DEVELOPMENT ALTERNATIVES IN THE BRAZILIAN AMAZON: AN ECOLOGICAL EVALUATION

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Brazil's current race to develop its Amazon Region carries with it many unique opportunities, as well as risks. It is a rare event in human history when such a large area of natural ecosystems is converted to human agroecosystems at least in theory as a planned development, under the aegis of government programs. To the extent that government programs control or influence the course of events, the opportunity must be seized to rationally guide such development into activities that maximize human wellbeing, and avoid potential ill effects. Since Brazil's development thrust in Amazonia has only just begun, and since the area is so large (5×10^6 km^2 in the Legal Amazon, or about one-third the size of the continental United States), even small changes in the direction of development policy carry tremendous potential effects, either for better or worse. Along with deliberate choices of land uses yielding products for consumption and sale, areas to be maintained undisturbed must be defined and defended.

Any planning must start with careful consideration of what development objectives are appropriate. The frame of reference is crucial. Here I start from the premise that planning is being done by the Brazilian government for the benefit of both present and future generations in the Amazon Region, including all levels of society. Note that emphasis is on benefit for the Amazon Region, not other countries or other regions of Brazil. It must be remembered that several conditions must be met for the objectives which follow to be attained, including the maintenance of human population below carrying capacity, a limit to the concentration of land holdings, and a limit to total consumption (presumably including a limit to maximum consumption). Appropriate objectives are summarized below.

Agronomic Sustainability

Agronomic sustainability requires a reasonable balance of nutrients in the system, with compensation for losses from leaching, erosion, and nutrient export in harvested products. Other requirements for continued productivity, such as control of soil compaction, must also be met. Energy sources should be renewable. Probabilities of destruction by pests or diseases must be low.

Social Sustainability

Social sustainability requires that the system be maintained, in practice, by society. To persist, a system must remain profitable over time. Sustainability can be jeopardized by fluctuations in yields (as from biological problems), and variations in market prices for the products, or in prices and availabilities of inputs. Regulations required for the system's functioning must be enforceable. Acceptability of social assumptions underlying a system can affect its long-term sustainability, as in the case of systems inseparable from extreme social inequalities. Sustainability is therefore linked with social forces arising from resource distribution and population pressure.

Unsubsidized Economic Competitiveness

Agricultural activities must be attractive without reliance on economic subsidies from outside. Distortions introduced by such subsidies as tax incentives and low-interest loans have a way of becoming self-perpetuating, even when a system's intrinsic economic merits do not justify the government expense.

Maximum Self-sufficiency

Dependence on imports of energy supplies, other agricultural inputs, and basic food staples is likely to lead to long-term risks from price variation and supply interruptions. Self-sufficiency is not to be confused with isolation from trade, necessary (within limits) for all agroecosystems that might be contemplated. Some cash crops are needed to supply funds for purchase of goods not locally producible; the problem is to prevent loss of self-sufficiency in locally producible products.

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Fulfillment of Social Goals

Minimum living standards, as measured by various criteria, must be met for those supported by an agroecosystem. For each criterion, probability of individuals failing to meet the standard must be maintained within acceptable limits. Employment generated by different development types must also be considered, as must effect on equitability of income distribution. On a regional scale, an agroecosystem's installation cost can also be important if opting for an expensive development type means that social goals are not fulfilled elsewhere in the region.

Consistency with Maintenance of Areas for Other Uses

Development plans must insure that adequate areas are available for ecological, Amerindian, and other types of reserves requiring intact forest. Reserve boundaries, once created, must be respected: developments surrounding areas must not create pressures leading to retraction of previously made commitments to reserves.

Retention of Development Options

Land uses should be avoided which preclude other possible future uses should a change be necessary, for example following a biological or other problem forcing abandonment of a production system.

Minimal Effects on Other Resources

Both social and biological effects of development activities in an area of land can affect other areas or resources. Pollution can affect nearby areas, including riverine fish populations in the case of water pollution. Fish populations can be harmed by habitat destruction in fish breeding and feeding sites in *várzea* (floodplain) and *igapó* (swamp forest) (Goulding, 1980). Uncontrolled expansion of human activities is a common effect of some development types on neighboring resources.

Minimal Macro-Ecological Effects

Sacrifice of species and genetic diversity, and diversity of co-evolved ecological relationships, as well as climatic changes, are not among considerations often entering the planning of specific development schemes. Long-term costs of ignoring these potential problems could be high. [2]

Comparison of Development Options

With the objectives discussed above in mind, as well as the potential for conflicts among objectives, it would be useful to compare some of the development options used and proposed in the Brazilian *terra firme* (unflooded upland) rainforest [3]. No single option should be considered desirable for the entire Amazon, but rather a patchwork of areas in different uses (Fearnside, 1979; see Odum, 1969; Margalef, 1968). The point bears emphasis that all possible options have drawbacks, although some are clearly more desirable than others. The idea that some development panacaea exists only awaiting discovery by researchers is a potent myth. Although research can indeed provide better agroecosystems, and should be supported and pursued at many times its present rate, the faith that research results will someday overcome any given agronomic and environmental limitations is pernicious: it can and does lead planners to dismiss concern for future consequences of present development decisions.

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Fourteen possible land uses are compared (Table I), using the criteria outlined in the preceeding section. Taking the development options in the order presented in Table I, roughly in ascending order of environmental perturbation, let us look at some of the reasons for rating them in this way.

1) Untouched Forest

Untouched Amazonian rainforest is clearly a sustainable use over any time horizon for human planning, having maintained itself in currently forested areas for most of the period since forests retreated into several "refugia" during the last ice age. A period of maximum glaciation confined forest to the smallest refugia, ending about 12,000 years ago; subsequently two forest advances and retreats to larger refugia occurred, the last ending about 2000 years before the present (Prance, 1978: 214). Provided forest is indeed untouched, the only threat to its sustainability would come either from region-wide climatic changes, or from isolation into patches sufficiently small that some animal and plant populations could not maintain themselves.

Social sustainability is problematical as a combined result of unacceptability of low rates of economic return to those who would benefit from a land use change, lack of effective social controls to prevent disturbance, and irreversibility of many changes resulting from human disturbance.

In the short term, untouched forest is uncompetitive with other uses. An exception is the value of forested land as a commodity for speculation, but expectation of future conversion to other uses forms the theoretical basis of the rise in value, even if each individual owner does not intend to underkate the conversion himself. Long-term holding of substantial tracts forested land for future economic exploitation can be a wise use in economic terms. The value of the wood alone in the Brazilian Amazon has been estimated at over US$1 trillion at current international prices for hardwoods on commercial markets (United Nations, International Trade Center, 1974 cited by United States Interagency Task Force on Tropical Forests, 1980: 36). As yet undiscovered pharmacological uses of rainforest plant products are far greater, the prospect of their loss being considered a substantial setback to cancer research (Myers, 1979). Economic advantages of postponing rainforest conversions would be even more apparent if a less short-sighted perspective were employed in discounting future returns. Apart from areas reserved for future exploitation, sufficient areas should be preserved untouched with guarantees that human disturbance will not be permitted at some future date.

