AGROFORESTRY IN BRAZIL'S AMAZONIAN DEVELOPMENT POLICY: ITS ROLE AND LIMITS AS A USE FOR DEGRADED LANDS

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ABSTRACT

Agroforestry is a use for deforested areas that is agronomically, socially and environmentally preferable to the cattle pastures that now dominate land use in Brazilian Amazonia. Agroforestry's advantages are for use in already deforested areas --native forest should not be cut to implant these systems. Much can be done to improve agroforestry systems themselves. Achieving the potential social benefits will require a clear definition of criteria for selecting the beneficiaries of the systems. Economic conditions must be created that remove the attraction of competing nonsustainable land uses such as pasture and increase the profitability of agroforestry. Evaluating proposals for agroforestry projects must use criteria that assign appropriate weights to environmental and social functions and that do not eliminate the projects because of the relatively long time required for economic returns to begin. The place of agroforestry must be defined in the context of overall development policy.

Commodity market and resource limits severely restrict the area to which agroforestry systems can be expected to expand. These limits make agroforestry an illusion as a means of (1) combating deforestation and (2) recuperating the vast areas of rapidly degrading pastures in the region. Three important questions remain: what to do with the rest of the deforested land that cannot be converted to agroforestry, what to do with the rest of the forest that has not been cut, and what to do with the rest of the rural population that cannot be supported by agroforestry. These questions require fundamental policy decisions with respect to population, land tenure, taxes, financing, zoning, highway construction, and the location and encouragement of industrial developments that offer employment alternatives to the agricultural misadventures that characterize Amazonia today. The size of the rural population must remain within the limits of the resources for its support. Agroforestry must be encouraged to fulfill its proper role in the region's development, but must not be used as an excuse for cutting forest or failing to recognize the limits of human carrying capacity in the region.

RESUMO

Sistemas agroflorestais representam uma forma de uso para áreas desmatadas tornando-se preferível agronomica, social e ambientalmente às pastagens que atualmente dominam o uso da terra na Amazônia brasileira. Embora florestas nativas não devem ser derrubadas para implantar estes sistemas, muito pode ser feito para melhorar as agroflorestas. Alcançar os benefícios sociais em potencial exigirá uma definição clara dos critérios para selecionar os beneficiários dos sistemas agroflorestais. Condições econômicas precisam ser criadas para remoção das atrações aos usos da terra concorrentes, não-sustentáveis, tais como as pastagens, e aumentar a lucratividade dos sistemas agroflorestais. A avaliação de propostas para projetos agroflorestais deve usar critérios que coloquem pesos apropriados sobre as funções ambientais e sociais e que não eliminem os projetos por causa do longo prazo antes do começo dos retornos econômicos. O lugar dos sistemas agroflorestais precisa ser definido no contexto da política geral de desenvolvimento regional.

Os limites de mercado para mercadorias e recursos restringem severamente a expansão em potencial dos sistemas agroflorestais. Estas limitações fazem com que os sistemas agroflorestais sejam uma ilusão como meio para 1) combater o desmatamento e 2) recuperar as vastas áreas de pastagens em rápido processo de degradação na região. Três perguntas importantes permanecem: o que fazer com o restante da terra desmatada que não pode ser convertida em sistemas agroflorestais, o que fazer com o restante da floresta que ainda não foi derrubada, e o que fazer com o restante da população rural que não pode ser sustentada através dos sistemas agroflorestais? Estas perguntas exigem decisões fundamentais sobre políticas relativas à população, posse da terra, impostos, financiamentos, zoneamento, construção de rodovias, e a localização e promoção de pólos de desenvolvimento industrial que oferecem alternativas de emprego às más-aventuras agrícolas que caracterizam a Amazônia hoje. O tamanho da população rural deve permanecer dentro dos limites dos recursos para o seu sustento. Os sistemas agroflorestais devem ser encorajados para desempenhar o seu devido papel no desenvolvimento da região, mas não devem ser usados como uma desculpa para o corte da floresta, nem para deixar de reconhecer os limites da capacidade de suporte humano na região.

INTRODUCTION

"Agroforestry" refers to the combination of trees or other woody perennials (either planted or unplanted) with other trees, arable farming, or grazing (e.g. Nair, 1993). There are several divergent definitions of the term, which leads to considerable confusion on the technical as well as the popular level. The term has been frequently used in a normative sense, indicating what is sustainable, not environmentally predatory, and in general, what "should" be promoted. This kind of use makes any discussion of sustainability of these systems circular, since the systems begin with this characteristic by definition. The use of the term lato sensu has been criticized by Van Leeuwen et al., nd.

The concept in the stricto sensu, used, for example, by the International Center for Agroforestry Research (ICRAF), headquartered in Nairobi, Kenya, has evolved over the years since the establishment of ICRAF in 1977 (reviewed by Nair, 1993 and Somarriba, 1992). Currently the definition used by ICRAF requires that the woody and non-woody components have some kind of biological interaction (not just economic), which can be direct (with the simultaneous presence of the components) or sequential (with effects occurring over time, for example, by means of soil regeneration by a fallow period). Under this definition, traditional shifting cultivation is considered as an agroforestry system. I prefer to limit my use of the term to systems with simultaneous interactions, since the inclusion of shifting cultivation serves to confuse the discussion about the role of agroforestry in development policy (almost always requiring some kind of caveat to exclude this type of agriculture).

