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PROSPECTS FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN TROPICAL FORESTS

Philip M. Fearnside
Department of Ecology
National Institute for Research
in the Amazon (INPA)
C.P. 478
69011 Manaus, Amazonas
BRAZIL

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SUMMARY

Farmers, ranchers, loggers and others are quickly clearing tropical forests for non-sustainable land uses. Changing this pattern will require slowing and eventually halting deforestation, which destroys the option for promising systems of sustained forest management and extraction of non-wood forest products. The most promising approaches to making agriculture sustainable maintain tree cover, use a high diversity of species, and use minimal outside inputs of nutrients and energy. Economic policies must be adopted which favor sustainable uses, in addition to perfection of the production technologies themselves.

BACKGROUND

Forest Loss

Tropical forests are rapidly disappearing around the world. The area climatically suited to tropical moist forest covers approximately 16 X 10^6 km^2, but the extent of such forests as of 1979 was estimated at only about 7.5 X 10^6 km^2, of which 13% were in Asia, 21% in Africa and 66% in the Americas (calculated from 1). The last major block of these forests remaining is in Amazonia, particularly in the two-thirds of the Amazon drainage basin located in Brazil (Fig. 1).

Tropical forests are cut for different reasons in different countries and regions. The relative importance of small farmers (as opposed to large ranchers or corporate agribusiness) varies radically among locations (2). Large cattle ranching operations, motivated less by prospects for beef production than by the potential gains from land speculation and from generous government subsidies, have dominated the scene in many parts of Amazonian Brazil where rapid clearing has occurred in recent years (3,4). In the locations of government settlement projects and roadbuilding activity, such as the explosively growing deforested areas in Rondônia, small farmers predominate. In the Amazonian parts of Peru, Bolivia, Ecuador, Colombia, and Venezuela, small farmers are relatively more important as agents of deforestation than in Brazil. In Africa and Southeast Asia, small farmers do most of the actual clearcutting, but their entry into the forest is in large part facilitated by roads built by logging firms. Because more of the species found in Southeast Asian forests are valued by international timber markets than are Amazonian species, logging has been a much more significant disturbance there so far. If present trends continue, this situation may soon change: when commercially significant volumes of timber are no longer available in Asia, international firms can be expected to focus on Amazonia. Africa's tropical timber stocks are already virtually exhausted. Logging in Asia and Africa has selectively removed the more valuable species, leaving the remaining forest heavily disturbed both by the loss of the valuable trees and by the damage done to non-valuable trees and to the forest understory during the logging operations. Such heavy disturbance is a form of "forest conversion" less drastic than the outright "deforestation" that predominates in Latin America.

Much deforestation has its roots in social, environmental and population pressures that lead to migration into forest areas. Examples include migration in Indonesia to forests on the islands of Sumatra, Sulawesi, and Borneo from the overcrowded islands of Java, Bali, and Madura; migration to Amazonian lowlands from Andean areas of Bolivia, Peru, and Ecuador, and migration to Brazil's Amazon region from the southern, south-central, and northeastern regions of the country. These migrations are often speeded by funds from multilateral development banks (5). In Brazil, the process has been hastened by the BR-364 highway that was reconstructed and paved in 1984 with funding from the World Bank to open Rondônia to migration under the POLONOROESTE project, and more recently by extension of the improved road into Acre with funding from the Interamerican Development Bank. In Indonesia the long-standing government Transmigration program to move millions of settlers into forest areas has received a succession of World Bank loans, as has the less publicized effort to establish settlers on large plantation estates.

The effect of international funding is often less direct, as when infrastructure installed for one project is also used for other, much more destructive, initiatives. This is the case in Brazil's Grande Carajás Program, where the railway in eastern Amazonia completed in 1984 with World Bank funding for the Carajás iron mine is the backbone of a massive regional development plan that includes pig-iron smelting using charcoal obtained from the forest (5-7).