Social goals are served by untouched forest from very poorly to very well, depending on the goals in question. Employment generation is low, inspecting and guarding areas from disturbance being the principal requirements, aside from research. Living standdards are not maintained from forest production on the short term, and so depend on the scale of salaries paid by whatever governmental or private organization would be responsible for the tracts. Low installation cost is a point in its favor, since both public and private capital resources are freed for other social requirements such as education and health. These requirements also include the installation of adequately capitalized sustainable agroecosystems elsewhere, either in Amazonia or elsewhere in Brazil, either in the *terra firme* rainforest areas or elsewhere in the region, and either as intensive management of small areas or as extensive management of large areas within the rainforest parts of Amazonia.

Whether social goals are served by retaining rainforest areas in untouched status hinges on whose social goals are in question. Excluding poor squatters from tracts designated for retention in forest for the future use of government or private owners clearly places these individuals or groups in

conflict. Ameridians are one group whose interests are intimately linked maintaining rainforest areas intact.

Untouched rainforest has the advantage of not adversely affecting adjacent areas, as by encouraging encroachment of human disturbance in areas for which this is not intended. Other positive points are the retention of development options, minimal adverse effects on other resources, and the absence of undesirable macroecological effects.

2) *Forest Products Extraction*

Extraction of forest products can provide income from rainforest areas in ways which, for many products, can be sustained indefinitely from an agronomic point of view. Products removed represent a relatively small drain on nutrients over a large area due to the small quantities involved, although the nutrients often are in concentrated form. Most important, nutrient cycling mechanisms are left intact. Income can be significant: the United States alone imported US$16 million worth of Brazil-nuts in 1977 (United States Department of Agriculture, 1978 cited by United States Interagency Task Force on Tropical Forests, 1980: 36). Income from most

TABLE I: COMPARISON OF DEVELOPMENT OPTIONS FOR TERRA FIRME (*)

	Agronomic Sustainability	Social Sustainability	Competiveness without Subsidies: Short-term	Competiveness without Subsidies: Long-term	Self-sufficiency	Social Goals	Consistency with Other Uses	Retention of options	Effects on Other Resources	Macro-ecological Effects
1) Forest untouched	1	3	3	?	—	1-3	1	1	1	1
2) Forest products extraction	1	?	3	1	3	3	1	1	1	1
3) Shelterwood	1	?	3	1	3	3	1	1	1	1
4) Highgrading with replanting	1	?	2	1	3	1-3	1	1	1	1
5) Highgrading without replanting or regulation	2	?	1	3	3	1-3	1	1	1	1
6) Enrichment and/or selective poisoning	1	?	2	1	3	1-3	1	1-2	1	1
7) Silvicultural plantations	2	?	2	2	3	1-3	2	3	2	2
8) Clearcutting without replanting	3	3	1	3	3	1-3	3	3	2	2
9) Perennial crop plantations	2	1	1	1	2-3	1-3	2	3	2	2
10) Taungya	2	1	2	1	1	1	2	3	2	2
11) Annuals in shifting cultivation	1-3	1-3	2	2	1	1-3	3	3	2	2
12) Annuals in continuous cultivation	?	1	3	2	1-3	1-3	2	3	3	3
13) Pasture with fertilizer	2	3	3	3	3	3	3	3	3	3
14) Pasture without fertilizer	3	3	3	3	3	3	3	3	3	3

* 1 = good, 2 = intermediate, 3 = bad, ? = unknown

forest products extraction operations is currently low on a per-area basis, but future increases in product prices and in the range of products marketable could easily change this. The sustainability of production would make this option more economically attractive were the future discounted less brutally.

Social sustainability is low for many forms of forest product extraction. Game hunting is unlikely to provide a continued production in any but the most isolated areas, since most regulations intended to maintain game populations are inherently unenforceable. Social sustainability is often unlikely due to competition with other land uses, Rubber gatherers in Acre have been violently expelled by ranchers or land speculators. Due to the violence, large numbers of *seringueiros* (rubber gatherers) have left Brazil to continue their livelihoods, a major contribution to the estimated 80,000 Brazilians now in Bolivia (Weyrauch, nd 1979). Many more have abandoned their profession to become *favela* (slum) dwellers in Rio Branco, Acre's capital.

The poverty and exploitation of rubber gatherers working on the estates or *seringalistas* (rubber "barons") has long been notorious (Benchimol, 1977). Rubber gatherers are still among the poorest of Amazonia's population. The sector's neglect has at least resulted in more self-sufficiency for gatherers, who maintain subsistence plots of basic food crops, rather than relying on company stores as was common during the rubber "booms".

Extraction of forest products leaves options for other uses entirely open, with the exception of losses of some animal populations from hunting. Damage to other resources and macro-ecological effects are also minimal.

3) Shelterwood Forestry

The tropical shelterwood system has given every indication of being a sustainable land use during the period it was employed in Nigeria and during testing underway at the Superintendency for Development of the Amazon (SUDAM) forestry experiment station at Curuá-Una near Santarém, since 1963 (Dubois, 1967, 1971). The minimization of breaks in canopy cover maintains physical factors in ranges appropriate for rainforest tree species, as well as leaving nutrient cycling mechanisms and coevolved pollination and dispersal systems as intact as possible.

Social sustainability is more uncertain for the shelterwood system. The system requires enforcing a regulated cycle over many years, thus presenting the continual temptation of faster gains through departing from the scheme. The danger is illustrated by Nigeria, where increased social pressure for agricultural land and timber, combined with lifting of British colonial rule, led to an end of the system. Regulations for a select-fell system in Kalimantan, the Indonesian portion of the island of Borneo, appear to be doomed from the start: a 1977 survey indicated that none of nine companies surveyed was complying with a law requiring that 25 select crop trees be left per hectare (Eckholm, 1979. 23). Eckholm (1979) concludes that "the notion that these areas will be ready for another valuable harvest in 35 years thus appears to be wishful thinking at best, or a convenient lie at worst." Such a fate for potentially renewable schemes in the Amazon is an ever-present possibility.

Profitability of shelterwood forestry on a short-term basis does not compare well with more destructive exploitation forms. Sustainability of production, however, means returns are much better over a long time span. The system relies entirely on exporting the product in exchange for cash to buy subsistence necessities. Wages and income are therefore determined by the larger institution required to organize the system.

The shelterwood system creates minimal conflicts with other land uses, retains development options open, does not adversely affect other resources, and avoids macro-ecological effects.

4) Highgrading with Replanting

Highgrading, or harvesting only the most valuable trees while leaving the remainder of the forest intact, has long been the preferred timber extraction practice in Amazonia due to its low costs. Replacement of trees removed with planted seedlings appears to form the basis of (hopefully) sustainable forest management plans being discussed for wider areas of the Brazilian Amazon (Pandolfo, 1978; Reis, 1978). Some form of highgrading with replanting would presumably be included in any forest utilization contract ("risk contract") scheme approved.

Prospects for sustainability are good, *provided* replanting is done in a way effectively leading to regeneration of trees removed. Advocates of systems wholly or partially based on replanting are wise to point out that trials in the Brazilian Amazon are so far insufficient to establish the viability of such schemes on a commercial scale (Reis, 1978: 14). Nutrients removed in the form of hardwood logs would be small relative to many other land uses, although eventual nutrient depletions would necessitate replacement of nutrients removed. Arkcoll (1979) calculates from Klinge's (1976) data that a one-time removal of 20,000 kg/ha of hardwood removes 145 kg/ha of nitrogen,

Long-term holding of substantial tracts of forested land for future economic exploitation can be a wise use in economic terms.

