not have legal protection beyond the little provided by the "identification" stage that begins the long process of reserve creation but carries little guarantee that the land will not be subsequently usurped by other interest groups. Mining is a rapidly increasing threat that usually wins whenever conflicts of interest arise with indigenous peoples; at least 77 reserves are threatened (SBPC, 1986; see also CEDI/CONAGE, 1988). Lumbering and hydroelectric dams are also increasing, along with the relentless pressure of invasion by ranchers, speculators and small squatters. Invasions are closely tied to the construction of roads: once a road is built though a tribal area, the subsequent arrival of migrants takes place largely outside of government control. In some cases such invasions have even been informally encouraged by government officials. The expansion of highway networks is greatly speeded by large internationally-funded development projects such as POLONOROESTE and Carajás. In Rondônia, planned roads cut through six reserves (Fearnside and Ferreira, 1984), while in the Grande Carajás Programme area nine reserves are cut by highways, in addition to cuts by railways and electric transmission lines (Fearnside, 1986d).

Disappearance of the tribes and their cultures implies one cost that even the most narrowly pecuniary of economic planners should appreciate: the loss of knowledge of how to use the diverse forest species. The medicinal and other properties of the thousands of species present in the forest are prohibitively expensive to assess if done from random samples of the vegetation. Much more efficient is a program of confirming the activity of species used by tribal peoples. Little of the knowledge of how to use forest species has been recorded (see Elizabetsky, 1987; Posey, 1983).

Recording and using the knowledge that is now the near exclusive domain of indigenous tribes and, to a lesser extent, of rubbertappers and caboclo farmers should be done with all due haste because of the unique value of the knowledge and because it contributes a strong argument for maintaining intact significant tracts of the forests on which these groups depend for their survival. Some people fear that passing this knowledge to the dominant society would represent a "last theft" from the tribes. The tribes' land and right to exist must be guaranteed independent of any economic value that the dominant society may see in preserving these cultures. Once all useful knowledge has been gathered from the tribes, they cannot be destroyed with impunity. At bottom, their right to existence is not a question of economic value but one of human rights.

III.) CAUSES OF ENVIRONMENTAL DESTRUCTION

Efforts to control the process of deforestation will be ineffective unless they are founded upon a correct understanding of the forces that motivate forest destruction. The deforestation process varies greatly in different parts of the region (Fearnside, 1986a). Forest is converted to a variety of other uses, often for ulterior reasons rather than the direct products of the new undertaking.

CATTLE RANCHING

Cattle pasture dominates land use in deforested areas of Brazilian Amazonia, greatly magnifying the impact of a small human population on the forest (Fearnside, 1983a). The yield of beef is miniscule because of a steady decrease in pasture grass productivity caused by decline in available phosphorus in the soil, soil compaction, erosion, and invasion by inedible weeds (Fearnside, 1979b, 1980b; Hecht, 1981, 1983). The beef is almost all consumed within Brazil: the presence of hoof-and-mouth disease (afthosis) blocks exports of frozen beef to North America and Japan, thus sparing Amazonia the awesome force that international markets exert in Central America through the "hamburger connection" (see Myers, 1981; Nations and Komer, 1983). Maintaining pasture productivity past the first decade or so requires inputs of phosphates (Serrão and Falesi, 1977, Serrão et al., 1979). The level of inputs required could not be justified without massive subsidies and, on the vast scale of Amazonian pastures, are limited by the dimensions of this nonrenewable resource (Fearnside, 1985d; see also Fearnside, 1987c). Amazonia has no known phosphate deposits, with the exception of a small deposit of phosphate-bearing bauxite on the coast of Maranhão (de Lima, 1976) and a hopeful but as yet unquantified find north of the Amazon River near Maicuru, Pará (Beisiegel and de Souza, 1986). Given the poor agronomic performance and unpromising long-term prospects of pasture, the reasons for this land use dominating the landscape lie elsewhere.

One reason is the generous suite of financial incentives granted to large ranchers by the Brazilian government through the programs administered by the Superintendency for the Development of Amazonia (SUDAM) and the Superintendency for the Manaus Free Trade Zone (SUFRAMA). These programs not only grant exemption from income tax on the ranching operations themselves but also allow the enterprises to invest in the ranches the money that the firms would otherwise pay as income tax on unrelated operations elsewhere in the country (Bunker, 1980; Hecht, 1985; Mahar, 1979; Fearnside, 1979c). Special loans are granted with interest rates below the rate of Brazilian inflation (making the interest negative in real terms). The loan programs create an additional motive to establish ranches as a front for receiving subsidized capital that, apparently, is sometimes in part diverted to more lucrative activities elsewhere (Mahar, 1979). Government subsidies account for up to 75% of the investment in the ranches (Kohlhepp, 1980: 71).

Programs for subsidizing ranches grew rapidly in the 1970s, but have ceased to expand since. In 1979 SUDAM announced that no "new" incentives would be granted in the "high forest" area of the Legal Amazon, but maintained the program of "old" (already approved) incentives for the over 300 projects underway in the high forest region, plus the possibility of "new" incentives for the wide area officially classified as transition forest along the southern fringe of the region. Most of the "transition forest" area is, in fact, an interdigitation of high forest with scrubland (cerrado) vegetation, rather than an intermediate vegetation type. LANDSAT imagery of this region reveals that ranchers preferentially clear the higher biomass forest (Dicks, 1982).

Subsidized ranching is still an important factor in deforestation, but the country's economic crisis has reduced the amount of money available for this purpose. Because the strictures are mandated by lack of money rather than by basic policy decisions on the worth of pasture, the flow of funds to the ranchers can be expected to resume once Brazil's economy recovers. Brazil's president was recently quoted as saying that he didn't "even want to hear" about the possibility of discontinuing the ranching subsidy programs (Isto É, 15 July 1987: 65).

Much clearing by both large and small landholders is done without benefit of the subsidy programs. Even in the heavily-subsidized ranching area on the Belém-Brasília Highway during the height of the SUDAM program only about one-half of the clearing enjoyed fiscal incentives (Tardin et al., 1978; see Fearnside, 1979c). The explanation for the bulk of the pasture is the key role of this land use in land speculation (Fearnside, 1979c; 1987a). The value of land in Amazonia has been steadily increasing at a rate higher than Brazilian inflation, yielding handsome returns to anyone that can hold onto a claim and sell it to someone else. For example, during the 1970s land values in Mato Grosso were increasing at an average annual rate of 38%, after correction for inflation (Mahar, 1979: 124); pastureland on the Belém-Brasília Highway has similarly outstripped inflation (Hecht, 1985). Part of the reason for the land value increase is desire for investments in real property as a shelter from inflation--serving a role as a store of value (similar to gold bullion) rather than functioning as an input to production. Individual properties increase several fold in value when they gain access to a road (a benefit provided by the Brazilian taxpayers and international banks that fund the highway construction program). A similar jump in value occurs when a land claim is legitimized by a "definitive title". Replacing the forest with pasture is the cheapest way to occupy the area and protect it from takeover by squatters, neighboring ranchers, or government agrarian reform programs. Pasture also counts as an "improvement" (benfeitoria) to justify the granting of a definitive title. Ironically, the investments in unproductive ranching enterprises are a significant factor in fueling Brazil's inflation (Gall, 1980), thus forming a vicious circle leading to more and more pasture (Fearnside, 1987a).

AGRIBUSINESS

Agribusinesses account for a small portion of the cleared area relative to pasture, but one that could expand significantly. Large-scale plans exist for financing mechanized agriculture and associated industries in the Grande Carajás area (Brazil, Ministério da Agricultura, 1983; see Fearnside, 1986e; Hall, 1987). Much of the agricultural portion of program is currently on hold awaiting funding; in contrast, the portions of the Grande Carajás scheme related to charcoal production have been rapidly expanding.

