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FRAGILE SOILS AND DEFORESTATION IMPACTS: THE RATIONALE FOR ENVIRONMENTAL SERVICES OF STANDING FOREST AS A DEVELOPMENT PARADIGM IN AMAZONIA

Philip M. Fearnside
Instituto Nacional de Pesquisas
da Amazônia-INPA
(National Institute for Research
in the Amazon-INPA)
C. P. 478
69011-970 Manaus, Amazonas
BRAZIL
Tel: 55 (92) 643-1822
Fax: 55 (92) 642-8909
Email: PMFEARN@INPA.GOV.BR

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AMAZONIAN DEVELOPMENT

Development in Brazil's 5 × 10^6 km^2 Legal Amazon Region has, until now, been based mainly on removing and selling natural resources, such as timber and minerals, or on agriculture or ranching operations that derive their products from the soil. Sale of commodities such as minerals and timber often fails to benefit the local population. Conversion of forest to cattle pasture, the most widespread land-use change in Brazilian Amazonia, brings benefits that are extremely meager (although not quite zero). High priority must be given to redirection of development to activities with local level returns that are greater and longer lasting. Tapping the value of environmental services offers such an opportunity. Keeping benefits of these services for the inhabitants of the Amazonian interior is the most important challenge in turning these services into development (Fearnside 1997a).

Soils in Amazonia are almost universally of low fertility and are "fragile", that is, subject to degradation. The fragile nature of the soil is one reason why the yields or agriculture and ranching are low and short-lived. Fragile soil should provide part of the justification, from Brazil's perspective, for giving priority to a new paradigm for Amazonian development based on tapping the value of the environmental services provided by standing forest. Impacts of deforestation provide the other part of the justification from the Brazilian perspective, and also provide the main motivation from the perspective of countries from which monetary flows might one day be derived on the basis of the services.

The predominant feature of development in Brazilian Amazonia has so far been conversion of forest to cattle pasture (Fearnside 1990a). Large and medium sized ranchers account for about 70% of the clearing activity, while small farmers (with < 100 ha of land) account for about 30% (Fearnside 1993a). Contrary to statements by the head of the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA) (Traumann 1998), deforestation data for 1995 and 1996 released by Brazil's National Institute for Space Research (INPE) in January 1988 (Brazil, INPE 1998) do not indicate that small farmers are now the primary agents of deforestation. The fact that about half (59% in 1995 and 53% in 1996) of the area of new <u>clearings</u> (as distinct from the area of the <u>properties</u> in which the clearings were located) have areas under 100 ha reinforces the conclusion that most deforestation is being done by ranchers, as no small farmer can clear anywhere near 100 ha in a single year. Only 21% of the area of new clearings in 1995 and 18% in 1996 were under 15 ha. Small farmer families are only capable of clearing about 3 ha/year with family labor (Fearnside 1980), and this is reflected in deforestation behavior in settlement areas (Fearnside 1984).

Continuation of present land-use trends would result in the landscape approaching an equilibrium of 4.0% farmland, 43.8% productive pasture, 5.2% degraded pasture, 2.0% secondary forest derived from agriculture, and 44.9% secondary forest derived from pasture (Fearnside 1996a). Cattle pasture is a land use that causes maximum impact on the forest while supporting only a very sparse human population (Fearnside 1983; Hecht 1983).

New initiatives may alter land-use patterns in significant ways. Soybeans are being promoted by the national and state governments (Fearnside 2001). Soybeans have expanded into large areas of *cerrado* (central Brazilian savannas) and are now spreading to other vegetation types. The first major plantations are in natural grasslands near Humaitá, Amazonas. The Madeira River waterway, opened in March 1997, lowers the cost of transport from this part of the region to one-third of its former cost, thus radically altering the economic picture for more intensive agriculture there. A 90,000 t warehouse has been inaugurated in Itacoatiara, Amazonas, and a second such warehouse is expected in a subsequent phase. Soybeans are also expanding into forested areas in southern Amazonas, and already represent an important crop in northern Mato Grosso and eastern Rondônia. Soybean planting initiatives are underway in Roraima and near Santarém and Paragominas in Pará. Little employment results from soybean cultivation, which is done using mechanized agriculture. For example, in the state of Paraná, in southern Brazil, when small farms growing coffee and annual crops were replaced by larger landholdings growing soybeans in the 1970s, for every person who found employment in the new system, 11 people were expelled from the state (many of whom moved to Rondônia) (Zokun 1980).

