Embora se exporte alguma madeira da Amazônia, destrói-se mais em sua extração, e, como resultado, tal madeira é um recurso que vai decrescendo. Este artigo assevera ser irracional a atual exploração da Amazônia e que a utilização das árvores constantemente produzidas seria a medida racional.

Though some timber is exported from Amazonia, more is destroyed in its extraction, and as result such timber is a dwindling resource. This paper asserts that current exploitation of Amazonia is irrational and that the rational course shoud be the utilization of the sustained-yield of trees.

Ecological development for Amazonia

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Section 1. INTRODUCTION

"If you plan for one year, plant rice.
If you plan for ten, plant trees.
If you plan for one hundred years, educate mankind."

Forestry Before Cattle

Brazil possesses as much tropical forest land (517.9 million ha.) as the World's next six largest tropically forested areas combined: Indonesia, Zaire, Sudan, Peru, India and Colombia, according to the 1973 FAO Production Yearbook (vol. 27:13). But if this is so, why then do Brazil's timber and sawn wood imports significantly exceed exports, and why must Brazil import 300,000 tons of pulp and paper every year? Part of the answer lies in the use to which the world's greatest forest is being put: primarily as pastures for export beef, and secondarily for the production of ephemeral crops such as rice, manihot and maize. Though some timber is exported from Amazonia, more is destroyed in its extraction, and as a result such timber is a dwindling resource. This paper asserts that current exploitation of Amazonia is irrational and that the rational course should be the utilization of the sustained yield of trees.

Sustained-yield has not been achieved in Amazonia and until it is approached, it is strongly preferable to exploit the environmentally more robust cerrado of Central Brazil. The case that sustained-yield has not been achieved and the case emphasizing cerrado development instead has recently been detailed elsewhere (SUDECO, 1975 a, b, c; Goodland and Irwin, 1975a, b, 1976, 1977). Deflecting development to the cerrado to maintain the options open and to "buy time" in which to learn sustained-yield for Amazonia, is, in our opinion, the most sensible course at present. Realistically, however, such a course is unlikely to arrest Amazonian development. This paper offers an approach to the rational use of Amazonia which though not sustained-yield, is greatly preferable to present practices.

Settlement in Amazonia

Amazonia's capacity to support the large numbers of people advocated by INCRA is highly questionable. We do not recommend Amazonia as a place for the settlement of people — there are ample and more amenable underpopulated regions elsewhere in Brazil. Since Amazonia now has been opened up by the construction of some 14,000 km of highway, the choice is between planned settlement and unplanned settlement. Once an area becomes accessible then the unplanned settlement occurring spontaneously cannot be prevented even by the Federal and State Governmental institutions involved.

Amazonia's rich natural resources will be utilized and the area will need people in settlements to undertake the utilization. This paper treats those settlements deemed necessary by the Government for the occupation and utilization of Amazonia. In poignant contrast to the sad settlements of today, we propose a more rational type of settlement which we believe can engender self-reliance while utilizing the Amazonian ecosystem without destroying it. Sustained-yield is the goal and our proposals approach it more than present practices. Small-scale, low-technology forestry settlements (Figure 1) are more appropriate for Amazonia than the existing emphasis on large-scale, imported-technology agro-industrial or peasant agricultural colonization.

Figure 1. Suggested settlement models for Amazonia

1. Agriculture on the rare pockets of more fertile soils.
2. Riparian agro-ecosystems, aquaculture including matupá.
3. Várzea cultivation — anually flooded and replenished.
4. Tree plantations on second growth and degraded sites.
5. Sustained-yield forestry including energy farming.

Section 2. THE CASE FOR TREES

"If you would be happy for a week, take a wife.
If you would be happy for a month, kill the calf.
If you would be happy all your life, plant a garden."

Options for forest utilization

The prime environmental issue of Amazonian exploitation is the balance between export cattlepastures and annuals on the one hand, and a sustained-yield tree-based agro-ecosystem on the other.