Silviculture

The silviculture plans in Carajás illustrate a common feature in Amazonian development: the "phoenix from the ashes" phenomenon. The plan to use charcoal for processing iron ore was originally announced in 1980 by Nestor Jost, then head of the Grande Carajás Interministerial Programme (Fearnside and Rankin, 1982b). A 2.4 million hectare _Eucalyptus_ plantation scheme was announced, together with a plan to collect charcoal made from native forest by ranchers, farmers, and even indigenous tribes. The scheme was greatly reduced in the 1983 "Programa Grande Carajás Agrícola" plan (Brazil, Ministério da Agricultura, 1983; see Fearnside, 1986e). Suddenly the charcoal plan reappeared on a huge scale, with a charcoal demand that would require over 700,000 ha of _Eucalyptus_--almost ten times the area of Jari's managed plantations (Fearnside, 1987d, 1988). Pig-iron production began in Açailandia, Maranhão on 8 January 1988 without fanfare (and without an environmental impact report).

The silvicultural plantations at the Jari Project, used to produce pulp manufactured in the estate's own mill, were initiated by the Northamerican shipping magnate D.K. Ludwig in 1968. Many features of the site, the project's founder and the concessions granted by the Brazilian government make it unlikely that similar undertakings will multiply in the region (Fearnside and Rankin, 1980, 1982a, 1985). Ludwig sold a controlling interest in the estate to a consortium of Brazilian firms in 1982; the price paid was a small fraction of the cost of establishing the enterprise. Jari has suffered a number of biological problems, including poor growth of some of the first plantations that were located on inappropriate soil, much lower growth rates overall than originally anticipated and losses to a variety of pests and diseases (especially the fungus _Ceratocystis fimbriata_ in Jari's hallmark tree species: _Gmelina arborea_). The dramatic rise in pulp prices that Ludwig foresaw for the 1980s has not yet materialized. Although a profitable Kaolin (China clay) mine in the estate has permitted the present operation to cover its operating expenses (but not its burden of debt service), the silviculture sector has been losing money: in 1985 the loss was US$ 47 million (Fearnside, 1988). While some of Jari's early problems can be attributed to uninformed decisions on the part of Ludwig himself, the continuing biological problems of the plantations in no way reflect poorly on the quality of management but rather indicate that large-scale silviculture in Amazonia is much more expensive and much more difficult than many planners might think. It is foolhardy to imagine that a plantation scheme in Carajás ten times larger than the one at Jari can operate without major difficulties.

The likely result in Carajás is that charcoal production will be supplied from native forest for as long as accessible stands remain in existence. The initial decision to implant the pig-iron smelters, apparently taken without benefit of any analysis of the environmental impacts of supplying the charcoal, could lead to the entire economy of the affected area being pulled into feeding these enterprises with wood, much as a bird is drawn into feeding a cuckoo's chick in its nest (see Fearnside, 1987d).

When the first pig-iron smelter began production on 8 January 1988, the company (Companhia Siderúgica Vale do Pindaré) had drawn up a forestry management plan for producing wood for charcoal in the future. However, at the time that I visited the operation two weeks later, it had not yet purchased a tract of land for implanting the management scheme. Clearly the management schemes are neither sufficiently detailed to require knowledge of a specific tract of land nor are the tracts pre-requisites for beginning operation. The Carajás pig-iron scheme is the latest in a long list of development misadventures in Amazonia where projects have been decreed before confirming their sustainability and level of impact (Fearnside, 1985a).

Alcohol

Alcohol is one product for which great potential has been proclaimed for development by agribusinesses (e.g. Abelson, 1975). The efforts to exploit this potential have so far met with mixed success. The Abraham Lincoln Sugar Cane Project (PACAL), begun in 1972 on the Transamazon Highway 90 km west of Altamira, Pará has experienced a long series of problems. Originally for sugar, the mill now produces only alcohol. The site was located in an area that agricultural zoning had previously shown to be climatically inappropriate for sugar cane (Moraes and Bastos, 1972: Fig. 8). The cane grown at the site has a low saccharose content, which has caused much of the production of surrounding farmers to be rejected by the mill, leading to severe social tensions. The social tension has been aggravated by grave administrative, technological and human-relations mistakes, for example telling farmers to harvest their cane on a specified date whereupon the promised transportation is not delivered and the cut cane quickly loses its sugar content. On several occasions the area's farmers have not been paid for many months after delivering their cane to the mill. A succession of firms running the operation have failed to establish a working relationship with the farmers, and have resorted to violence to keep the farmers in line. A larger cane alcohol project, with financing from the World Bank, is now being implanted by Alcobrás in Acre; the first 5000 ha plot of this 20,000 ha scheme is nearing completion. Cane from the Alcobrás estate will be supplemented with purchases from local farmers. Social problems have already begun in the Acre scheme in the aftermath of expelling 80 families of rubbertappers and small farmers from the area. A 5000 ha cane plantation and alcohol distillary will also begin production in late 1988 in Presidente Figureido, north of Manaus.

Manioc (cassava) alcohol produced in Amazonia, seen by Abelson (1975) as a potential solution to the coming end to fossil petroleum, has not proved the panacea that it was originally hoped to be. Producing alcohol from manioc is more expensive than producing it from sugar cane, in part because of the energy supplement the bagasse from the cane contributes to the process. At Sinop in northern Mato Grosso an agrochemical firm has produced manioc alcohol from tubers both grown on the company's own estate and purchased from surrounding farmers. Sweet potatoes and sorghum have also been used. In 1987 the firm discontinued using manioc because of the high cost and many headaches involved with the migrant labor force that harvested the tubers. The firm now uses sorghum grown in mechanized plantations on the estate for producing alcohol for use in beverages--a higher value product than the fuel alcohol obtained from manioc or sweet potatoes. The market limitations on expanding plantations of this kind are, however, much more severe than is the case for fuel crops.

Perennial crops

Market limits severely restrict the areas to which many of the crops can expand that are favored by agribusinesses. Because Amazonia is so large, any significant portion of the region planted to perennial crops would saturate world markets for these commodities. The prices of most products are already low from the farmers' point of view, with financial losses and changes in land use resulting whenever the prices dip. Cacao, for example, has been falling in price since its high in 1977, with the exception of a brief rise after the 1982/83 El Ni~o-provoked droughts in Africa destroyed cacao plantations there. A long-term fall in cacao prices was foreseen by World Bank economists <u>before</u> the major cacao planting effort in Rondônia was launched under the POLONOROESTE project (International Bank for Reconstruction and Development, 1981).

Plant diseases severely curtail the potential for conversion of large areas to perennials (Fearnside, 1980c, 1983b, 1985d). Cacao and rubber are both native to Amazonia, and consequently have all the diseases to which they are heir waiting to attack them. Witches' broom disease (<u>Crinipellis perinisciosa</u>) in cacao and South American leaf blight (<u>Microcyclis ulei</u>) in rubber already have devastating effect on plantations. These diseases do not exist in Africa and southeast Asia, thus giving a competitive advantage to planters in those places. Other important perennials such as coffee, black pepper and oil palm suffer from diseases that have followed them from the continents in which these crops originated. Coffee is attacked by rust

(*Helmileia vasatrix*), black pepper by the Margarita disease fungus (*Fusarium solani* f. *piperi*) and oil palm by a recently arrived shoot die-back. Disease has an unfortunate relationship with markets that reinforces the effect of either falling or rising prices. Because it costs money and effort to control disease, farmers are less motivated to make these outlays when the product price is low, thereby allowing the infestation to become worse and making it even more expensive to bring the disease under control.

Várzea development

Várzea (floodplain) has several natural advantages over *terra firme* (upland) areas for supporting agriculture. The rivers adjacent to all *várzea* areas offer a permanent and cheap transportion route that upland areas lack. The soils, made up mostly of recent sediments deriving from the erosion of igneous rocks in the Andes, are inherently more fertile than the ancient highly-weathered soils of the uplands. More important for sustaining agriculture over the long term is the eternally renewable character of this fertility, with fresh deposits of silt laid down annually by the river's flood waters. This natural renewal is a key part of annual crop systems used by small farmers, but so far has not been so exploited by agribusiness.