The question of who is to blame for tropical deforestation has profound implications for the priorities of programs intended to reduce forest loss. The prominence of cattle ranchers in Brazil (different from many other parts of the tropics) means that the social cost of substantially reducing deforestation rates would be much less than is implied by frequent pronouncements that blame "poverty" for environmental problems in the region. It also means that measures aimed at containing deforestation by, for example, promoting agroforestry among small farmers can never achieve this goal, although some of the same tools (such as agroforestry) have important reasons for being supported independent of efforts to combat deforestation (Fearnside 1995).

FRAGILE SOILS AND DEVELOPMENT OPTIONS

The soils in Amazonia are notoriously infertile: indicators of soil fertility such as pH, cation exchange capacity, total exchangeable bases and available phosphorus are low, while saturation of toxic aluminum ions is high (Fearnside and Leal Filho 2001). Under such circumstances, it is logical to maintain these areas under forest rather than converting them to short-lived low-productivity land uses. But to what extent would the situation be different if the soils were more productive? What level of soil quality would make it worthwhile to sacrifice the forest? There are no simple answers to these questions. Rational decision-making will require assessment of the value of <u>both</u> the agricultural production that can realistically be expected from the area and the environmental cost of sacrificing the forest.

One must consider the extent to which the relative economic attractiveness of forest over agriculture would change if technical advances were to occur that removed or relaxed the barriers presented by fragile soils. For example, recent progress has been made on removing aluminum saturation limitations through development of transgenic crop plants (Barinaga 1997; de la Fuente *et al*. 1997). It is not inconceivable that phosphorus limitations could be relaxed by development of crop plants with appropriate micorrhizal associations. Nitrogen limitations of various non-leguminous crops may be relaxed through pseudosymbiotic relationships with a variety of types of nitrogen-fixing bacteria, an area in which significant advances have been achieved in Brazil through the work of Johanna Döbereiner (e.g., Döbereiner 1992).

The temptation is strong to view Amazonia as a potential cornucopia capable of solving population and land distribution problems; the limits of applying intensive agriculture make this a cruel illusion. These limits are best illustrated by the lack of viability of applying to any significant part of Amazonia the "Yurimaguas technology" developed for continuous cultivation in Amazonian Peru (Sánchez *et al*. 1982; see Fearnside 1987, 1988; Walker *et al*. 1987). Despite a long list of subsidies ranging from chemical inputs to free soil analyses and technical advice on a field-by-field basis, this high-input management package did not gain popular acceptance in the area. The limits of physical resources, such as phosphate deposits, as well as financial and institutional restraints, make widespread use of such systems unlikely (see Fearnside 1997b).

Land-use decisions based on permitting the maximum intensity that physical conditions will allow can quickly pass limits in other spheres when individual allocations are considered together. One may examine each cell in a grid in a geographical information system (GIS), comparing the soil, rainfall, etc., with the demands of a given crop, and conclude that each individual cell can be allocated to the use in question, and yet arrive at a global conclusion that is patently unrealistic. This, for example, is the explanation of the conclusion that Brazil could support seven billion people reached by a study conducted by the Food and Agriculture Organization of the United Nations (FAO), in collaboration with the United Nations Fund for Population Activities (UNFPA) and the International Institute for Applied Systems Analysis (IIASA) (FAO 1980, 1981, 1984; Higgins *et al*. 1982). Unfortunately, the study's assumptions regarding Amazonian soil quality, land-use patterns, and the availability of resources such as phosphates make this scenario totally unrealistic (see review in Fearnside 1990b).