According to IBDF, an enormous 6,600,000 hectares of Amazonian forest already have been bulldozed, cut or burned in the formation of cattle pastures, and scarcely a single tree was sold from the vast 14,000 km x 70 m area bulldozed for the Transamazonian highway network (cf Moraes Victor, 1975). It is now realized that most of the nutrients in the tropical wet forest ecosystem are contained in the biomass of the vegetation itself, rather than in the substrate — the soils — as is the case in temperate ecosystems. EMBRAPA, INPA, SEMA, INCRA, SUDECO, and IBDF all urge the adoption of a rational *tropical* agro-ecosystem, rather than the importation of unsuitable *temperate* agricultural methods. Any sustained-yield system in Amazonia will, therefore, contain a large component of trees, regardless of whether they are to be used for forest industry, silviculture (including firewood) or plantations.

Brazil's campaign to reduce the current 80% dependence on imports of foreign petroleum will be assisted to the extent that the forest is recognized and utilized as a self-perpetuating source of energy. More than 59% of Brazil's total energy already is supllied by fuel-wood (Earl, 1975). Tropical wet forest is characterized by a superabundance of water and sunlight — essential ingredients severely restricted in many parts of the world. Products derived in the presence of sunlight, largely from water and air — such as carbohydrate, lignin and cellulose — are oligotrophic; they contain few mineral nutrients, so that their removal from the nutrient cycle is readily balanced. Exported eutrophic products which are rich in inorganic nutrients, such as cattle and annual grains, deplete the already low stock of mineral soil nutrients. This distinction between eutrophic and oligotrophic products is especially important because practically all tne soils and the region itself are so deficient in deposits of limestone, phosphate, potassium and other sources of plant nutrients.

Forest and tree plantations protect the soil and reduce erosion but only to the extent that the forest remains closed. Plantations producing a crop without the removal of the trees are thus environmentally preferable to timber or pulp operations. Brazilnut exports, for example, earned $ 13.5 million in 1972 and from forest sources, not plantations.

Even so, most timber is oligotrophic, and if bark, leaves and branches are allowed to remain in the forest, the net nutrient loss thorough export will be slight. It is for these reasons that the most rational development model in Amazonia will stress forestry: tree plantations, silviculture and forest industries. A convincing case can be made for the abandonment of management or exploitation of wet forest, concentrating on tree plantations (Wyatt-Smith, 1968) until such time as the ecosystem is better understood.

The environmental preference for tree plantations is balanced by the assertion that they are not labor intensive, but this need not be the case in Amazonia. Mechanization can be dis couraged there by not supplying advanced tecnological machinery to the colonists, so that labor input will be high. Furthermore, success will be achieved to the extent that the human resources of Amazonia can be added to the product. The labor of the colonist becomes a renewable resource when worked products and commodities are created, rather than by the export of crude unprocessed raw materials. For example, the production of planks and veneer employs more labor than does the export of unprocessed logs. In future trade including exports cabinets and furniture can replace planks; tires can replace rubber; cooking oil, soap and candles can replace crude palm oil.

Figure 2. An environmentally ranked list of possible methods of utililization of the wet tropical forest ecosystem

Examples of sustained-yield at the top of the list are environmentally prefer'ed over non-renewable examples at the bottom.

1. Intact forest	Scientific Repository, Amerindian Reservation, National Park, Environmental Services (including retention of cyclic soil fertility), Tourism, Recreation, Game Harvest, Collecting, Gathering, Tapping.
2. Utilization of natural forest	Shelterwood Forestry, Selective Felling, Refining, Liberation, Clearcutting, Underplanting, Regeneration.
3. Tree plantations	Mixed-species Products, Monoculture Products (e.g. rubber), Mixed-Timber plus product, Mixed-species Timber, Monoculture Timber.
4. Agri-silviculture	Intercropping (e.g. rubber with annuals), Taungya (annual crops planted at the same time as tree seedlings), Treed Pasture (products, browse, graze), Subsistence Gardens (trees, perennials, annuals).
5. Agriculture	Subsistence Annuals (e.g. manihot, rice, beans), Cash-crop Annuals (tobacco, sugar export), Pasture crop Rotations, Grass Pasture (cattle export).