The irrigated rice scheme at Jari is a unique attempt use the Amazonian *várzea* for agribusiness ventures. The silt from annual flooding, however, is excluded from the paddies by a polder (dike); Jari relies on fertilizers to maintain levels of soil nutrients. The plantation has 4,150 ha of rice, with plans to expand to 12,700 ha currently not being actively pursued (Fearnside, 1988; Fearnside and Rankin, 1980, 1982a, 1985). The expansion of irrigated rice to much wider areas in Amazonia, either by mechanized agribusiness as at Jari or by small farmers, is technically possible but appears unlikely under present economic conditions (see Fearnside, 1987c).

Water buffalo raising for production of milk, cheese and meat has been expanded at Jari to utilize 50,000 ha. Large ranchers in other *várzea* areas of the lower Amazon, such as the Ilha de Marajá, have also adopted this method of exploiting the *várzea*. Water buffalo have been promoted by EMBRAPA in *várzeas* in the Amazonas and Solimões (Upper Amazon) Rivers in the state of Amazonas, but have not yet reached the scale of lower Amazon developments. The "Estrada da Várzea", under construction in the state of Amazonas, will bring settlement to infertile *terra firme* areas as a side effect of roadbuilding activity justified on the strength of the *várzea*'s production potential, especially for water buffalo. Buffalo represent a means of using the *várzea* by large operators--competing with the subsistence and fibre crops of the small farmers that traditionally occupy this zone.

Neither buffalo ranchers nor small farmers "own" the *várzea*, since all land within 50 m of a river's high-water mark belongs to the Brazilian Navy.

The annual deposition of silt by the flood waters makes prospects for sustainable agriculture good in the *várzea*. Long term negative factors include loss of part of the *várzea* to rising sea levels in a greenhouse-warmed world, and the greater risk from higher and less regular floods provoked by watershed deforestation. The present constraints are more social than agronomic--most of the *várzea* is already occupied by undocumented small farmers, which means that development by agribusiness is likely to imply their expulsion. A more desirable alternative might be to encourage the small farmers already present to further diversify their plantings, as is done by indigenous groups (Denevan *et al*., 1984), and to make greater use of the rich fruit production of natural *várzea* forests as is profitably done near Iquitos, Peru (Peters, *nd*).

LUMBERING

Lumbering is rapidly increasing in importance as a factor in Amazonian deforestation. Timber exploitation has, in the past, been much less prominent in Amazonia than in the tropical forests of Africa and southeast Asia because of the lower density of commercially-valuable trees in South America. The tropical forests of southeast Asia are dominated by a single family of trees: the Dipterocarpaceae. Despite a high diversity on the level of species, the wood of many of these is similar enough to be grouped into only six classes for the purpose of sawing and marketing--as though there were only six species rather than several hundred. Amazonian species, being less closely related to each other taxonomically, have a correspondingly more heterogeneous set of wood characteristics. Amazonian trees have so far defied efforts to group the species into a relatively small number of categories for processing and marketing purposes. Another disadvantage is the dark color of the wood of most Amazonian trees, in contrast to the light colors that dominate in southeast Asian hardwoods. The light colored woods are more easily substitutable for such temperate species as oak and maple in European and North American furniture manufacturing.

Decimation of the tropical forests of Africa is essentially complete from a commercial standpoint, while those of southeast Asia are rapidly nearing a similar end. Exports from Amazonia are therefore increasing. Timber removal from Amazonia has occurred through rapid proliferation of small sawmills, for example in Mato Grosso, Rondônia, Acre and Roraima. Many of these have moved from areas of Brazil where timber is already reaching its end, such as Espirito Santo and the Belém-Brasília Highway in Pará. A steady stream of trucks bearing either logs or rough-sawn lumber can be seen entering São Paulo from the neighboring Amazonian regions.

Lumbering is becoming an important factor in incursions into indigenous areas in Rondônia, Acre and the western portion of Amazonas. Lumbering roads serve as entry routes for squatters who clear in the hope of securing land claims. Satellite imagery of Rondônia (AVHRR interpreted by C.J. Tucker at NASA, Greenbelt, Maryland, U.S.A.) shows that the burning of 1987 included areas in such Amerindian reserves as Pacaás Novas, Tubarões and Lajes. Several of these sites are known areas of logging penetration, such as the portions of the Pacaás Novas reserve supplying sawmills in Ouro Preto do Oeste.

Lumbering in the uplands (terra firme) is rapidly destroying stocks of some of the most valuable species, including "cerejeira" (Amburana acreana) and "mogno" (Sweitenia macrophylla). In the flooded várzea forests--the first to be affected because of the ease of transporting logs by water; commercial species such as "ucuúba" (Virola spp.) are rapidly declining.

Some of the processing and logging is done by large firms such as Georgia Pacific, which has a series of approximately 60 properties near Portel, Pará (R.W. Bruce, personal communication, 1988) totalling about 500,000 ha (Cardoso and M"ller, 1978: 161). The company's veneer plant at Portel produces 150,000 m^3 annually, and supplies approximately 25% of the North American market for tropical hardwood veneer. So far most of the wood is purchased from private loggers outside of the company's estate (R.W. Bruce, personal communication, 1988). Most logging, however is done by thousands of relatively small Brazilian operators rather than by large multinationals. In Amazonia as a whole, least half of the logging activity is believed to take place in "clandestine" operations outside of the control and tax-collection efforts of the Brazilian Institute for Forestry Development (IBDF).

The cutting of "noble" hardwoods is spreading rapidly as road access improves to previously-remote areas and as market pressure increases. The less-noble woods are also increasingly finding markets, and it is this sector that has the greatest potential for expanding the impact of wood harvest on deforestation. Contracts with less demanding markets such as China and India have been negotiated in some cases, for example, for wood from the Samuel Hydroelectric Project in Rondônia. Delegations from heavily deforested countries such as these have been visiting the region with increasing frequency in search of wood supply contracts. However, one contract to supply China with pig-iron (a product manufactured with charcoal) was recently cancelled (A Crítica, 8 August 1987).

Efforts continue to develop ways of using more of the forest's diverse species. The possibility that an entire forest can be simply ground up and shipped away for manufacture of chipboard or low-quality paper products is indicated by the use of this procedure in lowland Papua New Guinea. This is euphemistically called "total harvest" by the Japanese firms that practice it there (Routley and Routley, 1977). So far Amazonia has been spared the common sight in southeast Asia of mountains of wood chips being loaded onto ships for export. The dwindling of forest resources elsewhere, combined with continuing technological progress in using the available species, increase the likelihood of chipping becoming a factor in the destruction of Amazonian forests.

Chipping of selective native forest species is used as a supplement to plantation sources for pulpwood at Jari. The number of species used for this purpose has decreased from 80 in 1983 to 40 in 1986 (Fearnside, 1988: 18). The reduction in species used maintains a more consistently high quality in the pulp; for lower quality paper or cardboard such standards need not apply.

The use of wood chips for fueling thermoelectric plants is another possible contributor to deforestation. A series of wood-fueled power plants is under construction in the states of Amazonas and Rondônia. Two (Manacapuru, Amazonas and Ariquemes, Rondônia) are already functioning. The expansion of this use depends heavily on the price of oil. High oil prices made the initial plans a priority in the early 1980s, but subsequent decline in oil prices has removed much of this incentive. For example, the Balbina hydroelectric scheme had a 7.5 MW wood-burning thermoelectric plant to supply the construction site. This was deactivated and replaced with oil generators in September 1987, slightly over a year before hydroelectric generation is to begin. Two 50 MW thermoelectric plants were to use wood from the area around the reservoir; the parts for these, which were already arriving at Balbina, were transferred to Manaus for conversion to an oil-fueled supplementary plant there. The low price of oil is the key factor in the change of plans, not sudden awareness of the value of maintaining forest. Since the earth's stocks of petroleum are being rapidly depleted, oil prices are bound to rise in the future--thereby increasing the attractiveness of wood-fueled thermoelectric plants.