In the early 1970s when the fiscal incentives program for Amazonian pastures was rapidly expanding, the Brazilian Enterprise for Agriculture and Cattle Ranching Research (EMBRAPA) maintained that pasture improved the soil. Phosphorus was not among the soil characters indicated as improving as a result of pasture in EMBRAPA's original publications (Falesi 1974, 1976), but it was added to the list by others when the results were trumpeted to the world (e.g., Alvim 1981). EMBRAPA itself recognized that phosphorus was necessary, and in 1977 changed its position that pasture improves the soil, recommending instead that productivity be maintained by applying phosphate fertilizer at 200-300 kg/ha/dose (50% simple superphosphate, 50% hyperphosphate) (Serrão and Falesi 1977: 55), to supply 50 kg/ha P_2O_5 (Serrão *et al*. 1978: 28). This was subsequently modified to 25-50 kg/ha P_2O_5 (Serrão *et al*. 1979: 220), but more recent recommendations have been for the original 50 kg/ha (Correa and Reichardt 1995).

The problems limiting reliance on phosphate fertilizers are the cost of supplying phosphate and the absolute limits to minable stocks of this mineral. A report on Brazil's phosphate deposits published by the Ministry of Mines and Energy indicates that only one small deposit exists in Amazonia, located on the Atlantic coast near the border of Pará and Maranhão (de Lima 1976). In addition to the deposit's small size, it has the disadvantage of being made up of aluminum compounds that render its agricultural use sub-optimal, but not impossible if new technologies were developed for fertilizer manufacture (dos Santos 1981: 178). An additional deposit has been found on the Rio Maecuru, near Monte Alegre, Pará (Beisiegel and de Souza 1986), but estimation of its size is still incomplete. Almost all of Brazil's phosphates are in Minas Gerais, a site very distant from most of Amazonia. Brazil as a whole is not blessed with a particularly large stock of phosphates--the United States, for example, has deposits about 20 times larger (de Lima 1976: 26). Brazil's reserves total only 1.6% of the global total (de Lima 1976: 26). On a global scale most phosphates are located in Africa (Sheldon 1982). Continuation of post-World War II trends in phosphate use would exhaust the world's stocks by the middle of the twenty-first century (Smith *et al*. 1972; United States, CEQ and Department of State 1980). Although simple extrapolation of these trends is questionable because of limits to continued human population increase at past rates (Wells 1976), the conversion of a substantial portion of Amazonia to fertilized pasture would hasten the day when phosphate stocks are exhausted in Brazil and the world. Brazil would be wise to ponder carefully whether its remaining stocks of this limited resource should be allocated to Amazonian pastures.

A rough calculation can be made of the adequacy of Brazilian phosphate reserves to sustain pastures in Amazonia (Fearnside 1998). Brazilian reserves of phosphate rock total 780.6×10^6 t, with an average P_2O_5 content of 12% (de Lima 1976: 24), not counting the Maecuru deposit still being assessed. Discounting loss of 8% of the P_2O_5 in transforming the rock to phosphate fertilizer (de Lima 1976: 10), this represents 86.2×10^6 t of P_2O_5. The 53.0×10^6 ha of forest cleared by 1997 in the Brazilian Legal Amazon (Brazil, INPE 1998) would consume 1.06×10^6 t of P_2O_5 annually if maintained in pasture. This assumes that pastures are fertilized once every 2.5 years (Serrão *et al*. 1979: 220), at the 50 kg/ha dose of P_2O_5 per fertilization, considering a minimum critical level of 5 ppm P_2O_5 in the soil rather than the traditional critical level of 10 ppm, which would require annual doses of fertilizer to maintain. If the entire 400×10^6 ha of originally forested area in the Brazilian Legal Amazon were fertilized at the rate recommended for pasture, it would require 8.00×10^6 t of P_2O_5 annually. If all of Brazil's phosphate reserves were devoted to this purpose, they would last 81 years maintaining the currently deforested area (an area the size of France) under pasture, and only 11 years if the remainder of the originally forested area were also converted to pasture. However, Brazil's fertilizer deposits are already almost totally committed in maintaining agricultural production outside the Legal Amazon.