The entire span of options for the utilization of tropical wet forest, as summarized in Figure 2, is ranked in order of environmental priorities. Environmentally preferred uses include Indigenous Reservations, Scientific Repository, and National Parks, and these are followed by the utilization of the natural forest itself for selective logging, for example. Mixed-species tree plantations (e.g. rubber, cacau, oil palm, rosewood, Brazilnut) are the next environmental preference, followed by agri-silviculture — a combination of tree crops with other crops. On this purely environmental basis, annual crops (maize, rice, beans) and cattle pasture are the least preferred. Sustained-yield can be achieved by using the first two categories and, with suitable precautions, the third. Models based on the fifth category are not sustainable in high rainfall areas of Amazonia, and will necessitate moving to fresh areas of forest every few years.

The crux of evaluating the strategy to be adopted is to reconcile environmental preferences with the human objectives, thus working out a pragmatic compromise. The reasons for the preferred categories are related to the nature of the ecosystem.

The disadvantage of trees is that they take a long time before they can be cut or cropped — from three years for *Leucaena*, to ten years for *Gmelina*, to fifteen years or more for other species. Products such as fruits may be borne much sooner, however. Furthermore, the death of a tree represents a greater proportional loss than the death of individual plants in a more ephemeral crop. The provision of two-year-old saplings or cuttings of a wide variety of appropriate species (Figure 3) will go far towards alleviating this problem, and the collaboration of groups of colonists into condominiums or cooperatives, as encouraged by INCRA, would be most valuable from this point of view. Lumber operations, also, are usually on a larger scale than can be maintained on individual farms. The lumbering operation as a cooperative or village-size effort would be more in keeping with

Figure 3. Tree candidates for forest settlements
(After Dubois, 1971; National Academy of Sciences, 1975; Douglas and Hart, 1976)

Some valuable Amazonian trees not in plantation

Aniba rosaeodora	Lauraceae	Pau-rosa
Astronium lecointei	Anacardiaceae	Muiracatiara
Bagassa guianensis	Moraceae	Tatjuba
Bertholettia excelsa	Lecythidaceae	Castanheira do Pará
Bowdichia nitida	Leg. Papilionoideae	Sucupira
Carapa guianensis	Meliaceae	Andiroba
Caryocar villosum	Caryocaraceae	Piquiá
Cedrela odorata	Meliaceae	Cedro
Cordia goeldiana	Boraginaceae	Freijó
Couma macrocarpa	Apocynaceae	Sorva Grande
Didymopanax morototoni	Araliaceae	Morototo
Dipteryx odorata	Leg. Papilionoideae	Cumaru
Goupia glabra	Celastraceae	Cupiúba
Hevea brasiliensis	Euphorbiaceae	Seringueira
Lecythis paraensis	Lecythidaceae	Sapucaia
Lecythis usitata	Lecythidaceae	Sapucaia
Manilkara huberi	Sapotaceae	Maçaranduba
Platonia insignis	Guttferae	Bacuri
Platymiscium trinitatis	Leg. Papilionoideae	Macaúba
Simaruba amara	Simarubaceae	Marupa
Swietenia macrophylla	Meliaceae	Mogno
Tachigalia myrmecophila	Leg. Caesalpiniodeae	Tachi preto
Virola surinamensis	Myristicaceae	Ucuuba
Vochysia maxima	Vochysiaceae	Quaruba

Reclamation-site plantation exotics

International name	*Family*	*Vernacular*
Acanthocephalus cadamba	Compositae	
Agathis alba	Araucariaceae	
Chlorophora excelsa	Moraceae	
Cordia alliodora	Boraginaceae	
Eucalyptus deglupta	Myrtaceae	Eucalyptus
Eucalyptus citriodora	Myrtaceae	Eucalyptus
Eucalyptus saligna	Myrtaceae	Eucalyptus
Gmelina arborea	Verbenaceae	
Nauclea diderrichi	Rubiaceae	
Octomeles sumatrana	Tetramelaceae	
Pinus caribaea	Pinaceae	
Pinus oocarpa	Pinaceae	
Tectona grandis	Verbenaceae	Teak
Terminalia superba	Combretaceae	

Palm plantation candidates for oil, fruit or hearts of palm

International name	*Vernacular*
Altalia speciosa	Babaçu
Astrocaryum	
Attalea funifera	Piassava
Caryota spp.	
Cocos nucifera	Coco da Bahia

Figure 3 (cont.)