SLASH-AND-BURN AGRICULTURE

"Shifting cultivation", with long fallow periods capable of regenerating the soil after a year or two of use under annual crops, must be distinguished from "pioneer farming" practiced by recent arrivals in the region. Both systems rely on "slash-and-burn" to clear the forest, but the similarity between the systems largely disappears after this initial step. Pioneers coming to the region from other parts of the country fell and burn the forest in the same way as the first step in traditional shifting cultivation, but after the brief cropping period they either leave the fields fallow for a short time (insufficient to regenerate the productive capacity of the sites), or, more frequently, plant the area in pasture. Shifting cultivation as a sustainable practice requires a complex set of cultural traditions in the form of folk knowledge and respected customs such that farmers do not reduce the fallow period and set in motion the degradation process. Even though the system could potentially support a sparse population in a sustainable fashion, it is doomed to fail for pioneers because of population pressure, demand for cash generation, cultural bias against those who have secondary forests, and/or speculative motives for planting pasture instead. True shifting cultivation is minimal as a factor in deforestation in Brazil. Only indigenous peoples and some caboclo farmers use this traditional practice. Pioneer agriculture, however, is a major and growing force in Brazilian Amazonia.

Slash-and-burn pioneer agriculture has long been a major factor in Amazonian portions of Peru and Ecuador, but has been overshadowed in Brazil by the rapid increase of pasture on large ranches. The importance of slash-and-burn is increasing relative to large ranchers because of the shortage of funds for financing ranchers and because of the increasing expulsion of small farmers from southern Brazil. Slash-and-burn is increasing fastest in Rondônia, Acre and Roraima. The potential for spread of this kind of clearing by small farmers is much larger than what has been experienced so far, but the future course of its expansion depends on political decisions to which strong opposition exists. A far-reaching agrarian reform plan was announced by Brazil's President Sarney in 1985. The original plan called for the land for redistribution to be disappropriated from large landholdings (Brazil, MIRAD, 1985: 30). If implemented in this way, the plan would help slow deforestation. However, landowners have exerted strong pressure to (1) stop the plan altogether and (2) have the plan interpreted to require first the distribution of government land. Since virtually all of the land still in the public domain is located in Amazonia, such an interpretation would make agrarian reform a mere euphemism for colonization of the type that has given poor results on the Transamazon Highway, in Rondônia, and elsewhere. Colonists from southern states are already being resettled under the "agrarian reform" plan on public land in such areas as Presidente Figuereido, in the state of Amazonas. Carried to its logical conclusion, using Amazonia as an escape valve for settling landless people spells disaster in both sacrificing the forest and implanting a nonsustainable form of agriculture on a massive scale. Brazil's Legal Amazonia has an area of five million square kilometers; if the entire region (including reserves and already-occupied land) were divided equally among the country's 10 million landless families, each would receive only 50 ha (half the area of lots on the Transamazon Highway). The inability of Amazonia to solve the social problems of other parts of the country must be recognized by national policy makers.

HYDROELECTRIC DAMS

The 2010 Plan

Reservoirs for hydrolectric power generation are claiming a greater and greater share of Amazonian forest. The potential for expansion of impacts from this sector is large: ELETROBRÁS (the Brazilian government's power monopoly) has published a "2010 plan" outlining the possible construction of 68 dams by the year 2010, with the total rising to as many as 80 dams within a few decades (Brazil, ELETROBRÁS, 1987). The 80 dams would flood roughly 2% of Brazil's Legal Amazonia--a percentage that, while seemingly small, would provoke forest disturbance in much wider areas. Aquatic habitats would, of course, be drastically altered. Most of the sites that are favorable for hydroelectric development are located along the middle and upper reaches of the tributaries that begin in Brazil's central plateau and flow north to meet the Amazon River--the Xingu, Tocantins, Araguaia, Tapajós and others. This region has one of the highest concentrations of indigenous peoples in Amazonia.

The Tucurui Dam

The Tucurui Dam, which blocked the Tocantins River in 1984, flooded 2430 km^2, including part of the Parakanã Indian Reserve. The dam was built before 23 January 1986 when Brazil's National Council of the Environment (CONAMA) established its Resolution No. 001 to operationalize Federal Law No. 6938 of 31 August 1981 by requiring environmental impact statements (RIMAs). Compilation of available environmental information (Goodland, 1978) was commissioned by ELETRONORTE (the branch of ELETROBRÁS responsible for Amazonia). The World Bank refused to finance the dam construction because of environmental concerns. A more detailed series of reports was compiled by INPA (under commission for ELETRONORTE) during the period when the dam was under construction (Brazil, INPA/ELETRONORTE, 1982-1984). Problems include aquatic weeds, acid water provoking corrosion of the turbines, and sedimentation from the catchment basin that is experiencing rapid deforestation. The resettlement program for residents in the submergence area has created social problems (Mougeot, 1987). Construction of the dam simultaneously with the environmental studies guaranteed that the maximum effect that the findings could have would be to suggest minor modifications in procedures once the dam was already a *fait accompli* (see Fearnside, 1985a). Relegating research to a merely token role is an unfortunate tradition in Amazonian development planning (Fearnside, 1986f).

Despite recommendations that 85% of the vegetation be removed from the area to be flooded, ELETRONORTE adopted a plan to clear only 30% (A Província do Pará, 15 June 1982; Monosowski, 1986). Selective logging of valuable timber received higher priority, although this was carried out in only a small part of the area as a combined result of lower densities of valuable species than originally foreseen, the inexperience of the CAPEMI military pension fund that held the logging concession, and the short time available before filling the reservoir. A financial scandal led CAPEMI to bankrupcy in 1983 (A Crítica, 4 February 1983) after clearing only 0.5% of the submergence area. An additional area adjacent to the dam was cleared by ELETRONORTE; assuming all of this "critical" 100 km^2 area was actually cut, the cleared total would be 5% of the reservoir (see Monosowski, 1986). When vegetation left in reservoirs decomposes, the water becomes acid and anoxic (Garzon, 1984).

One of the most controversial features of the Tucurui Dam is that the power generated does little to improve the lot of those who live in the area: a fact dramatized by the high-tension lines passing over hut after hut lit only by the flickering of kerosene lamparinhas. Most of the power from Tucurui supplies subsidized energy for multinational aluminium plants in Barcarena, Pará (ALBRÁS-ALUNORTE, of Nippon Amazon Aluminum Co. Ltd. or NAAC, a consortium of 33 Japanese firms) and in São Luis, Maranhão (ALUMAR, of Alcoa). Companhia Vale do Rio Doce (CVRD) maintains 51 and 61% interests in ALBRÁS and ALUNORTE respectively (CVRD - revista, 1983). The power is sold at roughly one-third of the rate charged to residential consumers thoughout the country, and so is heavily subsidized by the Brazilian populace through their taxes and home power bills.

The role of research in planning, authorizing and executing major engineering projects such as hydroelectric dams is a critical matter if decision-making procedures are to evolve that prevent the kinds of misadventures that now characterize so much of the development process in Amazonia. The public relations focus of many of the environment-related activities, such as the highly-publicized effort to rescue drowning wildlife, is a matter of intense controversy. Research is used for similar purposes: for example, during a public demonstration in Belém against closing the Tucurui Dam, leaflets were dropped by helicopter reassuring readers that INPA's research in the area guaranteed that there would be no environmental problems (Brazil, ELETRONORTE, nd.(1984)). No such endorsement had been given either by INPA or by the individual researchers involved in the study. Publication results by the researchers is subject to approval by ELETRONORTE, according to the terms of the funding contract. It is essential that both the studies themselves and their subsequent dissemination take place free of interference from any source.