Nothing obliges Brazil or any other country to rely exclusively on domestic deposits of phosphates, so long as supplies continue to be available for export from more richly endowed countries. Some of the most richly endowed, such as Morocco, have little domestic agriculture to compete with an export trade. Reliance on imports implies disadvantages in terms of the price paid (including transport), the predictability of the price and the security of availability.

The existence of limits, such as phosphates, leads to the inevitable conclusion that population and consumption cannot grow indefinitely. There is no such thing as sustainable development for an infinite number of people, nor for a fixed population that is infinitely rapacious. There is also no way that development aimed at increasing the size of the pie can address problems that are rooted in highly unequal distribution of the pie. Many physical limits represent restrictions that need to be respected and lived with rather than as an agenda of items to be attacked. Recognition of this fact forces one to face fundamental problems of development that many people would prefer not to think about--resulting in a tendency to deny the existence of limits. Admitting to the finite potential for growth of the pie does not condemn the poor to poverty, but rather condemns the rich to dividing the pie (Fearnside 1993b).

Although a formidable array of limiting factors stands in the way of sustaining production in large areas of Amazonia if forests are converted to agriculture and ranching, this does not mean that the outlook need be gloomy for sustaining the region's current population provided the means of support is derived from the forest itself rather than through replacing it with nonforest land uses. This author believes that the best long-term strategy for providing a sustainable basis of development for the current population of rural Amazonia and their descendants is to tap the potential monetary value of the environmental services provided to the rest of the world by the natural forests in Amazonia (Fearnside 1997a).

DEFORESTATION IMPACTS AND ENVIRONMENTAL SERVICES

At least three classes of environmental services are provided by Amazonian forests: biodiversity maintenance, carbon storage, and water cycling. Amazonia's status as a "megadiversity" area is well known. Biodiversity has a variety of forms of value, both immediately utilitarian and not. Regardless of the value, if any, that any given individual may attribute to biodiversity, these values translate into a substantial willingness to pay to avoid these losses (Cartwright 1985).

Emissions of greenhouse gases that contribute to global warming are a major consequence of deforestation. The 1990 rate of deforestation (13.8×10^6 km^2/year) resulted in 267×10^6 t of CO_2-equivalent carbon as net committed emissions (the net long-term effect of one year's clearing activity), considering low values in the literature for trace gas emissions from each of the component processes. The equivalent value for the annual balance of net emissions in that year (emissions and uptakes over all of the originally forested area of Brazil's Legal Amazon) was 354×10^6 t C from deforestation and 62×10^6 t C from logging (Fearnside 2000a, updated from Fearnside 1996b and Fearnside 1997c).

One of the impacts expected to result should the extent of deforestation expand to substantially larger areas is reduction of rainfall during dry periods in Amazonia and in other parts of Brazil. Decreases would be approximately constant in absolute terms throughout the year, but in percentage terms they would increase substantially during the dry season. While the annual rainfall total would decrease by only 7% from conversion to pasture, in August the average rainfall would decrease from 2.2 mm/day with forest to 1.5 mm/day with pasture (a 31.8% decrease) (Lean *et al*. 1996: 560-561).

Preliminary calculations of indicators of "willingness to pay" for the services lost from 1990 deforestation in the Brazilian Legal Amazon total US$ 2.5 billion (assuming 5% annual discount); maintenance of the stock of forest, if regarded as producing 5%/year annuity, would be worth US$ 37 annually (Fearnside 2000b, updated from Fearnside 1997a). The magnitude and value of these services are poorly quantified, and the diplomatic and other steps through which such services might be compensated are also in their infancy. These facts do not diminish the importance of the services nor of focusing effort on providing both the information and the political will needed to integrate these into the rest of the human economy in such a way that economic forces act to maintain rather than to destroy the forest.