Impacts of Deforestation

Most tropical forests are converted to land uses that prove unsustainable after only a few years. Once destroyed, the forests we know today are unlikely to return on any significant scale because of the difficulty of re-establishing these highly diverse arrays of plant and animal species whose complex interactions are essential to the ability of each to survive and reproduce. Re-establishing tropical forests is also impeded by the loss of essential nutrients when clear-cutting or other heavy disturbance breaks the forest's tight nutrient cycling mechanisms and allows these elements to be quickly lost through burning, leaching, and soil erosion. Many tropical forests, such as those in Amazonia, are on very poor soils; unlike temperate zone ecosystems, tropical forests are especially vulnerable to nutrient drains because most of their nutrient capital is maintained in the vegetation rather than in the soil (8).

Deforestation closes the door to many potentially sustainable forest uses. Extracting small quantities of high-value products that are unique to the forest, such as pharmaceutical compounds, is one means of forest use that is already known to be sustainable. Most of the products that can potentially be produced sustainably by the forest are not even known to science or to the commercial economy, but rather to the native peoples that inhabit the forest (9). The knowledge of these uses is being rapidly lost as the native cultures are destroyed, a process intimately linked to deforestation. The speed of forest conversion and the irreversibility of the losses caused by this process mean that any strategy for promoting sustainable uses must begin with immediate steps to slow forest loss.

Deforestation carries the danger of severe global and climatic impacts on the environment if current trends continue unchecked. Global warming from the greenhouse effect caused by atmospheric carbon dioxide and trace gases would receive a substantial contribution from deforestation if Amazonia were converted to cattle pasture; if conversion to pasture occurred over a 50-year period, the annual CO_2 release would represent about 20% of the present annual release from fossil fuels (9-11). Impact on rainfall through reduced evapotranspiration is another major concern. The hydrological cycle of Amazonia and neighboring regions is dependent on water recycled through the forest for a substantial part of the precipitation that falls, especially during the dry season (12-14). Should the dry season lengthen as a result of deforestation, as would be expected, the high natural variability in rainfall in Amazonia could lead to an occasional very severe drought, killing many trees of more sensitive species and setting in motion a positive feedback process that would degrade the remaining forest (15). Wildfire entry into the damaged forest could greatly speed destruction of the remnants, as occurred in Borneo during the El Nin~o drought of 1982-1983.

Present Land Uses

When tropical forests are cut, virtually all of the newly cleared land is used for unsustainable systems of production. In Indonesia, upland farming becomes impractical after five to seven years when fields are invaded by the highly aggressive grass Imperata cylindrica. In many areas of Africa, shifting cultivation is practiced by forest settlers, but the accelerated cycle employed does not leave the land fallow for a sufficient time to regenerate site quality and maintain crop productivity. In Brazil, pioneer farmers employ slash-and-burn agriculture to grow annual crops such as upland rice for one or two years after felling the forest, then, rather than leave the no longer productive field fallow in woody second growth, they usually plant cattle pasture. Large ranchers plant pasture directly after felling the forest.

Grass production in the cattle pastures declines steadily as a result of decreasing levels of available phosphorus in the soil, soil compaction and invasion by inedible weeds (4,16,17). After about a decade, the grass production is miniscule and insufficient to justify the maintenance costs of controlling invading weeds. At this point, the land is usually abandoned to secondary forest, although in some cases pasture may be fertilized and replanted if government subsidies are granted for recuperating the degraded pastureland, or if ulterior motives are present (such as desire to demonstrate ranch productivity in order to avoid expropriation of land for agrarian reform). The norm is abandonment and is likely to remain so because of the limits that financial and physical resources impose on the area to which fertilizers can be applied. When degraded pastures are abandoned, secondary forest grows very slowly, in contrast to much more rapid growth in shifting cultivation fallows.

Impediments to Sustainable Systems

Many factors limit the options for land uses in tropical forest areas. Land uses must be agronomically feasible given the constraints of climate and soil. They must also be compatible with cultural limits (18). For example, even if it were found agronomically feasible to transform vast areas of Amazonia into irrigated rice paddies similar to those of tropical Asia, cultural differences between Asia and South America make it unlikely that any such radical alteration of agricultural behavior could take hold over a time span that would be relevant to the impending collision between increasing population and human carrying capacity in the region (19).