Agroforestry systems are being recognized as a land use which can play a significant role in development plans in Brazilian Amazonia (Dubois, 1979a,b; Fearnside, 1983a; Hecht, 1982; Monteiro and Nunes, 1994; Weaver, 1979). However, it is easy to expect too much of this land use as a means of resolving environmental and social problems in the region. Agroforestry is not an "alternative to deforestation," but rather a land use for implementation on already deforested lands. Money and effort directed to agroforestry can have a positive effect on sustaining production in the region, but great care must be taken to ensure that such funds reach their intended beneficiaries and that the necessary conditions are created to allow this system to fulfill its promise. Defining the place of agroforestry within the overall development framework is necessary for guiding decision-making now, while the shape of development in much of the region is still within the power of national leaders to:

1.) improve agroforestry production systems,
2.) establish criteria for selecting the beneficiaries of agroforestry,

3.) create favorable economic conditions for agroforestry,
4.) establish appropriate criteria for evaluating agroforestry proposals,
5.) remove motives for competing nonsustainable land uses, and,
6.) define the place of agroforestry in overall development policy.

The present paper intends to discuss and propose solutions for these six items.

1.) AGROFORESTRY PRODUCTION SYSTEMS

Much can be done to improve agroforestry systems and tailor technologies to the local environmental conditions and to the social needs in different parts of the region. Research must be carried out now because of the long lag time for obtaining results from experiments that include trees.

One category of needed improvement is increasing the diversity of species and combinations used (Montagnini, 1988). The tendency of fallows managed in Amazonian Peru is toward greater diversity even without any stimulus from research initiatives (Unruh, 1990). Greater diversity carries the advantages of better cycling of nutrients, better use of light, water and soil inputs, possibly protecting against outbreaks of diseases and pests, greater protection against price variations in commodity markets, less pressure on the capacity of markets to absorb any one product, and greater labor flexibility of small farmers (as compared to management of such plantings by large enterprises).

Selection and identification of species for inclusion in agroforestry systems should make maximal use of the accumulated knowledge of indigenous groups, caboclo farmers (poor Portuguese-speaking residents born and raised in the Amazonian interior), rubber tappers and others. Many such people have centuries of experience with diverse plantings of tree and non-tree species. The wide array of fruits, spices, medicinal plants, etc., used by these groups could expand the value of both subsistence and commercially oriented systems (Clay and Clement, 1993).

The choice of species for inclusion in the systems should be oriented towards producing high-unit-value products (oils, latex, resins, etc.) with relatively low nutrient demands and a relatively small fraction of the production cycle spent as bare ground or annual crops between the tree crop phases. For example, slow-growing but valuable hardwoods are better than wood for pulp or for charcoal. These patterns are difficult to follow in practice: products with high nutrient demands are often commercially valuable, and farmers generally choose the forms of production producing the fastest return regardless of sustainability. Industrial processing research and marketing efforts should be directed toward uses that provide high-value products with little nutrient drain: resins and fibers, for example, should be favored over wood intended for charcoal, alcohol, particle board and other bulk products. Fruits are also much better than wood: although they have highly concentrated nutrients, they also have high enough unit value to pay for nutrient inputs provided that farmers are oriented towards sustaining production rather than simply moving on to new locations.

The wisest choices of products are those that can only be produced in Amazonia. Land uses in Amazonia must, to a large extent, be chosen to produce the products that the region is most capable of supplying in a sustainable fashion, rather than imagining that the region should rush to supply whatever markets elsewhere are eager to buy. The fact that consumers want beef or pig iron, for example, does not mean that these are what should be produced in Amazonia.

For many of the products that Amazonia is capable of sustainably producing, the limiting factor lies in the creation and organization of markets. Various native fruits offer examples; this factor is considered one of the key limiting factors in agroforestry experiments at the Economic, Interplanted and High-Density Reforestation Project (RECA) in Acre (Diewald, 1995: 9). Delicate balances exist between providing enough of a product to make it economically feasible and passing the limits either of market demand or of the region's capacity for sustainable production. If supply becomes too great, as is usually the common lot of commodities such as cacao, the world market price falls. The result is both loss of the hoped-for sustainability (when the costs of combating agronomic problems such as the witches' broom fungus [*Crinipellis perniciosa*] become unjustifiable) and loss of the equally cherished maintenance of small farmer income levels.

The lack of an organized and reliable supply of a sufficient quantity of any one product presently renders many Amazonian products unsalable. One Dutch timber merchant shopping for hardwoods at the Jari Project expressed this to me succinctly when he claimed that he could find an industrial market for *any* tree for which a sufficiently large and regular supply could be guaranteed (Henk Rodenhuis, pers. comm., 1983). This raises the problem of producing sufficient quantities of single products while maintaining the diversity whose advantages were listed earlier, and the eventual problem of controlling expansion of the system once the threshold is passed to make its growth economically self-perpetuating.