2.4 kg/ha of phosphorus, 14.9 kg/ha of potassium, and 18 kg/ha of calcium. Replacing these nutrients would cost Cr$2972 (US$116) at July 1979 fertilizer prices in Manaus, as compared with a Cr$50,000 (US$1949) value of the wood removed (Arkcoll, 1979). Of these macronutrients, calcium would be limiting, but only 3.4% of the supply in the uppermost meter of soil would be removed in the harvest (Arkcoll, 1979).

Social sustainability requires that regulations for laborious replanting operations be enforced over an extended period. Doubt that replanting requirements would be carried out in practice is one of the major points raised in opposition to the version of the forest policy law currently being debated in Brazil (Kerr, 1980). Reliance on natural regeneration rather than artificial regeneration could eliminate much of the cost of replanting schemes, but strict enforcement of regulations is required to preserve seed trees, seedling crops, canopy cover, and coevolved relationships (Rankin, 1979a,b).

Highgrading with replanting is probably only moderately competitive on a short-term basis due to the high cost of replanting and the requirement of weeding under more difficult conditions than in plantations. Future price increases for hardwoods as the world's rainforests are decimated could change this, giving this use better prospects for long-term competitiveness.

Forestry schemes such as this require salaried labor under a larger institution's direction. Large areas are required to make the scheme economic, due to regeneration cycles of perhaps 20-30 years. Wage levels and distribution of income therefore depend on the institutions filling this organizational role.

The schemes, provided they are not abandoned in favor of other types of exploitation yielding quicker profits, score high marks for consistency with other land uses, retention of development options, effects on other resources, and avoidance of macro-ecological effects.

5) *Highgrading without Replanting or Regulation*

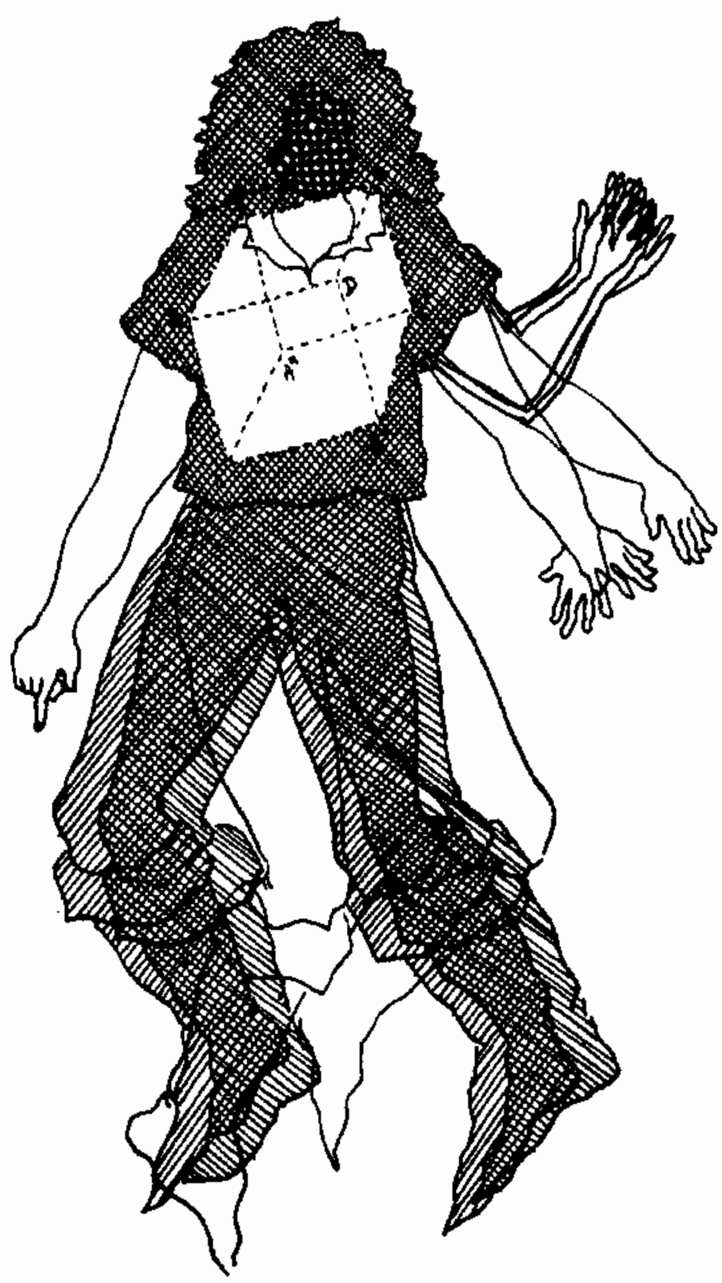
Highgrading without replanting or regulation of the cropping cycle and provision for leaving seed trees has little chance of being sustainable over the long term, although speed of decline in productivity may vary. Eventually the forest will become decapitalized as more valuable species are eliminated. The process is illustrated by the elimination of reproductive size rosewood trees *(Aniba duckei)*, valuable for use in the perfume industry, from virtually all accesible forests in the lower Rio Negro area, as well as many other areas including the Amazon National Park on tbe Tapajós River.

If highgrading without replanting or regulation were employed as a long-term land use, long periods would be needed between harvests for regrowth to justify each cutting. Not all species regrow. Low expected returns and low capital investment in anticipation of future returns result in lack of motivation to guard areas against pressures for conversion to other uses.

Short-term profitability should be high for this form of "predatory exploitation" as it is known in Brazil. The only costs are for land (or for access to it), and for direct expenses of removing the high-value product. Long-term profitability would be poor due to low productivity, unless a change to another land use is contemplated.

The social context of simple highgrading is similar to that of highgrading with replanting, except that less employment is created over the long term. So long as stocks of valuable trees last, harvesting operations can be carried out by small operators who buy logging rights from private land owners. Such a royalty system is employed in government forest lands in Trinidad, but Trinidad's forests have a far bigher density of valuable trees than in the Brazilian Amazon, enforcement of any regulations is difficult, and the system is ultimately not sustainable. Private landowners in Brazil, including to a small extent Transamazon Highway colonists with 100 ha lots, do sell logging rights to entrepreneurs who run small sawmills or own trucks. In the Brazilian case logging is not done with any intention of continued use of the land for forestry. Even preliminary removal of valuable timber only applies to a tiny fraction of land cleared for agriculture or ranching.

Highgrading does not necessarily pose a threat to other land uses in adjacent areas althought the temptation for loggers to cross boundaries to remove timber from nearby forested areas is clear. Options for a wide range of more intensive land uses remain open. Pollution or similar effects in other resources are minimal, as are macro-ecological effects.



6) *Enrichment and/or Selective Poisoning*

Enrichment, or planting seedlings of desirable species in the forest can substantially increase the forest's economic value when seedlings reach harvest size (Meijer, 1973; Dubois, 1979a). Labor and expense required for this type of operation can be excessive, and is often underestimated by planners. Seedlings often do not take, necessitating replanting. Planting from seeds is generally not possible due to losses to rodents, insects, or other problems. The labor required to transport and plant significant numbers of seedlings in the rainforest is very high, and periodic clearing of weeds and vines requires continued labor inputs for years after initial planting. Experiments with line and cluster plantings in a SUDAM reserve between Santarém and the Curuá-Una Hydroelectric Dam in Pará have left local foresters disappointed by the amount of labor required (J. M. Rankin and P. M. Fearnside, field notes, 1978). Labor requirements are even greater where selective poisoning and girdling are used in combination with enrichment plantings, as at Tapah Forestry Experiment Station in Perak, Malaysia (J. M. Rankin, personal communication, 1980). Maintenance operations demand labor, not only for poison girdling and planting, but also for a weed cleaning after the first six months and every year for the first five or six years followed by occasional thinning of the groups or lines planted (J. M. Rankin, personal communication, 1980).