The Balbina Dam

The Balbina Dam, 146 km from Manaus, is the worst case of environmental destruction from hydroelectric development. When the water level in the reservoir reaches its normal full level of 50 m above sea level, 2360 km^2 will be flooded. The reservoir will contain approximately 1500 islands, making the area of land affected much larger than that actually submerged. About one-third of the Waimiri-Atroari Indian Reserve will be flooded. Severe as these impacts are, the magnitude of the environmental and financial disaster at Balbina lies in the meagre benefits that the project will produce.

Balbina's nominal capacity is 250 megawatts (MW): the sum of five generators of 50 MW capacity each. The amount of power that the dam will actually produce, however, is much less than this. An average output of 112.2 MW is expected (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: B-51). Of this, 64 MW represents "firm power" at the maximum depletion of 4.4 m for which the turbines were designed (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: B-47). Losses in transmission reduce the firm power delivered to Manaus to only 62.4 MW (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: B-49). Although all dams generate less than their nominal capacity, at 26%, Balbina's firm output is less than normal.

Balbina's 250 MW nominal capacity is itself miniscule for a reservoir of this size--about as large as the 2430 km^2 Tucurui reservoir that will support a nominal capacity of 8000 MW. Balbina sacrifices 31 times more forest per megawatt of generating capacity installed than does Tucurui. Low output is a logical consequence of the area's flat terrain and of the Uatumã River's low streamflow--an inevitable limitation with such a small drainage basin (18,862 km^2: Brazil, ELETRONORTE, 1987). The drainage basin is only eight times larger than the reservoir itself--which must be something of a record in hydroelectic development.

Much of the reservoir is extremely shallow as a consequence of the flat terrain. The reservoir's 2360 km^2 at the 50 m level falls to 1580 km^2 at the 46 m level, meaning that 780 km^2 (33%) is less than four meters deep. Average depth when full will be 7.4 m (Brazil, ELETROBR'S, 1986: 6.12). The large shallow areas can be expected to support rooted aquatic vegetation, adding to the problem of floating weeds that could affect the entire reservoir. The combination of large surface area per volume of water in a shallow reservoir and high biomass of aquatic vegetation will lead to heavy loss of the stored water to evaporation and transpiration.

The Balbina reservoir will be a labyrinth of canals among the islands and tributary streams. The residence time in some of these backwaters will be many times more than the already extremely long average of 11.7 months (Brazil, ELETROBRÁS, 1986:

6.12). Tucurui, by contrast, has an average residence of 1.8 months, or 6.4 times less. Some parts of the reservoir may only turn over once in several years. The slow turnover means that the decomposing vegetation will produce acids that cause corrosion of the turbines. At the Curuá-Una Reservoir near Santarém, Pará, for example, power generation had to be halted temporarily in 1982, only five years after filling, to allow repairs to the corroded turbines at a cost of US$ 1.1 million (Brazil, ELETROBRÁS/CEPEL, 1983: 34). The cumulative cost of maintenance in the first six years totaled US$ 2 million, or US$ 16,600 per installed megawatt per year--70 times the cost for a comparable dam in the semi-arid northeastern part of Brazil (Brazil, ELETROBRÁS/CEPEL, 1983: 44). Lost generating time is not included in the costs. Balbina's longer mean turnover time (355 days versus about 40 days at Curuá-Una) and its abundance of stagnant bays and and channels, means that water quality and corrosion problems will be worse than at Curuá-Una. At the rate experienced at Curuá-Una, Balbina's maintenance can be expected to cost US$ 4.15 million per year, or 4.3 mils (US) per kilowatt-hour of electricity delivered to Manaus (about 10% of the tariff charged consumers). Repairs due to similar corrosion in the Brokopondo Dam in Surinam totaled US$ 4 million, or over 7% of the construction cost, in the first 13 years of operation (Caufield, 1983: 62). Vegetation is being left to decompose in most of the Balbina submergence area: only a token 50 km^2 (2%) of the reservoir area was cleared before the dam was closed.

Balbina is particularly unfortunate because it is unnecessary. The dam is expected to produce firm power that could be counted on for only about one-third of the 218 MW 1987 level of power demand in Manaus; the average power delivered in Manaus (109.4 MW after 2% transmission loss) would be half the 1987 demand. The dam will never supply this percentage of the Manaus demand because the calculations assume the 50 m reservoir level--at first the dam will generate a substantially lower amount (a figure not yet disclosed by ELETRONORTE) because the reservoir level will be kept at 46 m until water quality stabilizes, subsequent ELETRONORTE statements indicate that this concession is likely to be discarded and the reservoir filled directly to the 50 m level as quickly as the availability of water permits. The percentage of power consumed in Manaus supplied by Balbina will shrink with each succeeding year as the city continues to grow: Balbina's average output (at the 50 m level) delivered to Manaus corresponds to only 38% of the 285 MW power demand ELETRONORTE projects for the city in 1996 when another dam, to be built 500 km from Manaus at Cachoeira Porteira on the Trombetas River, is expected to make up the city's power deficit (Brazil, ELETRONORTE, 1987). Only one dam (Cachoeira Porteira) could have been built--with half the cost and half the impact--rather than building both dams. To make the futility of Balbina even more apparent, natural gas 500 km from Manaus in the Juru' River basin could supply Manaus with power (Goldemberg, 1984). Recent discovery of oil and gas at Urucu, nearer Manaus, could also supply the city with power without Balbina.

The power from Balbina will largely benefit the international companies that have established factories in the Manaus Free Trade Superintendency Zone (SUFRAMA). That power will be subsidized for these firms at the expense of residential consumers throughout the country is an irritant to many Brazilians. SUFRAMA was established in Manaus in 1967 to compensate western Amazonia for the concentration of SUDAM's investments in eastern Amazonia (Mahar, 1976: 360). The financial and environmental costs are high when political decisions lead to the location of industrial centers in places where power generation is difficult. All of the consequences of supporting industries and population need to be considered before the initial decisions are made.

The Balbina Dam was closed on 1 October 1987. The dam was exempt from the environmental impact report (RIMA) because of its being under construction at the time when the report became mandatory, but was nevertheless required to obtain a License for Operation from the Amazonas state government's environmental organ: CODEAMA. CODEAMA's director was suddenly replaced only nine days before the dam was licensed (Melchiades Filho, 1987). The license was granted on the same day that the last adufa (sluice base) was closed blocking off the Uatumã River. The precedent of making the environmental review process a mere token formality is perhaps the most far-reaching impact of this highly-questionable project.

The momentum of the construction effort at Balbina not only succeeded in crushing the Brazilian environmental review process, but also managed to circumvent the environmental hurdles within the World Bank. The World Bank rejected Balbina on environmental grounds when presented as a separate project, but subsequently approved the Brazilian power sector loan--thus underwriting hydroelectric projects throughout the country. If, as World Bank officials say, no Bank money was spent directly at Balbina, then this was avoided by shere luck. Whether or not the timing of ELETRONORTE purchases means that Bank money was spent directly at Balbina, the relief these funds provided to ELETRONORTE's overstretched budget was undoubtedly critical to allowing the agency to bring the apparently low-priority Balbina project to completion.

Other Dams

Other dams planned or under construction in the region have many of the same problems as Balbina. The Samuel Dam, under construction on the Jamari River in Rondônia, will flood a 656 km^2 area for little power (216 MW installed) and a high cost (US$ 610 million). The Ji-Paraná Dam, now in the final planning stages on Rondônia's Ji-Paraná (Machado) River, will flood 107 km^2 (6%) of the Lourdes Indian Reservation of the Gavião and Arara tribes, plus 37.7 km^2 (1.4%) of the Jaru Biological Reserve (Brazil, ELETROBRÁS, 1986: 6.23). The World Bank financed these reserves under the POLONOROESTE program, but will also be financing their flooding under the loan for building the Ji-Paraná Dam. The migration encouraged by the BR-364 Highway that was reconstructed under POLONOROESTE is, of course, what makes the power from these dams necessary. The explosive growth of population in the area is rapidly recreating the situation at Balbina, where the low capacity dams create impacts that only serve to postpone more definitive solutions--such as transmission lines from topographically favorable generating sites. The technology of long distance power transmission has improved markedly since many of the hydroelectric projects were planned (Pires and Vaccari, 1986).