With these reservations, research to expand the use of Amazonia's forest products, and institutional arrangements to organize the purchase, transport and marketing of these products, should continue. Much more investment needs to be made in agronomic research on the production systems themselves. This should start with systematic observations in examples of agroforestry systems already implanted by farmers in the region. Research institutions often have the tendency to scorn the "unscientific" observations of humble farmers. Much time and money can be wasted in testing on experiment stations the combinations of crops that traditional farmers have already found inviable. In fact, the difference between a system that works and one that does not is usually readily apparent to the naked eye, requiring no carefully controlled comparisons or statistical analysis. The most promising alternatives identified on the basis of folk knowledge can later be tested in controlled trials. Starting from existing systems carries the additional advantage of greater acceptance when the improved technologies are subsequently promoted through extension programs. Experimentation in Iquitos, Peru, is obtaining promising results from systems based on local indigenous practices (Flores Paitán, 1988). Indigenous systems in Amazonian Peru offer examples of components which can be substituted in a natural succession in place of ecologically similar species, according to the strategy proposed by Hart (1980) for use of secondary succession as a model for choosing agroforestry components.

Species and local practices in Brazilian Amazonia have been studied by Bahri (1992, 1993), Costa et al. (1994), da Gama e Silva et al. (1994), Medrado et al. (1994) and Smith et al. (1995a,b). Traditional knowledge, however, is not sufficient to guarantee commercially viable systems. The species utilized are almost always those for subsistence consumption, and usually have no potential for commercial production. Research is necessary to build on the aspects of traditional systems that lead to sustainability and, at the same time, introduce components that increase the commercial value of production. A relevant aspect is the capacity of some species to concentrate nutrients and improve soils (E.C.M. Fernandes et al, 1994, 1995; Montagnini et al., 1995).

The process of selecting the best combinations of species and spatial arrangements can be greatly speeded by increasing our capabilities to model agroecosystems in computer simulations. Advances are needed both in modeling and in data collection on the species and their interactions, relative growth rates, shading by different strata, tolerance to low levels of light, water and/or nutrients, allelopathic properties, nitrogen fixing and phosphorus solubilizing symbionts, and ability to concentrate nutrients. Modeling offers a great potential improvement over haphazard choices of component species and spacings for inclusion in trials of agroforestry systems. This tool permits available information to be organized such that one gains the maximum possible from the data in hand. In the long run, feedback between processes of modeling and experimentation leads to improving the utility of both. Modeling must never be allowed to take the place of careful field observations, the great value of empirical knowledge of traditional peoples in the region, and the need for common sense. Models also do not substitute for actual trials to confirm the functioning of the theoretical systems identified.

Modeling tools exist to select species, spacings, and fertilizer inputs (Fernandes and Matos, 1995; E.N. Fernandes et al., 1994; Wojtkowski and Cubbage, 1991; Wojtkowski et al., 1991), to reduce financial risk exposure (Lilieholm and Reeves, 1991; Reeves and Lilieholm, 1993), and to evaluate the sensitivity of agroforestry systems to changes in prices and productivity (Thomas, 1991). Models which include variability in the parameters are essential to understanding the role of productive systems in supporting the agricultural population (Fearnside, 1986b).

Communication between researchers working on agroforestry should be facilitated. This is especially important because of the need for testing promising combinations in a wide variety of habitats and because of the barriers to communication through normal scientific channels. The Rede Brasileira Agroforestal-REBRAF (Brazilian Agroforestry Network), with its newsletter Informativo Agroflorestal, is a needed step (address: C.P. 70.060, 22422-970 Rio de Janeiro-RJ, Brazil) (Dubois, 1994). REBRAF has collated, in the form of a manual, many experiences with agroforestry techniques in the region (Viana et al., 1996).

Initiating an agroforestry scheme requires that the farmers be provided means to live until the trees begin to produce harvestable products. The best way of passing this barrier is to introduce agroforestry gradually, with annual crops interplanted between the young trees in order to provide food and income during the critical transition to forestry production. A start in this direction is a survey of agroforestry systems in the region of Manaus (Amazonas) currently being undertaken by the National Institute for Research in the Amazon (INPA) (Van Leeuwen and Gomes, 1995; Van Leeuwen et al., 1994, 1995) and the Center for Agroforestry Research in Eastern Amazonia (CPAA) and the Brazilian Enterprise for Agriculture and Cattle Ranching Research (EMBRAPA) (E.C.M. Fernandes et al., 1995; Lieberei et al., nd).

Finally, any agroforestry systems developed must be spread among the farmers through some sort of extension system. The ineffectiveness of the current system of short-courses and irregular field visits by young, inexperienced "agronomic engineers" is well known. Severe cultural impediments result in much inappropriate advice being offered--and block acceptance of any appropriate suggestions that are given (see Fearnside, 1980a, 1986; Moran, 1981). One solution can be the use of a combination of on-farm demonstration plots where the farmers can see the systems for themselves. There can also be established a network of "barefoot agronomists" recruited from within the farmer population along the same lines as China's famous "barefoot doctors."

2.) BENEFICIARIES OF AGROFORESTRY DEVELOPMENT

The beneficiaries of any agroforestry development must be identified at the outset and the programs designed to ensure that the benefits are not usurped by others. The question of "development for whom?" must be answered before any other.