Selective poisoning in combination with highgrading, a class of exploitation pattern including the "Malaysian Uniform System," can cause severe problems for natural regeneration of rainforest species by extensive breaking of the forest canopy, with consequent increases in understory light levels leading to weed invasion and poor growth conditions for rainforest tree seedlings. Breaking the web of ecological interactions may have later consequences. In forests where many trees are not desirable species, poisoning operations may lead to significant nutrient losses. Clearly many possible degrees of selectivity exist in forestry systems involving tree poisoning. Much more basic ecological research needs to be done to provide the basis for rational planning schemes of this type (Rankin, 1979a).

Enrichment and/or selective poisoning programs have much the same implications for social goals as other forestry schemes. The labor-intensive nature of enrichment planting and maintenance operations means employment is generated. A stable institutional structure is needed to direct and pay for these operations while awaiting subsequent harvests. Wage policies in effect influence both the system's social desirability and its long-term economic competitiveness.

Effects on other land uses, future development options, other resources, and macro-ecological factors are all low, as with other forms of forestry. Depending on the extent of forest destruction through poisoning, options requiring more intact forest are closed, and irreversible ecological changes occur. Effects are mild when compared with uses involving clearing and burning.

7) *Silvicultural Plantations*

Silvicultural plantations involve removal of the original rainforest and replanting with one or a few species of trees (Synnott and Kemp, 1976). Agronomic sustainability of these operations is less assured, at adequate profit levels, than is the case with forestry operations leaving more of the natural forest's ecological buffers intact. Silvicultural plantations are usually large monocultures, with the inherent weakness of these for disease and pest attacks (Janzen, 1973). The silvicultural plantations most often presented as a potential "model" for development are at Jari (see Fearnside and Rankin, 1980).

Agronomic sustainability of timber and pulpwood plantations is probably intermediate between that of many uses involving clearcutting and those leaving all or most rainforest cover intact. Biological problems are not so easily or cheaply avoided by switching to other varieties or crops as in the case of annuals. Longer cycle timber species, such as teak *(Tectona grandis)* or other hardwoods, require less inputs than pulp species or softwoods to counter site degradation through nutrient export and between-cropping erosion and compaction.

Social sustainability of plantations depends on several unknowable factors, including long-term maintenance of management schemes, and relative prices of inputs (such as labor) and products. Changes in management, availability of funds, and other organizational problems can cause severe difficulties for silvicultural plantations, as has happened on occasion in the case of government experimental plantations at Curuá-Una, Pará.

Competitiveness of silvicultural plantations with other investment options is only fair on the short term, although, depending on sustainability, long-term prospects may be better. Expected world shortages of pulp (Briscoe, 1978) and hardwoods (Reis, 1978) may improve long-term prospects by significant increases in the relative prices of these products.

Silvicultural plantations depend on outside sources of food and other necessities. On the scale of large enterprises, food production activities can be associated with plantations, as is a goal at Jari. Attainment of many social goals depends on the social system in effect, since wage scales for the country at large apply to these enterprises. Silvicultural operations are almost always large enterprises, leading to the skewed income distribution usually accompanying these in Brazil. Probability of failures due to fluctuations in yields should be relatively small as compared with many crops. Employment generation should be higher on a per-area basis than for many forestry operations, but lower than for those involving unmechanized annual crops. Installation cost is quite high.

Consistency of silvicultural plantations with other uses in adjacent areas is probably intermediate between the low risks of invasion of plantations by squatters, and the higher risks associated with uses where the potential loss to the owner is lower if invaded. Silvicultural plantations may, in fact, prove to be important as buffers between forest reserves and areas with high potential as sources for invasion. Silvicultural operations are large and normally guarded against the entrance of unauthorized passers through, therefore serving to insulate reserves from smallholder areas laced with public roads and trails. Managed forest uses would serve a similar function in protecting reserve areas. Unfortunately, the usual case in Amazonia is the juxtaposition of small farmers raising annual crops with Amerindian or other reserves, leading to rapid uncontrollable invasion by squatters. The Aripuana Indian reserve in Rondônia and Mato Grosso is a case in point (Davis, 1977). Although the size of silvicultural operations may be a barrier to penetration by small squatters, responsible agencies must beware that the firms themselves do not expand into reserve areas.

Silvicultural plantations close development options involving retention of rainforest cover. Silvicultural plantations are often called by the euphemism "reforestation" (reflorestamento) in Brazil, wrongly implying that the stability and other characteristics of natural forest are restored, and diverting attention from the fact that, in most cases in Amazonia, such proposals involve clearing rainforest in order to install the plantations. Both effects on other resources, and macro-ecological effects are probably intermediate between those from clearcutting options which do not restore tree cover, and options leaving rainforest canopy to some degree intact.

> Apart from areas reserved for future exploitation, sufficient areas should be preserved untouched with guarantees that human disturbance will not be permitted at some future date

8) *Clearcutting without Replanting*

Clearcutting without replanting has minimal prospects as a sustainable land use in tropical forests; few would maintain illusions to the contrary. Radical increases in light levels, among other factors, favors dominance of non-rainforest vegetation in the regrowth, appropriate conditions for most rainforest species not being regained until after an extended process of ecological succession. Destruction of seedlings, seed sources, and coevolved relationships inhibitis regeneration of many mature forest components (Gomez-Pompa *et al.*, 1972). Clearcutting alters soil physical properties, microorganism populations, and both soil and total ecosystem nutrient stores, usually to the detriment of rainforest species competing with invading second growth (see Ewel and Conde, 1976, 1978; Jordan, 1979).

Were commercial exploitation of regrowth from clearcutting contemplated on a repeated basis, social sustainability would probably be low. In contrast to a silvicultural plantation or other management scheme involving more inputs, second growth would be considered by potential invaders and by government authorities alike as "unused" or "abandoned", and so effectively available for re-clearing by a third party of more intensive use.

Clearcutting without replanting should give an attractive short-term return, since most of the exploitation costs go directly into removing the saleable product, establishment and growth of the forest having come to the exploiter at virtually no cost. Even with this great windfall from the point of view of the potential clearcutter, high costs can make large scale operations unattractive under present conditions. The Brazilian government has found it difficult to interest enterprises in clearfelling the 2160 km² area to be flooded by the Tucurí Hydroelectric Dam, currently under construction on the Tocantins River in Pará with completion scheduled for 1983. Removing trees in the reservoir area is necessary to prevent losing the reservoir's usefulness for fisheries and activities beyond power generation, as occurred in Surinam's Brokopondo Lake (Leentvaar, 1967) [4]. Profit levels may change radically in the future for Brazilian Amazonia, as they have in many parts of Melanesia where "integrated" exploitation, a euphemism meaning clearcutting for combined lumber and chipboard production, has created a rush expected to destroy virtually all lowland rainforests there by the year 2000 (Routley and Routley, 1977).