In Brazil, a strong popular myth holds that Amazonia has infinite land area and infinite agricultural potential, and Brazil's president José Sarney has adopted the slogan that "the country that has Amazonia has no right to fear for the future." This myth represents a powerful impediment to taking actions to halt deforestation, solve social problems in non-Amazonian parts of the country that are being temporarily postponed by shunting population flow to Amazonia, and face the technological and social challenge of developing and promoting sustainable uses for tropical forests (18).

The vast scale of Amazonia places severe limitations on the types of potentially sustainable systems that can be promoted. One can undertake intensive agriculture requiring high inputs provided only a small area is so developed. One quickly reaches limits of financial resources and of physical resources such as phosphates--deposits of this vital mineral are virtually nonexistent in the Amazon region, and therefore phosphates would have to be transported over long distances to sustain fertilizer-based agriculture or pasture. World commodity markets also constrain choices: conversion of a significant fraction of Amazonia to any particular crop would leave the farmers unable to sell their harvests. Markets for crops such as cacao are already well enough supplied that any further increase in planted areas would result in lower prices. Markets are particularly limited for perennial crops, which have better prospects for sustainability than annual crops or pasture. Expansion of cattle pasture, which has the poorest prospects for sustainable production (20,21), is not currently limited by availability of markets.

The way that financial calculations are now made in assessing potential developments mitigates against many potentially sustainable forest uses. Non-sustainable uses are indicated as more profitable because of rapid discounting of future costs and benefits. The rate that salable products can be generated from forest trees, for example, is controlled by the biological rates that limit the growth of each species; these rates have nothing to do with the returns available from industrial or other activities available as alternatives to investors. The discount rate applied in financial calculations, derived from the rates of return available in the economy as a whole, is usually much higher than the sustainable rates of production, making destructive exploitation perfectly rational so long as this form of assessing projects is used. Not only must the future not be discounted so brutally, but appropriate values must be attached to the environmental functions fulfilled by the forest and to the products that it alone can produce (22,23).

CURRENT STATUS

A variety of approaches has been taken to developing sustainable systems for tropical forest areas. Heavy inputs of fertilizers and agricultural chemicals are used in a system for continuous cultivation of annual crops under trial in Yurimaguas, Peru (24). The system, dubbed the "Yurimaguas technology" by its developers, is unlikely to be adopted by Amazonian farmers on a significant scale because of serious agronomic, economic, institutional, and resource supply problems (25). Low-input systems now under development by the same research group show greater promise than the earlier high-input system (26).

Annual crops are grown in industrial scale monocultures in Brazil's Jari project in irrigated rice paddies established in the floodplain or várzea (27). This mechanized system has encountered a series of pest and disease problems, which have so far been countered with crop variety changes and chemical treatments. High costs and risks, together with unique features of the Jari enterprise, make large scale repetition of these techniques in similar undertakings unlikely.

Arboreal perennial crops are preferable to annuals because they offer greater protection from the soil erosion, they recycle nutrients more tightly, and as trees they perform at least some of the environmental functions of forest. Diseases are a serious limit on many perennials in Amazonia. Cacao is severely attacked by witches' broom fungus (*Crinipellis perniciosa*) throughout Amazonia. Rubber is attacked by the South American Leaf Blight fungus *Microcyclis ulei* in plantations. Oil palm was to be greatly expanded in the region, but these plans were suspended in 1987 when spear rot, a viral disease present in Surinam, suddenly became a problem in plantations near Belém, killing as many as 4000 trees per month. Greater diversity would be desirable in perennial crop systems, partly as protection against outbreaks of pests and diseases (28,29).

Silvicultural plantations also run a high risk of pest and disease loss when expanded to vast monocultures. The massive Jari project begun by D.K. Ludwig in Brazil's Amazon region has suffered losses from the *Ceratocystis fimbriata* fungus in the estate's most valuable plantation tree species: *Gmelina arborea*. Desire for greater security from such losses has been a continuing motivation for the enterprise to increase the number of tree species planted. None of the species in the commercial stands comes close to attaining the high growth rates originally anticipated by Ludwig for *Gmelina*. Jari is able to continue thanks to the favorable terms under which the infrastructure was purchased by the present owners, and the presence of a profitable kaolin (China clay) mine on the site. Similar plantations are unlikely to proliferate in the region (7,27).