What are the ingredients of a rational decision on the question of attempting or not attempting to overcome a limitation on development? The starting point must be a clear definition of the objectives of development. For example, if the objective of development is to provide a sustainable livelihood for the populations of the region, then little benefit will be achieved by augmenting the productivity or the life expectancy of cattle pastures on large ranches by supplying fertilizers and improving management. Many efforts to push back limits to agricultural crop production have as their rationale supporting an ever-larger population of farmers, for example, of immigrants who come to Amazonia from other parts of Brazil. This is not necessarily in the best interests of Amazonia's current population and their descendants. It would be better to recognize that the ability of Amazonia to support population is limited and to guide development in such ways that the population size and environmental impacts are kept within those limits (Fearnside 1997b).

On many fronts, one of the major challenges to finding rational uses for Amazonian forest lies in gathering and interpreting relevant information. Making environmental services of the forest into a basis for sustainable development is, perhaps, the area where information is most critical. Providing better understanding of the dynamics of deforestation, as well as understanding of deforestation's impacts on biodiversity, carbon storage and water cycling, is a necessary starting point on the long road to turning environmental services into a basis for sustainable development in Amazonia.

It is essential that proposals for use of monetary flows from environmental services come from local communities themselves, rather than being packaged and imposed from above. This is the most effective way to guarantee that poverty eradication is achieved, and to guarantee that on-the-ground pressure is effective in avoiding invasion of the forest. A natural alliance of interests exists between those whose primary concern is environment and those whose primary concern is indigenous or other traditional peoples. It is important to realize, however, that it is an alliance, not an identity of interests. In other words, values for environmental services represent a payment for services rendered, not a human right. Adequate means of monitoring and accounting are needed (Fearnside 1997d).

ROLE OF TRADITIONAL PEOPLES

Because the income stream that can be obtained from environmental services derives from services rendered, rather than simply as a human right, it is important to quantify and document the role that Amerindians, rubber tappers and other traditional peoples play in providing the services. This is very much in the interests of the traditional peoples, since they could be major beneficiaries of making environmental services function as a basis for Amazonian development. Traditional peoples have so far had the best record of maintaining forest intact. In many heavily deforested parts of Amazonia, the only forest left standing is that in indigenous areas (Schwartzman.*et al*. 2000).

Traditional knowledge forms a part of the cultural system that makes traditional peoples effective guardians of the forest. If traditional communities lose their cultural identities, they are likely to be no more effective in defending the forest than are their non-traditional counterparts. Traditional populations must have an economic livelihood if they are to remain as viable communities. Income derived from traditional knowledge can make some contribution to this, particularly if appropriate mechanisms are created to guarantee that a portion of the value later derived from this knowledge is returned to the traditional group from which it came. However, it is important not to exaggerate the role of traditional knowledge (cf. controversies regarding the rosy periwinkle of Madagascar: Djerassi 1992). In addition, the amounts that can be obtained from pharmaceutical products are not likely to be very large, contrary to the expectations of some. An indication of this is the well-known Merck contract with Costa Rica's Institute of Biodiversity (Inbio), which provides approximately US$ 1 million annually in exchange for samples collected in the country's natural ecosystems by a network of parataxonomists. This flow of samples is sufficient to satisfy Merck's capacity to invest in searching for new compounds from tropical forests. It is important to realize that Brazil is in competition with Costa Rica and the rest of the tropics, and that the limiting factors to gaining income from biodiversity in this way are laboratories and taxonomists, not forests and tribal peoples (Fearnside 1999).

Traditional knowledge can be rewarded with a premium paid for information received, in a manner similar to that paid for certified forest products. The amounts available for this kind of subsidy depend on public perception of the importance of traditional peoples and of the environment. This willingness to pay fluctuates widely depending on fashion and press interest in the subject. Although one may expect a long-term trend to increasing willingness to pay for using and maintaining traditional knowledge and its products, turning this into monetary flows, and making those flows useful to the traditional peoples involved, will require much work to build appropriate institutional mechanisms. This could be done in conjunction with the similar mechanisms that must be created to turn provision of environmental services into a form of sustainable development for rural Amazonia. The hurdles to be crossed in changing the development paradigm in Amazonia are many, but, as the Chinese proverb explains: "A journey of a thousand leagues begins with a single step."

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