The Altamira Complex on Pará's Xingu River will flood a total of 7365 km^2, of which 1225 km^2 will be for the Kararaô Dam (to be built first, downstream of the city of Altamira) and 6140 km^2 will be for the Babaquara Dam to be built upstream (Brazil, ELETRONORTE/CNEC, nd. (1986)). Kararaô and Babaquara are part of a chain of reservoirs in the Xingu River Basin Hydroelectric Project that would disrupt the lives of 4000 Indians (Survival International, 1987: 1). While some reports indicate a total of 21 dams planned in the Xingu Basin (SBPC, 1986), ELETRONORTE lists five (Brazil, ELETRONORTE, 1985). Despite public statements to the contrary, these dams are listed in the most recent (December 1987) version of the 2010 plan (Brazil, ELETROBRÁS, 1987), including the Jarina Dam that would flood part of the Xingu Indian Park (CIMI, CEDI, IBASE and GhK. 1986).

The two reservoirs in the Altamira Complex itself (Kararaô and Babaquara) will flood portions of areas occupied by tribes from four different linguistic trunks--cultures as different as, for example, China and Europe (D. Posey, personal communication, 1987). The Kararaô Dam will have 4675 MW of generating capacity installed and will cost US$ 5.52 billion (Brazil, ELETRONORTE/ CNEC, 1987). The entire complex is expected to cost US$ 10 billion, which would worsen Brazil's international debt crisis substantially (Environmental Policy Institute, 1987). The installed power capacity of the complex is a colossal 17,000 MW, making it the largest in the world. Almost all of this power would be transmitted to southern Brazil, rather than being used to create employment in the region (Brazil, ELETRONORTE/CNEC, nd (1986)). The first dam (Kararaô) will have substantially greater power output in relation to environmental and human impact than the other dams. This indicates the urgency of linking the environmental impact analysis of all of the dams, to avoid repetition of the problem caused by the Carajás mine and railway where a high-value project causing relatively little direct disturbance was allowed to justify a series of extremely damaging subsequent projects that were not included in the evaluations of the initial scheme.

MILITARY BASES

Calha Norte, meaning "northern channel," is a program to build or enlarge military bases and/or airstrips in 16 locations in a 150 km strip along the portion of Brazil's border north of the Amazon River (Amazonas and Soliões rivers). The plan was announced in 1986, and is already being funded and executed without benefit of any environmental review. Secrecy surrounding the plan has inhibited public discussion (Brazil, Universidade Federal do Pará, NAEA, GIPCT, 1987). Estimates of the indigenous population in the Calha Norte zone range from 50,000 (Matias, 1987) to 60,000 (Comité Interdisciplinar de Estudos sobre o Projeto Calha Norte, 1987: 5) out of Brazil's 220,000 Amerindians. The Calha Norte zone includes 84 indigenous areas, only 16 of which are demarcated (Comité Interdisciplinar de Estudos sobre o Projeto Calha Norte, 1987: 5).

One of the principal impacts of the program is its impeding the demarcation of Amerindian reserves. Reserve demarcation is blocked in a 150 km wide strip not only in the Calha Norte zone but also along all international borders, affecting tribes in Acre, Rondônia and Mato Grosso (Survival International, 1987: 2). The position of the tribes was further eroded in 1987 when the government abolished the concept of "Indian Reserves" and replaced it with one of "Indigenous Colonies"--thereby denying the tribes the special protections mandated by the country's constitution and legislation (thus allowing the land to be bought or otherwise taken away by non-Indians). Paving of the BR-364 from Rondônia to Acre has been financed by the Interamerican Development Bank on condition that 35 reserves in Acre be demarcated; disbursements have been suspended now that current policies block the demarcations, but the money for construction has not been returned (unlike the US$ 5 million loan received from the World Bank for the expense of actually demarcating the reserves themselves).

The impact of the bases being constructed under Calha Norte is potentially much wider than the immediate environs of the military installations. Although not contained in the current budget, the plan calls for building roads and promoting settlement in the area. The ministers of foreign relations, interior, planning and national security wrote in their exposition of motives to President Sarney: "It is fundamental that the action of the government contemplate, also, expansion of highway infrastructure .... and increase in the colonization of that frontier area" (Setubal et al., 1986: 3). Once roads are built, settlers and speculators can be expected to enter and clear the forest regardless of official policies, as has occurred repeatedly elsewhere (see Fearnside and Ferreira, 1984).

Population flow from Rondônia is already rapidly pushing back the agricultural frontier in Roraima.

Military reasons are often convenient excuses for developments wanted for other reasons, as occurred in the case of the Transamazon Highway (see Fearnside, 1984c; Kleinpenning, 1979). Deciding where to place roads and colonization areas on the basis of geopolitical strategy rather than the agronomic potential of the soils is a sure formula for agricultural failure. None of the land in the Calha Norte area is shown by RADAM maps as suitable for agriculture (Brazil, Projeto RADAMBRASIL, 1974-1977: Vols. 6, 8, 9, 11, 14).

The best example of the danger of allowing military reasons to determine the location of settlements is the Sidney Girão colonization area, which was placed on Rondônia's border with Bolivia for strategic reasons (Mu"eller, 1980); the area's poor soil resulted in such rapid abandonment of the lots that the government was unable to fill the project until long after all other areas in Rondônia were overflowing with landseekers. The project's failure has been officially recognized as due to poor soil (Valverde et al., 1979).

MINING

Mining is another activity that is rapidly increasing as an agent of environmental destruction in Amazonia. Some of the impacts are direct, while others are indirect. Open pit mines obviously completely transform the environment in the specific localities affected, such as the iron mine at Carajás (Pará), manganese at Serra do Navio (Amapá), kaolin at Jari (Amapá), bauxite (aluminium) at Trombetas (Pará) and cassiterite (tin) at various locations in Amazonas and Rondônia. The areas destroyed are small, although the destruction is total. Only the bauxite mine at Porto Trombetas has an active program of revegetating the mine site (Knowles, 1988), although the Carajás iron project has plans for future revegetation of its pits (de Freitas and Smyrski-Shluger, nd. (1983)).

Waste from mining can be significant. The fines from the Trombetas bauxite mine form a "red mud" that has completely filled the 200 ha Lago da Batata and suffocated trees along its margin and approaches; preparations are being made to transport future production of red mud back to the mine site itself. Devastated as the Lago da Batata is, it represents a tiny area in Amazonian terms. The Balbina reservoir, for example, will be over 1000 times larger.

The silt from cassiterite mining is a large source of sediments in the drainage basins affected. In Rondônia measurements in rivers with mining indicate much heavier silt loads than those in rivers without mining (Arnaldo Carneiro, personal communication, 1988). One negative effect of the increase could be more rapid sedimentation of reservoirs, including the Samuel Dam. One mining operation (Mineração Oriente Novo) released large amounts of sediment into the Rio Preto (a tributary in the Samuel catchment) until it was stopped in 1986 by a federal court order. Other operations in the Samuel catchment, such as the BRASCAN mines, store their fines behind small retaining dams. An undetermined amount of sediment would be released into the reservoir were these dams to break, as occurred in the state of Amazonas in 1987.