Agroforestry, or the simultaneous growing of trees with annual crops and/or pasture, holds much more promise than most of the systems' components would separately. These systems are well suited to small farmers because they provide food and income from the annual crops during the period while the trees are not yet large enough to produce. They are relatively good at maintaining protective cover for the soil over a long cycle, and are amenable to use with diverse plantings. The component species can include legumes that fix nitrogen and deep-rooted species that draw nutrients up from lower layers in the soil and deposit them on the surface in the form of the leaves and branches that either are allowed to fall or are cut by the farmer in regular prunings. Diversity not only affords greater protection from biological problems, but also reduces exposure to fluctuations in commodity market prices. The advantages of agroforestry do not, however, make its promotion a cost-effective remedy for deforestation in Amazonia: funds whose primary intent is slowing forest loss would better be spent on directly addressing primary causes such as land speculation and migration. Agroforestry should only be encouraged as a use for already deforested land, not as a replacement for natural forest ecosystems.

Forest management is attractive as a use for wide areas of tropical forest because, in addition to generating income, it maintains environmental functions and future use options by leaving the forest relatively intact. While several systems are being tested experimentally, forest management has received low priority as a research goal and has not yet been adopted on commercial scale. The reasons lie not in the technical difficulty of designing sustainable systems but in the inherent disadvantage of the systems in competing with non-sustainable alternatives. Only revised criteria for economic decision-making can shift emphasis to these potentially-sustainable forest uses and secure their long-term benefits for society (22).

"Extractivism"--the name given in Brazil to removing non-wood forest products such as latex, resins and Brazilnuts--has excellent prospects as a sustainable use. Beginning in 1985, the establishment of "extractive reserves" in Brazilian Amazonia has become a possibility for securing substantial areas of forest for use in this way by resident rubber tappers. The first reserves were decreed in the state of Acre in 1988; others are proposed in Rondônia, Amazonas and Amapá. If this option is to have a significant impact on Amazonian land use patterns in the future, speed will be required in demarcating and legalizing reserves, and road building in nearby areas must be restrained. The extractive economy of the rubber tappers, at present heavily dependent on the subsidized price in Brazil for natural rubber, must diversify to use many more than the approximately 20 products presently marketed. Identification of potentially useful pharmaceutical products requires a concerted research effort. Marketing arrangements must also be improved to eliminate middlemen; otherwise, extractivists will remain poor regardless of how much wealth they generate, as occurred during Amazonia's rubber boom (1885-1913). Economic policies must confront the difficult question of subsidies, which have done so much environmental damage in the case of Amazonian cattle pastures, yet are one of the only mechanisms available for directing monetary flows to sustainable systems that maintain environmental functions that have heretofore been pocketed by society as "free" services.

FUTURE DIRECTIONS

Much research needs to be done on identifying and improving low-input agricultural systems, particularly those that emphasize diverse plantings of perennial crops. Development of forestry management systems also requires substantial increases in research, especially since these experiments are inherently long-term while the opportunity to apply them in practice is rapidly disappearing. Research is needed to identify useful forest products, especially pharmaceutical compounds. Use of indigenous knowledge is the most efficient means of initial screening for the thousands of species occurring in the forest, many of which are not even formally "known to science." So far, commercial firms have been more interested in forest products for use in cosmetics than for medicinal properties; while cosmetics can generate some cash income, they lack the tremendous non-monetary payoff that pharmacological uses have. Most drugs are originally discovered in natural plant products; only after activity has been confirmed are the compounds synthesized by the pharmaceutical industry. Loss of tropical forest is viewed as a serious potential loss to efforts to find cures for cancer and other diseases.