The most common conflict of interest in parts of the world where agroforestry is more widely used is between small farmers (or landless people) and large corporations or landowners. In India, for example, the "social forestry" programs provide an example. Although the systems implanted are not agroforestry in the strict sense, this type of plantation represents a large fraction of the systems that have been discussed under the heading of "agroforestry" in discussions on the use of agroforestry systems to sequester carbon (e.g. Winjum et al., 1992). The social forestry programs in India now receiving increased support from the World Bank have benefited wealthy landholders and paper mills at the expense of the rural poor (Centre for Science and Development, 1985: 51-62; Environmental Defense Fund, 1987). So-called "wastelands" on public property such as roadsides, or in unplanted portions of private landholdings provide critical supplies of firewood and animal fodder to poor villagers. When these lands are converted to eucalyptus or other tree species either by private owners or by village authorities, the poor are deprived of these resources. Ironically, India's social forestry program was launched with the avowed objective of helping the poor (see Eckholm, 1979: 48-56). While the present situation in Amazonia is quite different from that in India, similar conflicts of interest can arise. One such conflict is between people already living in the region and those brought in from outside for special agricultural developments. Private colonization projects, such as those at Tucumã in Pará, and near Alta Floresta and Sinop in Mato Grosso, have sold lots to farmers from southern Brazil who have sufficient capital to pay for them. Benefits for those already in the area are minimal. Settlement projects for promotion of agroforestry could similarly produce benefits only for outsiders. The rationale for directing developments in Amazonia only to the region's present residents and their descendants is argued elsewhere (Fearnside, 1984a, 1986).

Agroforestry developments, like other forms of development, should be designed and implemented in full consultation with the participant population. Implanting the systems as a grassroots effort has the advantages of better guaranteeing that the local people are benefited, ensuring greater dedication to the scheme on the part of the farmers, and allowing maximum adaptation of the technology to local edaphic and social conditions. The existence of "local support and willingness to participate" is considered one of the key factors in the choice between agroforestry systems and simple silviculture for the recuperation of degraded areas (Lovejoy, 1985: 4).

3.) ECONOMIC CONDITIONS FOR AGROFORESTRY

A number of economic obstacles must be overcome to make agroforestry systems attractive. One impediment is competition from nonsustainable exploitation of the native forest: in the case of wood products, people cannot be expected to pay for wood produced by agroforestry when this raw material can be had for "free" by destroying the forest. Within limits, the discrepancy in prices can be reduced by imposing taxes on forest products obtained in nonsustainable ways and by lowering the costs of agroforestry through tax benefits, price regulations, financing and other subsidies. Any concession of subsidies to agroforestry should be approached with great care--the subsidies given to nonsustainable enterprises such as ranches, sawmills and pig iron smelters represent one of the principal reasons why agroforestry has not been competing successfully with destructive exploitation in Brazilian Amazonia.

The history of cattle pasture in the Brazilian Amazon illustrates the potential for subsidies to deflect development in ways that are not sustainable and which are environmentally destructive. Pastures were planted with subsidies contributing up to 70% of their costs despite obvious signs that beef production would be negligible (Fearnside, 1979a,b, 1980b; Hecht, 1985). Were agroforestry to be made highly profitable through subsidies, the vested interests that would form to defend continuation of these payments could maintain expansion until such ill effects resulted as clearing of virgin forest for agroforestry, depression of product prices driving out unsubsidized competitors, and installation of poorly maintained and economically questionable plantations as a front for receiving government largesse.

Difficulties often arise in limiting subsidies to their intended beneficiaries. Subsidies in the form of price supports and tariff barriers against competition from imports can go to other interest groups within the country who are also producing the same product. Rubber, (which is rarely produced with agroforestry systems) furnishes a good example. This product is much more cheaply produced on plantations in Southeast Asia than in Brazil because of the presence of the South American Leaf Blight fungus (*Microcyclus ulei*) in Brazil. The fungus eliminates plantations (or raises their costs tremendously), and the cost of latex collection from native forest is higher due to the greater distance between the trees. Therefore, costs of producing rubber in Brazil are higher than in Asia. The high price paid by Brazilian consumers of rubber products, although largely absorbed by intermediaries who purchase the latex from rubber tappers in the forest, goes in part to subsidize the rubber tapper population. Tapping rubber is a potentially sustainable extractive system that has great benefits for society in maintaining the environmental functions of the forest, protecting from destruction unused and undiscovered products within the forest, and providing a livelihood for a population of traditional residents (Allegretti, 1990; Fearnside, 1989a). The price subsidy is also paid to landowners installing rubber plantations, especially in non-Amazonian parts of Brazil (N.B.: the interests of the plantation owners, rather than rubber tappers, are probably the primary reason for government policies causing artificially high domestic rubber prices).

As these plantations expand, the cost of purchasing rubber at the subsidized price could become prohibitive (presently only one-third of Brazil's natural rubber comes from domestic sources). Prices might well be lowered once the domestic market is saturated--possibly endangering the extractive system (unless the array of products marketed is increased). The domestic price of rubber declined in the 1990s, owing to the high cost of maintaining the subsidy. Such a scenario raises doubts about the feasibility of a dual price system where commodities produced by systems judged worthy of a subsidy would be purchased at higher prices than those produced in other ways. Presumably agroforestry would be awarded a subsidy, although it must be remembered that in the case of rubber it is plantations (some of which are installed through agroforestry) that threaten the sustainable and environmentally preferable extractive system.