The incident in the state of Amazonas occurred at a cassiterite mine on the Pitinga River where Mineração Taboca (a subsidiary of Paranapanema) stores tailings in holding ponds for possible future use should the price of tin increase and justify more thorough extraction procedures. The dikes for four of these ponds broke in 1987, releasing its sediment into the adjacent Alalaú River, a tributary of the Rio Negro. The pollution affected fish in the Waimiri-Atroari Indian Reserve downstream. The reserve had already suffered many impacts from the mine, including being reduced in size in order to make room for the mining operation and having a road built through the area to connect the site with the Manaus-Caracaraí (BR-174) Highway that also bisects the reserve.

Gold mining contributes greatly to the silt load of rivers. Much of the mining is done in river beds, either by dredging alluvium from the river bottom or by panning it from the banks. The river water is often a milky color from the silt load far below the mining sites themselves. As with other minerals, roadbuilding spurred by gold strikes sets in motion the process of invasion and deforestation of the affected areas. The "Rodovia do Ouro" through the Reserva Garimpeira de Tapajós in Pará was the first such road (Veja, 28 November 1984); similar highways in Roraima may follow soon.

Mercury pollution is rapidly becoming a public health crisis in Amazonia. Use of mercury to amalgamate the fine gold particles in the extraction process dumped an estimated 250 metric tons of highly toxic mercury into the rivers between 1984 and 1988 (J. Dubois, personal communication, 1988). The estimate of mercury discarded is derived from the weight of gold extracted and the 1.2 grams of mercury used per gram of gold; the amount of mercury could be much greater since much of the gold is smuggled out of the country illegally. Mercury concentrations in fish in the Madeira River (draining Rondônia) are as high as six times the levels permitted in food by the World Health Organization (B.A. Forsberg, personal communication, 1988; Martinelli et al., nd.). In Itaituba, Pará--a gold mining center on the Tapaj's River--heavy incidence of human diarrhea with blood is associated with mercury poisoning from eating contaminated fish (J. Dubois, personal communication, 1988; O Liberal, 1 February 1988). Fish supply a major part of the protein in the diet of Amazonian residents, including the indigenous peoples that inhabit some of the most active gold mining regions. The Madeira River is also a major supplier of fish to the cities of Manaus and Porto Velho.

Indirect effects of mining promise to be even greater than most direct effects. Roads built to the mining areas bring in population, with subsequent deforestation. The population of miners themselves add to this impact: what will become of the approximately 75,000 gold miners at the Serra Pelada "anthill" in Pará is a major question if the often-postponed plans are put into effect to have a government-controlled mining firm mechanize the operation. A major impediment to such a move is the threat of the miners to invade the neighboring Carajás iron project area in order to stake out prospecting and farming claims.

Amerindian areas suffer some of the most direct effects of gold prospecting. These include frequently bloody encounters with the gold miners, spread of disease, and the more subtle effect of providing motivation for not demarcating the tribes' land as reserves. Many delays and reductions in reserve demarcations are believed to result from the influence of large mining companies, the population of individual garimpeiros (prospectors) and the pilots, merchants and others that serve them. When demarcation is delayed, the areas are taken over by non-Indians.

The presence of minerals can make possible agriculture and silviculture projects that would otherwise be inviable. Examples include Jari, where the silviculture sector depends financially on the estate's kaolin mine (Fearnside, 1988). The AMCEL silviculture operation in Amapá would likewise be improbable without the associated ICOMI manganese mine at Serra do Navio.

On a much larger scale, the entire Grande Carajás Program is justified by the extraordinary mining potential of this region--where minerals such as iron, gold, copper and manganese were squeezed up from the earth's mantle at the point where the primordial continents of South America and Africa once joined. The Grande Carajás Program includes a mammoth agricultural plan, the pig-iron smelting scheme with its associated forestry management and/or plantations for charcoal production, a railway and highway network, hydroelectric dams (including Tucurui), power transmission lines and mineral processing facilities such as the Barcarena Aluminium complex. The potential environmental impacts of these developments are unprecedented (see Fearnside, 1986e).

IV.) POLICIES FOR SUSTAINABLE DEVELOPMENT

OVERCOMING OBSTACLES TO SUSTAINABLE DEVELOPMENT

Obstacles to sustainable development of Amazonia's natural resources include growth of the human population in this region to levels that exceed carrying capacity, severe inequalities in the distribution of resources (particularly land), policies leading to implanting unsustainable land uses (such as cattle pastures) and ultimately, the accelerating destruction of natural ecosystems. The rapid deforestation for cattle pasture that dominates land use in the Amazon Region of Brazil is in many ways a symptom of deeper causes that must be addressed if development is to be channeled to a wiser course. Simply outlawing deforestation is completely ineffective, as has been demonstrated in Brazil by the unenforced Forestry Code (Decree Law No. 4771 of 15 September 1965) limiting clearing to 50% of any property and the 1986 law (Decree Law No. 7511 of 7 July 1986) prohibiting deforestation completely.

Many of the structural changes needed to strike at the root causes of deforestation will require years of effort. Nevertheless, a start must be made now. Population growth must be slowed both in Amazonia and in the regions from which migrants come. The effect of population growth is currently overshadowed by transformation of the agricultural systems in Southern Brazil from one dominated by small farms producing labor-intensive crops such as coffee to one dominated by large agribusinesses growing mechanized crops such as soybeans. The Southern Brazilian states should make the social choices as to how to absorb the "excess" population expelled by this transformation, so long as the solution is not the present one of simply transferring the problem to Amazonia. One means of absorbing more people in the rural areas is by redistributing large unproductive landholdings. Another is by favoring labor-intensive crops over mechanized ones in allocating agricultural credit. Ultimately, absorbing more people in the urban sector must be facilitated. The movement of population from rural areas to urban slums, a longtime trend throughout all of South America, has been resisted by governments because of the crime and political explosiveness associated with the slums. The tendency of urban dwellers to oppose incumbent governments provides strong motivation for any ruling political party to keep the population in the countryside. Instead of adopting totalitarian regulations forcing people to remain in the countryside, as China and the Soviet Union have done, South American governments divert a large part of these flows to less populated regions like Amazonia. Both the Transamazon Highway and the Cuiabá-Porto Velho (BR-364) Highway in Brazil were partly justified as means of relieving pressure on cities. Bolivia, Peru and Ecuador have also built roads in part to lead population outflow from the Andean uplands away from the urban centers. Bucking the tide from the countryside to the cities may not be in the best interest of the countries. Advantages of having the population in the cities include the tendency of urban dwellers to have less children, the greater environmental damage done by the same number of people if moved to Amazonian colonization areas, and the great expense to the government of installing the settlers in Amazonia where they require roads, surveying of lots and provision of agricultural extension, credit and social services. The expense would be even more prohibitive if the settlers were given infrastructure equivalent to that of officially sanctioned urban settlements (year-round road access, rural electrification, etc.) and if the agriculture implanted were to be sustained through a constant supply of costly fertilizers from distant sources.

Adequate employment opportunities must be given to urban residents, including those who are attracted from the countryside: much more could be done to expand industry. For example, both the 12.6×10^3 megawatt hydroelectric dam at Itaipu and the 8.0×10^3 megawatt dam at Tucurui have only a fraction of their generating capacities installed. More power could be had by simply mounting the remaining turbines and generators, without incurring any of the environmental and financial costs of building more dams and creating more reservoirs. Since both of these dams have transmission links to the cities in migrant source areas such as Paraná, the power could attract new factories that would employ some of the migrants that now leave for Amazonia, especially Rondônia.