The long-term competitiveness of clearcutting without replanting is undoubtedly very low, since the long time needed for succession to produce stands of saleable timber, and the low value of the second growth stands, makes other uses more attractive.

Logging operations are inherently not self-sufficient, depending on outside supplies for all of the workers' needs. Social goals related to employee living standards are therefore dependent in prevailing wage structure. Employment generated would be low when considered on a long-term basis, since no labor is required except for the immediate harvesting operations. Only the quick profits and short-term employment generation are positive features, aside from more flexibility in the size of exploiting enterprises than is the case with some forms of forest exploitation requiring more elaborate equipment and long-term management.

The risks to adjacent reserves from clearcutting without replanting are probably greater than for other land uses requiring more fixed investments in crop planting and subsequent management. Firms might be tempted to expand clearing into neighboring reserves. Options after clearcutting are severely limited. Those requiring forest cover are precluded, and erosion, compaction, and other problems lower site quality for many non-forest uses.

Other resources are only moderately affected. Silting is a potential problem in watershed areas for dams, and alteration of runoff patterns can affect downstream areas dependent on continuous stream flow. Macro-ecological effects accompanying deforestation apply to clearcutting, although second growth regeneration makes some effects more temporary than in the case of land uses where tree cover is suppressed for long periods.

Whether social goals are served by retaining rainforest areas in untouched status hinges on whose social goals are in question.

9) Perennial Crop Plantations

Perennial crop plantations can potentially he sustained for long periods, but these periods vary greatly with the crop and the management applied. Most perennial crops are by no means "permanent" crops, as they are usually called in Brazil. The devastating effects of *Fusarium* fungal attack in black pepper, the South American leaf blight *(Microcyclus ulei)* in rubber plantations, and witches' broom *(Crinipellis perniciosa,* formerly *Marasmius perniciosus)* in some cacao plantations illustrate this (Fearnside, 1978, 1980, nd). Nutrient supplies can be maintained through fertilization, provided the cost is compensated by production, and the farmer is disposed to follow agronomists' advice on fertilization rather than the conventional wisdom among many traditional farmers that the land "gives" its production for nothing *(i.e.* without nutrient inputs).

Social sustainability of perennial crops should be quite high. Perennial crops are appropriate for small farmers, as well as for large enterprises. They are also highly labor-intensive, generating large amounts of employment on a small area. The high investment involved means that plantations are defended against invasion by squatters, speculators, or neighbors.

Perennial crop plantations have good prospects for competitiveness with other uses both on the long and short term, assured by high product values and high productivity as compared with many less-intensive management systems. Continued competitiveness depends on world prices for products, a factor beyond individual planters' control. Recently, falling prices for cacao, coffee, and especially black pepper, have begun to discourage some potential planters in the Amazon. Planting large areas in these crops could itself have a significant effect on prices, a concern apparently worrying cacao growers in traditional plantation areas in the northeastern state of Bahía with respect to the future impact of new plantation areas in Rondônia. World Bank economists estimate that Brazil's cacao expansion plans will be a major factor in a projected world price drop from the 1977 peak price of US$3.74/kg to levels half of this value by 1985 and one-third of this value of 1995 in 1977 dollars (Skillings and Tcheyan, 1979). Both limited demand on world markets and the limited extent of relatively fertile soil types in Amazonia insure that perennial crops will only account for a tiny fraction of the Amazon's land area (Alvim, 1981: 140).

Perennial crop plantations are not, in themselves, self-sufficient. The aptness of perennial crops for small farming operations, however, leads to the possibility of many basic subsistence requirements being filled by plantings elsewhere in the same lots. Self-sufficiency is less likely for larger enterprises staffed by hired laborers.

Social goals may be well or poorly served hy perennials depending on circumstances. Most perennial crops should provide relatively high mean income due to high product values. Yields should vary less than for annual crops although disease and pest attacks are always potential problems making diversification a wise precaution. Price fluctuations are another matter, the export (and often luxury) products involved being subject to wide variation from year to year. Wage distribution depends on the system under which the crops are grown, ranging from small independent farmers to large estates with paid labor forces. Relative to annual crops at least, the labor demand is fairly evenly distributed throughout the year for most perennials (Fearnside, 1980c). High and continued need for labor makes perennials attractive for social reasons, especially when contrasted with the most common competitor: pasture.

Perennials are expected to be intermediate in their effect on adjacent areas. High installation costs should reduce the risk of their spilling over into adjacent properties, but the high concentration of laborers needed to maintain the plantations would probably result in some incursion on any nearby reserves, at least for hunting and similar activities.

Options for many other forms of land use, as with all choices involving clearcutting, are restricted with perennial crops. Effects on other resources are probably not excessive, and macro-ecological effects are expected to be intermediate between those maintaining some of the forest cover and those maintaining no arboreal cover at all. Some perennial crops, such as black pepper, would have effects more like annual crops due to the large amounts of bare ground maintained between plants, while others, like cacao, would be more similar to silviculture in their effects.

10) Taungya

The taungya system, or agrisilviculture, involves planting one annual crop following clearing with a timber crop such as teak interplanted; the trees shade the ground to form a silvicultural plantation following harvest of the annual crop with a minimum of additional effort on the part of the farmer (King, 1968, 1980; von Maydell, 1979; Mongi and Huxley, 1979). The silvicultural part of the cycle serves a function analogous to that of bush fallow in shifting cultivation, except for its being harvested and removed rather than burned before planting the next annual crop. The taungya system, and its name, originated in Burma. Taungya has been used on a wide scale in Indonesia (J. Bennema, personal communication, 1979). Prospects for sustainability are reasonable, although chemical inputs would probably be needed after a few cycles. The same potential biological and other problems applying to silviculture must be considered in the case of taungya.

Social sustainability of taungya should be quite high, since the system produces both food and cash crops, and the silvicultural plantations formed during the cycle would be of sufficient value to justify defense against invasion or other pressures for a premature switch to other uses. Greatest chance of abandoning the system would be at the silvicultural phase harvest time. While taungya fits ideally into the traditional shifting cultivation pattern practiced for generations in many parts of Southeast Asia virtually none of the immigrants to the Amazon have the cultural tradition of allowing bush fallows to regenerate for repeated returns to crop in the same location. Taungya, once started in Brazil, would be much more likely to end with the first cycle than would be the case among traditional shifting cultivators.

Taungya's competitiveness on a short-term basis should be somewhat similar to that of annual crops under shifting cultivation, or only moderately attractive given today's product and input prices. As with other systems involving annual crops, taungya has the advantage of producing a return beginning in the first year. The additional costs of planting trees would detract considerably from taungya's acceptability, given the heavy discounting of future returns by most Amazonian farming operations both small and large. In the long term, once the first cycle is complete and income from the silvicultural phase is being produced, the system should be much more attractive.

A high degree of self-sufficiency is one of taungya's principal advantages. The annual crops produced every year can relieve dependence on exchange with outside suppliers to meet subsistence needs. Modifications of the system, with more diversification of tree crops planted (Clarke, 1976; Bishop, 1980a, b; Dubois, 1979b), can extend the range of subsistence needs fulfilled, along with other advantages of diversification in minimizing the chances of failure.