The possibility of a dual price system raises the problem of controlling such an arrangement to insure that production from nonsustainable systems is not simply certified as coming from one of the sustainable operations, thus allowing the subsidy to encourage the destruction it was intended to avoid. The system of licensing and commercialization of transportation of lumber provides an example. Forest management plans and deforestation authorizations frequently serve as mechanisms to obtain documents to allow transport and sale of illegally cut lumber. Any subsidy scheme for agroforestry would have to include sufficient controls to minimize similar abuses.

Financial institutions can accelerate the spread of agroforestry systems by providing support for training, supply of seedlings and other inputs, and organization of processing and marketing. Such channels are difficult to establish and represent part of the reason for the traditional preference of multilateral banks for funding large public works instead of small farmers. Channeling money to small farmers requires a substantial administrative structure with great opportunity for inefficiency and corruption. Inspection of records and of farmers' lots represents a major task. Additional complications include the requirement of land titles as a prerequisite for receiving bank financing (many small farmers are excluded from official programs because their land is untitled). The Demonstration Projects (PD/A) subprogram of the Pilot Program to Conserve the Brazilian Rain Forest (PP-G7) began activities in April 1996, providing invaluable lessons in overcoming these impediments.

Institutions need to be fostered that actively promote the products among potential consumers and that minimize the share of income that farmers lose by selling to intermediaries. In the absence of cooperatives or other institutions, intermediaries between the farmer and the final consumer reap the vast majority of the financial benefits. Unless these losses are controlled, farmers remain poor no matter how valuable the products they produce may be. The wretched conditions of the rubber tappers during the height of the rubber boom (1850-1913) are testament to this (Bunker, 1985: 65-72). The cooperative at Tomé-Açu is the best example of a successful organization for supplying inputs and arranging sales of perennial crop production (Homma et al., 1994; Subler and Uhl, 1990). Finding buyers for diverse products is an essential function. Although the unique cultural traditions and social ties of the Japanese-Brazilians at Tomé-Açu make their example difficult to emulate by others in Brazil, much can be gained from their experience in overcoming one of the greatest impediments to agroforestry: the drain of money to middlemen.

Cooperatives also can help production on small lots become viable, allowing activities that the farmers would be unable to enter individually because of lack of capital for infrastructure. In Tomé-Açu, a cooperative provides transportation and maintains a factory for preparing fruit pulp. The processing of products locally allows them to retain much of the added value. Cooperatives also can compensate for lack of experience and knowledge of many small farmers in relation to luxury export markets, which offer profits far higher than do markets for basic products. Also, in some cases, they can help supply "green" markets, which can pay better prices to a small number of communities for social and environmental reasons (Fearnside, nd-a). Examples include chocolate produced by the El Ceibo Cooperative in Alto Beni, Bolivia (Healy, 1988) and "ecological" coffee produced in Chiapas, Mexico (Bray, 1995).

Agroforestry requires that farmers stay in the same place for many years. While this fits the traditions of Asia, it runs against the norm in Amazonia. The turnover of small farmers in Amazonian colonization projects is extremely high. On the Transamazon Highway, for example, the colonist population turned over during the first four years at a rate corresponding to a half-life of only 11 years (Fearnside, 1986: 117). Because the new owner of a lot is likely to radically change the production strategy adopted, there is a danger that agroforestry plots initiated in any given lot may be abandoned or converted to other uses when a new owner takes over. Mechanisms are therefore needed to discourage the sale of lots. These could include bureaucratic impediments to transferring titles and heavy taxes on capital gains.

4.) EVALUATING AGROFORESTRY PROPOSALS

When proposals are analyzed for financial support by national governments or by banks, the criteria normally applied would eliminate agroforestry projects, especially those producing timber or other slow-growing products. This is because of the high discount rates against which the expected financial returns of prospective projects are compared. Because the yield of forest products is limited by biological factors that have ?nothing to do with what can be earned on alternative investments in other parts of the economy, waiting for trees grow to harvestable size or to begin to produce non-wood products is almost invariably judged to be uneconomic. Different criteria must be applied if the values of agroforestry and other slow-yielding land uses are to be recognized (Fearnside, 1989b; Price, 1995).

Agroforestry has a social value in employing a significant number of people in productive labor. By generating income for presently poor sectors of society, it could help to alleviate somewhat the great disparities in resource distribution. Fixing farmers on the land and encouraging local industry to process the products are both goals espoused by Brazil's government and by international lending agencies. Furthering these goals would require strict control over who benefits from agroforestry programs, as mentioned earlier.

One value that must be recognized and somehow compensated is the value of forest in preserving environmental functions (Fearnside, 1996b). The environmental value of agroforestry areas is less than that of native forest but is considerably greater than cattle pasture. Agroforestry systems incorporate multiple objectives, and analysis of these systems can consider more than one objective (Mendoza, 1987; Mendoza et al., 1986, 1987). Environmental values must be included in these analyses. The potential role of agroforestry for combating the greenhouse effect has been emphasized (Schroeder, 1994; Winjum et al., 1992). The best way to evaluate these benefits is still under discussion (Nilsson, 1995; Hoen and Solberg, 1995).