It is unrealistic to think that Brazil can adopt agricultural patterns similar to those in North America and still keep over 30% of its population in the rural zone. The rural population of the United States, for example, declined over the course of this century from a proportion similar to that of Brazil to less than 5% today. If scarce capital resources are to create a vastly increased number of urban jobs in Brazil the location of cities must be planned more rationally than at present. Manaus, for example, grew from approximately 120,000 in 1967 to 1.3 million in 1987 because of population drawn to industries that have located themselves in a special duty-free zone. The city is now being provided with a hydroelectric dam: Balbina. Construction cost will total US$ 3,000 per kilowatt of installed capacity. Similarly, the Samuel Dam in Rondônia is being built to provide power to that new state whose population has been swollen by migration along the World Bank-financed BR-364 Highway, will cost US$ 2,800 per kilowatt installed because, like Balbina, it is on a small river in a flat region inappropriate for hydroelectric development. For comparison, when completed Tucurui will cost US$ 675/kilowatt (4.6 times less than Balbina) and Itaipu US$ 1206/kilowatt (2.6 times less than Balbina) (construction costs from Veja 20 May 1987: 30). In other words, the same investment in a more topographically favorable site could produce several times more power, and generate proportionately more industrial employment. That employment could absorb many of the migrants now being forced to leave Southern Brazil for Amazonia.

Brazil's policy of a "unified" tariff for electricity means that industry and population can locate themselves where they choose, and the power authority is then obliged to take heroic measures to provide them with electricity. Power in unfavorable places like Manaus is subsidized by the consumers living nearer favorable sites like Itaipu. Were electricity sold at rates reflecting its cost of generation, industrial centers would relocate themselves and the total amount of urban employment would be significantly greater.

WHAT GOVERNMENT ACTION CAN DO

Measures needed to contain environmental destruction in Amazonia can be divided, somewhat arbitrarily, into short-term and long-term targets. It is important that action on long-term targets not be simply postponed in favor of concentrating on actions with immediate payoffs--such a course would be just as short-sighted as Brazil's rush to trade its rainforests for a few years of pasture production. Issues that must be confronted squarely now include population growth, resource distribution, and economic mechanisms to allow sustainable management of slow-growing biological resources like tropical forests.

At the same time a number of important changes could be made literally at the stroke of a pen, providing that it is the right pen. Actions that require no consciousness raising, long-term research programs or similar slow activities include stopping highway construction in Amazonia, abolishing subsidies for cattle pastures and ending energy subsidies to the Amazon such as the price unification policies for petroleum products and electric power. Land tenure policies could be changed to disallow pasture or annual crops as "improvements" for establishing claims. Sustainable uses of standing forest should replace the present focus of agricultural research and, especially, of credit. The presently-favored forms can only be sustained if confined to a miniscule fraction of Amazonia--i.e., fertilizer-dependent agriculture and pasture.

Protection is needed in fact of natural forest reserves that are now only declared on paper. Governments cannot continue to renege on previous commitments to reserves whenever land is wanted for another purpose without condemning all of the remaining forest to the axe. The tendency to renege on commitments is a more fundamental menace than is the fact of explosive deforestation.

Despite the tremendous needs for change, Brazil has made great advances in protecting examples of its natural ecosystems and incorporating environmental factors into development procedures. At the time of the Stockholm Conference on the Environment in 1972, Brazil was labeled the "villain of Stockholm" for its role in leading the countries of the developing world in condemning any suggestion that these nations should protect their environments (Sanders, 1973). Today Brazil has a Special Secretariat of the Environment (SEMA), a system of national parks, and a law requiring an Environmental Impact Report (RIMA) prior to approving any major development project. The legal and legislative advances in protecting the environment must be further fortified by building a corps of qualified people to carry them out and a tradition of serious consideration of the environment in development planning--especially in the early phases of project formulation before major developments become "irreversible" faits accomplis.

WHAT FOREIGNERS CAN DO

What can foreigners do to further sustainable development in Amazonia? Direct pressure on the government of Brazil or on the governments of other Amazonian countries can easily backfire to the detriment of whatever change might be desired by well-intentioned persons abroad. For example, in 1987 a petition signed by 45,000 Austrians in an effort to convince Brazil's Constitutional Convention to strengthen protection of indigenous peoples was instead used for a newspaper campaign against Brazilian indigenous rights groups and against the provisions of the draft constitution that (prior to their deletion) would have provided some protection for the tribes.

Taxpayers in countries that contribute to the budget of agencies such as the World Bank have every right to influence how their money is spent. These banks represent a great force, for good or for evil, in the developing countries where the money is applied. Expanding and improving the environmental sectors and procedures within these banks is a legitimate and effective focus for environmental concerns. The World Bank has already benefited from the efforts of environmental groups and national legislatures in the donor countries. The benefit for the recipient countries would be greatest if environmentalists, researchers and the direct and indirect employees of the Banks worked together.

One mechanism for applying funds from international sources to environmental problems in Amazonia is through agreements under which countries in the region are released from portions of their foreign debt on the condition that the money owed (or a specified fraction of it) be spent on establishing national parks or on other environmentally beneficial activities. Such schemes both help relieve the burden of debt and achieve goals that the countries themselves ostensibly espouse. A major park in the Amazonian part of Bolivia has recently been created under an agreement of this type, but the device has not yet been used in Brazil.

The lending policies of banks, including commercial banks, should be tightened to reduce the temptation to run up heavy debts and to promote short-sighted land use policies in order to pay them back. For example, the emphasis on producing soybeans in Southern Brazil may in part be an effort to generate export earnings to relieve the country's burden of debt; the mechanized cultivation of soybeans forces small farmers to migrate to Rondônia.

Direct investments from foreign countries also further the replacement of forests with unsustainable land uses. Examples include the Volkswagen and Armour-Swift/Brascan ranches in Pará and the Suiá-Missu Ranch (of the Italian multinational Liquigas) in Mato Grosso. French financing and equipment sales for the extensive and economically questionable hydroelectric projects at Balbina and Samuel is another example. Deforestation also results from the land speculation that investors employ as a means of turning Brazil's astronomical inflation to their advantage. The inflation is in part fueled by ill-conceived projects from abroad that inject money into the economy without producing a corresponding flow of products for the consumers to buy with it. Examples include the inefficient dams and marginally-productive ranches in Amazonia, as well as the economically disastrous German-financed nuclear power plants near Rio de Janeiro.

Foreign countries also influence land use choices in undesirable ways through purchases of the products generated by unsustainable activities. Demand for endangered animals and plants is one form of influence. Demand for beef, which is a major force in Central America through the notorious "hamburger connection," is a much weaker influence in South America because the presence of foot-and-mouth disease (afthosis) blocks export of beef in frozen form to North America and Japan. Plans for a "sanitary pocket" in part of the Grande Carajás Program in Brazil could unleash the full force of this connection in part of Amazonia.

In addition to refraining from damaging activities, foreigners can have a positive effect on land use choices through direct inputs within limited fields of activity. One of these is scientific research, where both contributions of money (to such organizations as the World Wildlife Fund) and time are needed. Much fieldwork needs to be done in a broad range of fields. Particularly urgent is screening possible economically useful products that can be extracted from standing forest. Institutional mechanisms need to be developed that will facilitate this while guaranteeing that the economic rewards derived from any salable products will remain in the South American countries where the forests are located. Field-based research in many areas of South America needs the collaboration of a substantial network of researchers elsewhere, especially taxonomists, pharmacologists and analytical chemists.

Training is another area where foreign scientists can make an important contribution to sustainable development. Although universities and research institutions in tropical areas of South America are rapidly growing stronger, they are still pitifully small when compared to the magnitude of the challenge of devising sustainable forms of development for Amazonia's vast, complex, and poorly studied ecosystems. These institutions need to be strengthened quickly because of the explosive pace at which the options for sustainable use are being closed off by deforestation. At the same time, strict adherence to academic standards is essential, and the consequences of lapses are grave. The quality as well as the number of scientists in the region must be increased so that more of the intellectual activity of designing projects and interpreting results takes place in the Amazon, rather than at distant locations in southern Brazil or abroad. The negotiation of research and training programs with countries such as Brazil is one of the most far-reaching and effective but difficult ways that international institutions can contribute to sustainable development in Amazonia.

In summary, environmental destruction in Amazonia is rampant and the forces behind the destruction are formidable. These facts, however, are not reason for despair. Effective measures can be taken by governments, financial institutions and individuals to help contain environmental destruction in the region and to direct development in sustainable, non-destructive directions.

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