Social goals are well served by taungya. The system is labor-intensive, creating more jobs per unit area than many other options. Average income is probably fairly high, especially after the silvicultural phase begins to produce a return. The system is well adapted to using family labor. Large enterprises are not a prerequisite for the system, fairly small farms being able to operate it provided purchasers exist for the silvicultural products and provided each farmer controls at least enough land for one complete cycle of annual crop patches, similar to the land area required for shifting cultivation. The system encourages colonists to think of themselves as permanent residents, although the frequent pattern in Amazonia of succesives waves of settlers selling their properties to newer and wealthier arrivals could also work with taungya . The chances increase of the system being discarded in favor of some other management plant each time a parcel of land changes hands. Income from taungya should be fairly stable once silvicultural production begins, although fluctuation in product prices will affect this as with other crops.

The effect of taungya operations on nearby reserves or managed rainforest areas should be moderate, but not insignificant. The high investment required to establish the plantations makes spillover into adjacent areas less likely than for some other uses, although the annual crop phase, without the accompanying tree plantations, could over-

Silvicultural operations are almost always large enterprises, leading to the skewed income distribution usually accompanying these in Brazil.

flow its bounds should land areas on individual properties be insufficient for a full cycle. More importantly, the concentrated population associated with taungya would undoubtedly be tempted to enter and disturb adjacent forested areas, as occurs in virtually all situations in Amazonia where population concentrations and forests are in close proximity.

As with other land uses involving clearfelling, taungya closes all options requiring rainforest cover. The irrevocable destruction of rainforest implicit in the taungya system is a principal reason for caution in recommending it for wide areas presently under rainforest cover, although the system has many clear advantages in areas of Amazonia where cover has already been destroyed.

The system's effects on other resources, as with pure silvicultural operations, are moderate but not inexistent. Macro-ecological effects are reduced by the presence of arboreal cover during most of the cycle.

11) Annuals in Shifting Cultivation

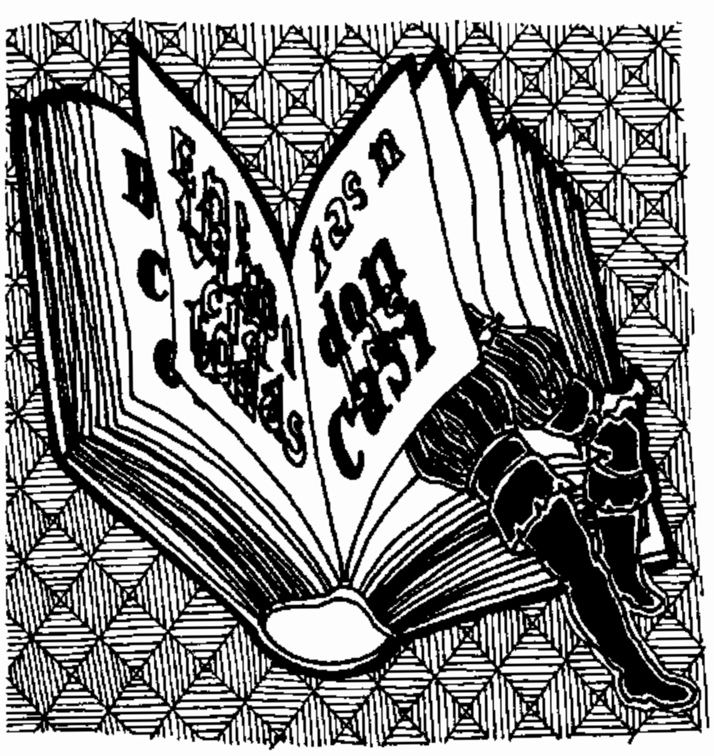
The sustainability of shifting or swidden, cultivation of annual crops depends very much on the faithfulness with which the appropriate fallowing schedule is followed. Shifting cultivation may go on for centuries under conditions of low population density where a lengthy fallow is not only possible but is also used by farmers. The opposite is much more common, many areas having followed a pattern of shortening fallows and declining yields until either the system or the area is abandoned. Through successive cropping cycles one could expect the second growth regeneration of site quality. The common practice of judging when to clear a stand of second growth based on the stand's size rather than its chronological age makes possible an adjustment for regrowth rates differing with site time period.

Social sustainability of shifting cultivation can be either good or poor depending on circumstances. The temptation to hasten the cycle or to switch to other land uses is likely to make shifting cultivation unsustainable among settlers in the Amazon. Low returns from shifting cultivation can make such changes in land use quite attractive. The agricultural population lacks the necessary cultural traditions to sustain the pioneer agriculture being practiced as a shifting cultivation system. In addition, fallow areas would be classed as "unused" or "abandoned", and so would be vulnerable to squatting or other forms of takeover by third parties .

Shifting cultivation is moderately competitive with other uses on a short-term basis, or before exhaustion of available virgin forest obligates the system to depend on re-use of second growth. Required cash inputs are low, and returns begin in the first year. Over the long term the system's competiveness would be reduced as the area occupied by fallows increases, and as possible options for slower-yielding crops appear more attractive. Few settlers in goverment colonization projects view annual cash crops as anything other than a temporary cash source while establishing pasture or perennial crops. Shifting cultivation would soon become a poor competitor with other options were it not pursued using a sustainable fallowing schedule.

Shifting cultivation has the advantage of self-sufficiency, the farmer getting most daily necessities from his own fields.

Social goals can be well served by shifting cultivation, with the exception of the farmers' extremely low mean income. Low mean income (aside from the low contribution of saleable items to the wider economy) is the principal reason presented for the near universal condemnation of this system among agricultural planners (Alvim, 1978a,b,c). Fluctuations in yields can cause shortages, but these can be minimized in traditional systems by the "normal surplus," a buffer in production in excess of anticipated needs (Allan, 1965: 38-39). Diversification of crops: varieties, and planting dates also minimizes the risk of inadequate production to meet subsistence needs. Shifting cultivation does supply large amounts of employment, utilize family labor, work well for small farmers, require minimal inputs of capital from public or other sources, and promote an even distribution of income.



A mayor drawback of shifting cultivation is its inherently uncontrolled nature, threatening nearby land in forested areas. Shifting cultivators in close proximity to forest reserves or managed forest areas can be extremely difficult to keep from entering and clearing in these areas, especially as pressure on the land in the shifting cultivation area increases.

Silvicultural plantations are often called by the euphemism "reforestation" *(reflorestamento)* in Brazil, wrongly implying that the stability and other characteristics of natural forest are restored.

Shifting cultivation closes options for all uses requiring forest cover. Effects on other resources can occur, such as silting problems resulting from the erosion accompanying annual crops (Fearnside, 1981). Fires from burning fields sometimes burn into adjacent areas, a problem varying greatly from one region to another, being more common, for example, in the area of Manaus than on the Transamazon Highway near Altamira.

Deforestation accompanying shifting cultivation has macro-ecological effects, as with other uses involving clearfelling. The regeneration of woody vegetation on a substantial portion of the land does mitigate some of the effects, at least as compared with uses maintaining the entire area without arboreal cover.