One of the arguments frequently used to support agroforestry is that it reduces rates of deforestation (e.g. Fernandes and

Serrão, 1992). Proponents of expanding agroforestry ?envisioning combating the greenhouse effect have argued that "a hectare of sustainable agroforestry yields goods and services that, potentially, can avoid 5-20 hectares of deforestation" (Dixon, 1995: 99), and that up to 50% of all deforestation done annually in tropical areas of the world could be avoided through promotion of agroforestry systems (Dixon et al., 1994: 84). Among the problems with this argument is that the estimate of 5-20 ha of avoided deforestation was not based on production in agroforestry systems. The systems referred to were fertilized agriculture (at "low" levels) and, in the case of the higher value (20 ha), irrigated rice (Sánchez and Benites, 1987).

Agroforestry, it should be made clear, is not a cost-effective remedy for deforestation in Amazonia. If prevention of deforestation is the main reason for supporting agroforestry, then funds could better be spent in measures to remove the motivation behind the present rush to cattle pasture. Such measures will be discussed in the next section. Agroforestry's restraint on deforestation theoretically derives from the system's capacity to satisfy both the farmers' ambitions for increasing their wealth and the market's demand for forest products. Pioneer farmers in Amazonia have virtually limitless demand for material goods, in contrast to some traditional shifting cultivators. Rather than stopping clearing when production is sufficient to feed the farmers and their families, clearing continues to the limits of the available financial and labor resources (Fearnside, 1980a, 1984b). In Rondônia, cacao, which has often been promoted as a restraint on deforestation, has frequently resulted in increased clearing when yields are high: the profits are invested in deforestation for cattle pasture (see Fearnside, 1987a).

Even in cases where the population uses shifting cultivation for subsistence, implantation of agroforestry can increase deforestation. This was documented in Sumatra, Indonesia, in a system where farmers produced upland rice for subsistence (Mary and Michon, 1987). With the adoption of an agroforestry system for market production in areas that had been left in second growth for later clearing in a system of shifting cultivation, the population continually advanced into virgin forest instead of reusing the same areas for planting rice.

One of the inherent dilemmas in agroforestry development, as in other types of development, is that if a system proves to be a financial success, it can attract immigrants wanting to share in the success, which leads to further deforestation to expand the system. This happened on the island of Sumatra, Indonesia, where areas with financially successful perennial crops experienced an increase instead of a decrease in deforestation (Alternatives to Slash and Burn, 1995: 131). The situation is one of "damned if you do, and damned if you don't": if a market crop project is an agronomic failure, then people invade the forest to slash and burn more agricultural fields, while if the project is a success, then other people are attracted to the area and also cut the forest.

As for the possibility of saturating markets for forest products, this is extremely unlikely in the most urgent case at present: the already initiated scheme to produce pig iron from charcoal in the Grande Carajás area. Use of agroforestry in this scheme is not recommended because the heavy nutrient drain caused by exporting large quantities of wood would make chemical inputs expensive to sustain production--and would create a strong temptation to abandon the system after degrading its nutrient capital. The planned smelters would require a eucalyptus plantation almost ten times the area of managed plantations at the Jari Project, a possibility that is as unlikely to occur before all accessible native forest is sacrificed as it is unlikely to function without major agronomic problems (Fearnside, 1988). With 18 billion metric tons of iron ore at Carajás, the potential demand for wood for producing charcoal is virtually infinite.

The Carajás case is important in the debate about the role of agroforestry in combating global warming, owing to the tendency of proposals for massive expansion of silviculture to be seen as environmentally and socially benign if agroforestry components are added. For example, Myers and Goreau (1991: 220) affirm that "One need not envisage vast tree plantations stretching from one horizon to another ... other tree-planting strategies are available, notably social forestry and agroforestry."

In June 1990, then-President Fernando Collor de Mello and then-Environmental Secretary José Lutzenburger announced that 10^6 ha of plantations would be established along the Carajás railway, with the justification of absorbing carbon for greenhouse effect abatement. It should be noted that these plantations, now being installed by Brazil's government-run mining firm Companhia Vale do Rio Doce (CVRD), will also supply a source of raw materials for pulp manufacture and possibly for the pig iron program. The greenhouse abatement benefits of the plantation scheme have, unfortunately, been exaggerated by a factor of two, since the calculation was done using biomass of the plantations at the moment of harvest instead of the average over a landscape of plantations in different stages of growth (see Fearnside, 1990). The cheapest way to diminish Brazil's contribution to global warming would be to slow deforestation (Fearnside, 1989c, 1995a), instead of trying to reabsorb part of the carbon in plantations. The same logic applies equally to agroforestry compared to pure plantations from the standpoint of carbon absorption.

5.) REMOVING MOTIVES FOR COMPETING NONSUSTAINABLE LAND USES

People cannot be expected to invest in sustainable land uses as long as nonsustainable alternatives produce greater returns. Agroforestry in Amazonia now competes with the highly profitable activity of land speculation. Land is cleared and planted to pasture as quickly as possible in order to secure title to the land and/or to prevent squatters or neighboring ranchers from usurping the claim. Pasture, as the cheapest means of occupying the cleared land, results in a handsome profit when the land is sold--even if beef production is zero. Construction of highways greatly increases the value of nearby land, thus adding to the motive for clearing to secure speculative profits. The financial gain to investors planting pasture has been even greater in projects that have received incentives and special financing through the Superintendency for the Development of Amazonia (SUDAM) and the Manaus Free Trade Zone Authority (SUFRAMA). On 16 January 1991 a law (No. 167) limited incentives, only to be reversed on 17 April 1991 (Decree No. 101); not until 25 June 1991 was a decree (No. 153) issued barring "concession of incentives that entail deforestation in areas of primary forest" (Article 15, paragraph 3). As this is a modification of a previous decree, this applies only to incentives included under previous decrees, that is, it does not include already approved incentives, which represent a greater problem than the relatively modest increase through addition of "new" projects. Amazon pasture is not sustainable without heavy inputs that are unjustifiable on their own economic merits and ultimately are limited even if subsidized (Fearnside, 1979a, 1980b, 1985). The economic picture has improved for expansion of pasture independent of subsidies and incentives (Mattos and Uhl, 1994).