Research into crop combinations and forest management treatments is necessary but not sufficient to put development on a more sustainable course in tropical forest areas. Even were guaranteed sustainable systems available, farmers and loggers would be unlikely to adopt them under most conditions today. Research is needed on the economic mechanisms that control farmer choices, and how government policies might be modified to make sustainable systems profitable and non-sustainable ones unprofitable.

While improvement of agricultural systems to increase their sustainability should be a high priority, decision-makers must recognize the limits of agricultural development in tropical areas as a means of solving other problems, including problems of other geographic regions. Problems such as population growth, highly skewed land tenure distribution, and inadequate employment opportunities to accomodate rural-urban flows must be addressed directly in the locations where these problems occur. Policies must reflect the limits of human carrying capacity at the national level and within the regions of each country (18,30).

Rapid action is needed to slow and eventually stop the cutting of tropical forests. Among the losses brought by deforestation is the loss of some of the best opportunities for sustainable use. Research to improve the sustainability of agricultural systems is needed, but in no way substitutes for directly addressing the forces driving deforestation. Disappearance of tropical forests is not foreordained; neither is conversion to non-sustainable uses.

KEY CONTRIBUTORS

The following short list of other workers presents some of the diversity of approaches to arable farming (A), agroforestry (B), forest management (C), extractivism (D), and ranching (E). It should be remembered that the greatest store of knowledge on sustainable forest use does not lie with academic experts, but rather with the native peoples, rubber tappers, and traditional farmers who live in the forest.

M.H. Allegretti, Instituto de Estudos Amazônicos, Curitiba, Paraná, Brazil (D)

A.B. Anderson, Museu Paraense Emílio Goeldi, Belém, Pará, Brazil (C,D)

J. Dubois, C.P. 33.110, (CEP) 22.442 Leblon, Rio de Janeiro, Brazil (B,C)

G. Hartshorn, Tropical Science Center, San José, Costa Rica (C)

S.B. Hecht, Graduate School of Architecture and Urban Planning, University of California, Los Angeles, California, U.S.A. (B,D,E)
R. Lal, International Institute of Tropical Agriculture, Ibadan, Nigeria (A)

D. Posey, Museu Paraense Emílio Goeldi, Belém, Pará, Brazil (D)

P.A. Sánchez, Soil Science Department, North Carolina State University, Raleigh, North Carolina, U.S.A. (A,B,E)

C. Uhl, Buckhout Laboratory, Pennsylvania State University, University Park, Pennsylvania, U.S.A. (E)

GLOSSARY

agroforestry: Combination of trees (either planted or natural) with annual crops, grazing or both.

deforestation: Complete or nearly complete clearing of forest, as for pasture or annual crops.

extractivism: The term used in Brazil for harvest of non-wood forest products such as rubber, Brazil nuts, and other commodities that can be collected without damage to the structure of the forest.

forest conversion: Perturbation of a forest to change it to another land use, either forested or not. Includes both deforestation and less drastic alterations such as selective logging.

human carrying capacity: "The maximum number of persons that can be supported in perpetuity on an area, with a given technology and set of consumptive habits, without causing environmental degradation."

perennial crops: Crops which produce for an extended number of years without removing and replanting, in contrast to annual crops which must be replanted every year. Tree crops such as cacao, oil palm and rubber are examples of perennial crops; they are not, as sometimes mistakenly termed, "permanent crops."

polyculture: Growing of two or more useful plants simultaneously in the same plot.

shifting cultivation: A form of agriculture where forest is felled, burned, and cultivated for one or a few (<5) years, after which the plot is allowed to revert to secondary vegetation; the farmer later reclears the plot and recommences the cycle.

slash-and-burn agriculture: Agriculture where forest is cut, burned, and planted in annual crops (as in shifting cultivation), but farmers do not necessarily leave the land fallow and return to the same plot to cultivate at a future time.

tropical moist forest: Wholly or partly evergreen forests in areas receiving at least 100 mm of precipitation in any month for two out of three years, with mean annual temperature of at least 24°C and essentially frost free. These forests are often popularly referred to as "rain forests," although, in technical terms, a higher annual rainfall is necessary to qualify as a rain forest. Most tropical moist forests receive at least 1500 mm of annual precipitation.

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