12) Annuals in Continuous Cultivation

The sustainability of continuous annual crop cultivation on Amazonian *terra firme* is not known at present. Agronomic experiments at the Yurimaguas station near Pucallpa, in the Peruvian Amazon, have shown the need for supplying an increasing number of nutrients through fertilization as cultivation continues for such crops as maize, rice, and sorghum (Sánchez, 1977: 559-60; 1979: 107-09). Crop production in these experimental plots can pay for fertilizers at current prices after eight crops, provided a strict crop rotation is followed and each field's fertilizer doses are continually changed in accord with regular soil analyses. Results are encouraging so far, but the requirement of continuous input (and acceptance) of technical information, in addition to cash inputs for fertilization and liming, would prove a hindrance to widespread use of the scheme.

Hopefully, appropriate crop rotation schemes, interplantings of different crops, mulching, and other techniques in addition to fertilization will eventually yield a sustainable and economically competitive system. So far such a system has not been developed. One attempt to develop a sustainable subsistence gardening system for tropical rainforest areas in lowland Mexico uses "modules" of garden plots in association with animal raising and fish farming (Gleissman *et al.*, 1978). Many biological factors, in addition to nutrient supply problems, need to be solved for large scale agricultural operations with annual crops to succeed on a sustainable basis. Weeds are one such problem. Herbicides may help eventually, remembering the pollution potential of many available herbicides, although much more experimentation is needed to verify that a sustainable and economic system can result. Insect populations increase in continuous cultivation areas: cropping schemes often become inviable after a few years of successful production as insect populations develop resistance to insecticides and the pests' parasites and predators are destroyed. Insects have destroyed cotton plantations in such widely separated areas as central Africa (Gilham, 1972), Madagascar (J. L. Guillaumet, personal communication, 1980), Peru (Barducci, 1972), Lousiana (Newson, 1972), and several Central American countries (Smith and Reynolds, 1972).

The continuous cropping system of Asia are often held up as examples of what the Amazon could potentially produce. Why should the Amazon valley not resemble that of the Ganges at some future date? The poorer soils and less favorable topography in Amazonian *terra firme* are one reason, but seemingly impossible obstacles have been overcome in some parts of Asia on both counts. More important are the deep cultural differences. Transformations to higher levels of agricultural intensity and population density could probably

best be viewed as a process of coevolution much like the coevolution of biological interactions, rather than as either population increase "causing" intensification (Boserup, 1965) or *vice* versa (Geertz, 1963). Radical cultural changes can occur, but they develop gradually relative to the current pace of events in Amazonia. By the time any significant cultural adaptation could take place, irreparable ecosystem changes would have occurred.

Social sustainability of continuous annual crop cultivation should be excellent, if agronomic problems can be solved. Such a system would not leave areas in second growth or low-intensity forest uses which could be classed as "idle" and open for occupation. Depending on the type of continuous cultivation scheme in use, such systems could or could not involve small farmers rather than large plantations with their attendant social tensions.

Annual crops in continuous cultivation are currently not competitive with other uses, excepting vegetable growing near large city markets. In the future this situation may change as better techniques are developed, and as the relative prices of products and inputs (especially great increases in the price of land) make continuous cultivation a higher priority among annual crop cultivators.

Self-sufficiency can be high or low under annual cropping schemes. Diversified food crop cultivation can supply a large part of farmers' dietary needs, while large plantations of cotton or other purely cash crops lead to dependence on market sources for subsistence requirements.

Social goals are likewise highly dependent on the type of annual crop grown and the cultivation system adopted. Large plantations with hired laborers would depend on the level and distribution of wages prevailing in society at large. At present this type of labor, especially migrant labor, does not normally enjoy living standards most planners would envision as appropriate social goals. Fluctuations in market prices and crop yields would also have varying effects depending on the crops, and the diversity of different crops, chosen. Diversified plantings of annual crops which include a variety of food crops could contribute to the security of the farmer's consumption levels.

Continuous cultivation of annuals should pose somewhat less threat to neighboring areas in forested land uses than does shifting cultivation of annual crops. Concentration of population near forested areas would inevitably lead to people entering these areas and causing some disturbance, even if not entering for the purpose of expanding the cultivation system.

Development options involving forest are closed, as in the case of other agroecosystems in cleared areas. Potential for effect on other resources through pollution is much higher than with other uses, since continual chemical inputs are needed to combat weeds and insects, in addition to fertilization. Erosion and siltation are also potential problems in watershed areas, as are attendant changes in the hydrological cycle. Macro-ecological effects can be expected from large areas in continuous annual cropping, since all tree cover is removed.

13) Pasture with Fertilizer

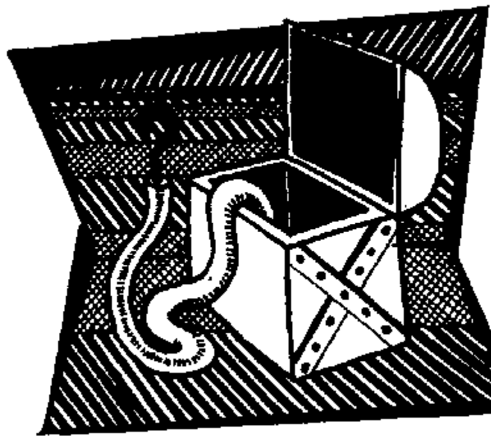
The agronomic sustainability of pasture with fertilizer applications is under intensive research in the Brazilian Amazon though the PROPASTO (Pasture Program) section of EMBRAPA (Brazilian Enterprise for Agriculture and Cattle Ranching Research). Fertilizer applications on degraded pastures have produced encouraging results which PROPASTO researchers believe are sustainable (E.A.S. Serrão, personal communication, 1980). The experiments have been underway since 1977 (Serrão and Falesi, 1977; Koster *et al.*, 1977; Serrão *et al.*, 1978, 1979). More time will give a better idea of potential sustainability of the fertilization system.

Fertilization to replace lost nutrients is only one of several conditions required for pasture production to continue on a long-term basis. Soil compaction under pasture (Daubenmire, 1972; Schubart *et al.*, 1976; Dantas, 1979) can retard pasture growth. Regulation of stocking rate is necessary to prevent overgrazing and consequent invasion of inedible weeds. Statements regarding sustainability of pasture in Brazil almost invariably carry a qualifier that "adequate management" or "rational management" is needed for sustainability.

This is certainly true, but it should also be remembered that such measures must be realistically expected to be applied to any pasture management scheme proposed. Otherwise such a qualifier only provides a convenient escape for the researcher: if a pasture fails at some future time, then it is the fault of the rancher for not having "rational" or "adequate" management.

Social sustainability of pasture with fertilizer is not very likely at present. Fertilizers have been supplied at highly subsidized rates. Very few ranchers in Amazonia presently use fertilizers of any kind, due to the high cost of fertilizers, low cost of land, and ulterior motives for maximizing area of land cleared rather than concentrating financial resources on raising productivity of limited areas.