Measures that would remove some of the profitability of pasture include:

1.) disallowing this land use as an "improvement" (_benfeitoria_) for establishing land tenure claims,
2.) taxing pasture, perhaps with a heavier tax for degraded pasture,
3.) heavily taxing the profits from land sales,
4.) erecting bureaucratic impediments to transferring land titles to new owners,
5.) extension of the present decree regarding incentives for pasture such that tax advantages and a variety of other subsidies halt for all projects (including the 300+ SUDAM projects already approved), and,
6.) not building roads into presently inaccessible parts of Amazonia.

Since the above measures are all either administrative changes or stopping of public expenditures, they could be acted upon at no expense, and in some cases at considerable savings, to the government.

6.) AGROFORESTRY IN OVERALL DEVELOPMENT POLICY

Agroforestry projects have an important role to play in Amazonian development, but the temptation to expect too much from these systems is very great. As already stated, agroforestry does not represent a cost-effective remedy for deforestation in Amazonia today. Agroforestry is often seized upon for promotion in such a role because it is non-controversial: no one opposes agroforestry. Such easy agreement is lacking for issues of agrarian reform, population growth, questions surrounding Brazil's foreign debt, and vested interests in road construction, ranching incentives, etc. Agroforestry can only be expected to occupy a relatively small part of Amazonia's vast area of already deforested land. Markets for many of the commodities produced by agroforestry systems can only absorb the production of a relatively small area. Perennial crops such as cacao and rubber offer good examples of tree species whose expansion is sharply limited by markets (in addition to biological problems). Diversifying the crops used could expand the area potentially converted to agroforestry systems.

Financial resources that can be devoted to agroforestry systems are only sufficient for a relatively limited area--especially on degraded lands requiring fertilizer inputs. The approximately five million hectares in Brazilian Amazonia indicated by an EMBRAPA estimate as already degraded pasture (Serrão and Toledo, 1990) represent an area more than fifty times that of the managed plantations at Jari. An additional five million hectares are indicated by the same estimate as having been recently planted to pasture, which is presumably still productive. This area, while not classified as "degraded" now, can be expected to enter this category within a decade. A Markov matrix of annual probabilities of transfer between categories of land use indicates that the landscape in already deforested areas will tend to evolve (assuming no change in people's behavior) to an equilibrium with 44% productive pasture, 4% agriculture, and the rest in degraded pasture or second growth. (Fearnside, 1996a). The costs of establishing and maintaining such an area in any land use that requires planted trees would be colossal.

Agroforestry systems must only be promoted on already deforested land, even if virgin forest land is better from the point of view of the systems' productivity. Agroforestry can help alleviate pressure for clearing forest by providing wood products (Winterbottom and Hazelwood, 1987: 102), but insistence on not sacrificing native forest is essential if the planted trees are to fulfill their promise in slowing deforestation (Budowski, 1984: 74). Making this kind of requirement work in practice can be difficult, as is shown by the explosion of deforestation in Bolivia in 1991 in anticipation of a major World Bank project that was scheduled to begin in 1992 for the benefit of lands that had "already" been cleared (John Robinson, pers. comm., 1991).

The temptation to use forested land is great because of the "free" nutrient capital present at the outset. In Rondônia, for example, the Executive Commission for the Cacao-Growing Plan (CEPLAC) insisted on virgin forest land as a precondition for financing cacao (Fearnside, 1984b). Use of degraded land, rather than virgin forest or high-biomass secondary forest, implies a cost in inputs and/or lower yields. One set of annual cropping systems proposed as transitions to agroforestry and other land uses is specifically not recommended for "nutritionally depleted, compacted or weedy soils that are a product of mismanagement" (Sánchez and Benites, 1987: 1527; see also Benites, 1990). Indeed, the nutrient recycling advantages of agroforestry are lost if there are no nutrients to recycle (Sánchez, 1987, 1995; Szott et al., 1991).

This problem also applies to farmers' decisions about land use within their own properties. The majority of properties contain areas in different stages of degradation, including virgin forest and recently deforested areas with relatively fertile soil, besides degraded areas. When supplied with seedlings and/or other inputs to set up agroforestry, such farmers naturally are going to put them on the parts of their property where the expected yield would be the highest and not on the degraded parts.

Decision-makers pondering what to do with Amazonia's vast expanses of degraded pastures must confront the issue of how to pay for the increased costs and/or foregone production implicit in using these areas rather than prime virgin lands. This leads immediately to the question of who should benefit from such a program. Much of the degraded land is on large ranches that have already received generous subsidies from Brazilian taxpayers in the form of fiscal incentives administered by SUDAM. Should these same firms and individuals receive further largesse in the form of subsidies to recuperate the degraded land for agroforestry? One solution would be to distinguish between "new" and "old" incentives. "Old" incentives would be retained by their original beneficiaries, but would be diverted to agroforestry: provided that funds were used exclusively for implanting these systems on degraded land, ranchers would continue to receive any money disbursed on the basis of "acquired rights" to loans and tax incentives for ranching projects approved by SUDAM prior to the 1979 policy change that discontinued "new" incentives in the primary forest portion of the Legal Amazon, a change reaffirmed in October 1988 by the Programa Nossa Natureza (Our Nature Program). The only use permitted for "new" incentives, however, would be to recuperate degraded lands for the benefit of small farmers.

The Brazilian government's agrarian reform program to transfer land from the failed cattle ranching schemes to small farmers is proceeding at a snail's pace because of resistance both inside and outside of government. Whatever political decisions reached with regard to the future scale of agrarian reform and of any program to promote agroforestry in the degraded pastures, land and other resource limitations dictate that these measures will only make modest contributions to solving either the problem of degraded land or that of landless rural population (see Fearnside, 1985, 1987b).

The limitations of agroforestry outlined above lead immediately to the questions of what to do with the still forested parts of Amazonia (since agroforestry should only be promoted in already cleared areas), what to do with the rest of the already deforested land that cannot be allocated to agroforestry, and what to do with the rest of the people that cannot be accommodated in the projects. The land which has not yet been deforested should be used for such activities as the extractive reserves proposed in Rondônia and Acre (Allegretti, 1990) and for systems of sustained management of native forest (see Fearnside, 1989b; Rankin, 1979). The approximately 2% of Brazil's Amazon region now allocated to National Parks and Forests should be increased at least fivefold. The feasibility of land uses that maintain the presence of forest requires measures to slow deforestation. These include restricting road building and reforming decision-making procedures to ensure that environmental impact analyses are performed, publicly debated and impartially judged for approval before any decision is made as to the ultimate existence of the projects in question.

The issue of what to do with the portion of the already deforested land that cannot be converted to agroforestry systems has no solution at present. The inputs needed to maintain this land in production, either in pasture or in other uses, are currently unjustified and, in the case of systems requiring fertilizers, are incompatible with the limited stocks of these nonrenewable resources. Options for many of these areas may be limited to allowing them to remain in secondary forest for the foreseeable future, thereby at least gaining some of the environmental functions of forest cover plus whatever production can be obtained from the stands as a result of enrichment with economically valuable trees.

What to do with the rest of the people that cannot be accommodated in agroforestry or other sustainable systems is a question that requires immediate answers. Agrarian reform is needed so that more rural population is supported in Amazonia and in the source areas from which the migrants to the region are coming. In addition to this, however, Brazil must address the question of rural-to-urban migration. Government policy has always been to do everything possible to prevent rural people from migrating to cities, where migrants cause problems such as increasing crime and the visibility of poverty precisely in the country's centers of political power. Problems occurring in remote Amazonian locations receive much lower priority. People in large cities also have a tendency to support opposition political parties, regardless of what party is in power (a phenomenon evident not only in Brazil but all over the world). Political leaders are therefore strongly motivated to divert to rural areas in Amazonia the flow of people leaving the countryside in other parts of Brazil.

The government facilitates the flow of population to Amazonia at great financial cost by building highways and establishing settlement projects. The expense would be even more prohibitive were accounting made of the long-term cost of providing fertilizers and other inputs that would be needed to maintain indefinitely the agriculture implanted by settlers. Environmental costs of encouraging population flow to Amazonia are also high: a person clearing forest in Rondônia has a much more negative impact on the environment than does someone living in São Paulo. From the standpoint of greenhouse gas emissions, the average rural person in Amazonia emitted greenhouse gases through deforestation in 1990 equivalent to 150 Brazilians burning fossil fuels in other parts of the country (Fearnside, 1992). People living in the countryside also tend to have more children than those in cities, thus further magnifying their future environmental impact. The percentage of the population living in rural areas has declined steadily from 69% in 1940 to 25% in 1991 (Brazil, Presidência da República, IBGE, 1992). Brazil's agriculture is rapidly transforming into mechanized and extensive systems more similar to those in North America where less than 5% of the population is rural. The country can only buck the rural-to-urban tide for a brief moment in its history, but most or all of the Amazon forest could be lost in the process. Rather than trying to divert to Amazonia the exodus of rural population from Brazil's South and Central-South regions, these people should be encouraged to move to urban areas, and employment providing an acceptable standard of living should be offered.

CONCLUSIONS

Ultimately Brazil's policy makers must recognize the necessity of keeping the population within the carrying capacity of each region and of the country as a whole. Defining carrying capacity inevitably leads to specific decisions on the productive systems used and the limits of their sustainable levels of production, the distribution of wealth within the population, the average standard of living and the minimum level acceptable, as well as intergenerational allocation of resources. Although agroforestry should be an important component of land-use plans in Amazonia, many of the wider problems that policy makers frequently hope to solve by promoting this land use are bound to remain unsolved unless the limits of agroforestry are recognized and the more difficult but more far-reaching decisions are taken to halt deforestation and bring population into balance with resources.

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