Competitiveness of fertilized pasture with other uses, without government subsidy, is doubtful both on the short and long term. Principal problems are higher fertilizer prices and need for more fertilizer to achieve a given effect as compared with other regions. Some nutrients are heavily leached, but in the case of phosphorus, the limiting element for pasture in most of the region, leaching is not a significant problem in comparison with conversion of P_2O_5 applied into unusable compounds in the soil. Phosphorus fixation capacity of the soils in the areas is high, with the greatest effects occurring at low (and most probable) levels of fertilizer application (Dynia *et al.*, 1977). In red-yellow podzolic (ULTISOL) from the Transamazon Highway, up to 40% of phosphorus applied is fixed after seven days, while *terra roxa* (ALFISOL) fixes up to 83%, at 75 and 53 ppm P applied, respectively (Dynia *et al.*, 1977). Such problems can be overcome by applying more fertilizer to saturate the soil's fixation capacity. Marked increases in pasture grass yields have been obtained in experimental plots on the Belém-Brasília Highway (Koster *et al.*, 1977; Serrão *et al.*, 1978, 1979) using 50 kg of P_2O_5 per hectare, which translates into about 300 kg/ha of superphosphate fertilizer. Similar experiments in Amazonian Peru have shown increases in productivity for a few years followed by a decline due to compaction and probable other nutrient deficiencies, in addition to disease attack in associated legumes (Peru, Instituto Veterinario de Investigación del Trópico y Altura, 1976 cited by Sánchez, 1977: 563). Solving fertility and other problems requires substantial cash inputs on the part of ranchers, if not paid for by government subsidies. The question of sustainability is an economic one. Continual increases in the cost of chemical and other remedies as pasture is degraded will make long-term economic sustainability a dificult goal to achieve with fertilized pasture.



Cattle ranching operations are rarely self-sufficient in basic foodstuffs, since these crops do not form a part of the production system. Self-sufficiency is not impossible for many items if the rancher is inclined to place a priority on maintaining subsistence plots of food crops.

Most social goals are poorly served by ranching. Ranching operations are usually large, often replicating the great social inequalities of the Brazilian Northeast. Little employment is generated by ranches once initial forest felling is completed. A survey on the Belém-Brasília Highway of 11 ranches with a total of 216,685 ha revealed that they had created only 275 jobs in all categories from laborers through managers, or one job per 778 ha (Hébette and Acevedo, 1979: 140).

Ranches have often posed threats to neighboring forested lands. Expansion of clearings into adjacent land is a way of gaining possession, the legal formalities of title being worked out later in accord with the fact of occupation. Even if title is not eventually gained, use of the land is retained. Expansion of ranching into a number of Amerindian areas has occurred in this way (Ianni, 1979; Bourne, 1978; Davis, 1977). Clearing by a ranch beyond the boundary of a SUDAM experimental forestry reserve near Santarém in 1978 illustrates this danger (J. M. Rankin and P. M. Fearnside, field notes, 1978).

Ranching closes all options for land uses involving forest cover, as well as making it difficult to change to alternative uses without a period of fallow in woody second growth. Changes are difficult due to aggressive competition of pasture grasses and weeds in fields of other crops, aside from soil compaction and other problems associated with pasture. The colonization of pasture grasses in nearby crop areas has been an occasional problem in and among colonist lots on the Transamazon Highway. Aerial sowing of pasture grasses in annual crop plantings of Amerindians and squatters as a means of expelling them from areas claimed by ranchers is testimony to the strong competition offered by these grasses as weeds in annual crop fields. Effects on watersheds and hydrological cycles and on siltation are expected to be severe under pasture, as has occured in some tropical countries (Wadsworth, 1978).

Macro-ecological effects are a major concern with pasture development, especially due to the large expenses required by this land use. Climatological effects are expected to be most pronounced under pasture since the land is maintained free of tree cover.

14) Pasture without Fertilizer

Sustainability of pasture without fertilizer is limited to a few years. Soil phosphorus depletion, soil compaction, and weed invasion soon result in declining productivity and replacement of pasture grasses by second growth (Fearnside, 1979a, 1980b). Competitiveness with other land uses, aside from the influence of government subsidies and land tenure establishment, is poor due to low yields. The poor record of pasture in meeting social goals, in permiting other land uses in adjacent areas, in retention of options, and in effects on other resources and macro-ecological effects are all equivalent in the cases of pasture with or without fertilizers. Pasture, with the poorest prospects of any option on many counts, is nevertheless rapidly occupying most cleared areas of the Brazilian Amazon.

Conclusions

1) Development objectives in the Brazilian Amazon need to be carefully thought through, with the reference to the long-term benefit of the region's population. Appropriate objectives for agroecosystems to be promoted include agronomic sustainability, social sustainability, unsubsidized economic competitiveness, maximum self-sufficiency, fulfillment of social goals, consistency with maintenance of areas for other uses, retention of development options, minimal effects on other resources, and minimal macro-ecological effects.

2) No single development type should be recommended for Amazonia, but rather a patchwork of

different types, including diverse agro-ecosystems and reserves of natural eco-systems. A variety of economic decision-making procedures must be adopted to fit the biological constraints of options selected on the basis of these multiple criteria.

3) All development alternatives have drawbacks. No development strategy provides a panacaea, be it a single development type or a combination of types.

4) Development alternatives can be divided into extensive and intensive uses, and into uses which maintain rainforest canopy cover and those which do not. Intensive use of cleared areas, preferably areas where forest cover has already been lost, has a number of advantages over extensive uses. Perennial crops providing arborescent cover (not all do) have better prospects than annuals. Markets and soils, among other limitations, greatly restrict the areas to which this form of management can be applied. Forest management schemes based on natural regeneration have the best prospects for producing sustainable economic returns in the vast areas of the region not suited to intensive farming. Pasture has the worst long-term prospects of all.

5) Social forces pressing in the direction of unwise land uses must be minimized by careful placement of areas zoned for different uses to reduce invasion risk for reserves or areas in non-intensive uses. Plans should be designed to require a minimum of enforcement, but necessary steps must be taken to assure compliance with needed regulations for protection of reserves and realization of long-cycle management schemes.

6) Long-term wellbeing in the region requires that interdependent problems be solved simultaneously with the adoption of appropriate land uses: social changes needed to reduce inequalities in income distribution and land tenure, and to maintain population levels below carrying capacity, must be brought about.

NOTES

1) Paper for presentation at "Seminário Expansão da Fronteira Agropecuária e Meio-Ambiente na América Latina," Associação Nacional de Centros de Pós-Graduação em Economia — ANPEC, Universidade de Brasília, Brasília, 17-20 de novembro de 1981.

2) See Fearnside (nd) for a more complete discussion of the above development objectives, including potential conflicts among goals.

3) Comparisons of various options have been made on the grounds of "profitability" and/or "environmental diruption" by Arkcoll (1979), Goodland (1980a,h), Rankin (1979a), and Dubois (1979a). I agree with most of the rankings made by these authors for the criteria used in their schemes.

4) Difficulty in stirring interest in clearfelling at Tucuruí has been complicated by the short time remaining until the reservoir is flooded, a problem made more intimidating by the combination of long standing restrictions prohibiting export of wood as logs and the lack of sawmill capacity in the area. Until a series of attempts to locate a suitable firm had failed, a restriction of eligible candidates to Brazilian firms also narrowed the field of potential takers to the point where the profitability of logging by clearcutting may not have been the critical factor. Two promotional campaigns open to both foreign and Brazilian firms were undertaken before a contract was awarded. No foreign firms presented themselves, and the contract was awarded to a Brazilian firm apparently previously judged not to "fill the basic requisites" for the task *(Jornal do Brasil)* (Rio de Janeiro), 10 de julho de 1980, 1º cad., p. 20). Nevertheless, the weak response of lumbering firms to logging opportunities at Tucuruí may, in part, be a reflection of current insufficient profit levels from clearcutting.

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