Elaeis guineensis	Dendê
Euterpe edulis	Assaí
Euterpe oleraceae	Assaí
Bactris gasipaes	Pupunha
Iriartea exorrhiza	
Jessenia polycarpa	
Mauritia flexuosa	Buriti
Maximiliana	Inajá
Orbignya cohune	Cohune
Orbignya martiana	Babaçu

sustained-yield than would a private or purely commercial and entirely export-oriented enterprise which needs immediate returns for its capital investment. Village lumber cooperatives would sell the best timber for cash while at the same time providing housing materials and fuel wood from the less-marketable timber. This cooperative would only function, of course, when there is enough lumber to harvest, so its existence will probably be intermittent. Meanwhile, the same group could manage the village energy plant, sawmill, tree nursery, varzea plots, palm oil extraction and so on.

Lumbering in conjunction with reforestation will be the major activity of most forestry developments, although all developments will vary depending on the capability of the land. Land classification, forest inventory, and soil survey must always precede colonization. The results of these processes will determine the emphasis of the colony. Extensive second growth, scrub or "capoeira" will be designated for tree plantations which will ease pressure to convert primary forest. In such areas, and also in the rehabilitation of degraded land, tree plantations will be appropriate, possibly even including exotics — *Eucalyptus, Pinus, Gmelina* — if local species will no thrive. Similarly, colonies near mangrove forest will emphasize the production of tannins. We must beware of imposing uniform models on a most diverse and heterogeneous ecosystem. Each development will be different depending on the environment, as the adage has it: "If we all pulled in the same direction, the whole world would topple over!"

Successful long-term projects must learn to use *all* native tree species, not just the few at present 'hi-graded' or 'creamed' from the forest. Since this practice leaves the least valuable species to reproduce, such forests rapidly decline in quality. Silvicultural and harvesting practices, refining, transportation, rotation, nursery management, and the optimal size of plot per colony require much clarification (Dubois, 1971; Bene *et al.*, 1976). Careful trials, assiduous research and the interpretation of pilot projects will indicate the optimum resource allocation in each case. Boards will probably be a major product but veners (especially if ucuuba, *Virola surinamensis*, plantations thrive) can be lucrative. Plywood and compressed fiberboard also should be manufactured in some of the development sites. We feel Brazil can readily become self-sufficient in pulp, paper and boards, and even export valuable worked wood products, but that this can be arranged in Southern Brazil with less environmental damage than in Amazonia. Emphasis on pulp and paper industries is highly appropriate for large areas of Southern and Central Brazil and will reduce the pressure on Amazonian forests. Should, however, pulp industries be established in Amazonia, small-scale thermal-mechanical pulp factories powered by wood-fuelled steam are preferable to large-scale chemical pulp manufacture.

Rubber occurs naturally in much of Amaznia. In view of the fact that Brazil imported 42,000 tons of rubber in 1975 (at a cost of about US$ 23.8 million in foreign exchange) and in addition manufactured a further 150,000 tons of the synthetic product, rubber should be emphasized in Amazonian models. SUDHEVEA should be invited to assess the potential for rubber and should supervise the use of disease-tolerant strains. The 1976 National Rubber Plan calculates that Brazil will need 1/5 million hectares of rubber to achieve self-sufficiency within ten years. Rubber and other latices are promising sources of hydrocarbons, valuable products harvestable without killing the tree. *Ocotea pretiosa* sap, for example, is flammable as taken from the tree (Prance, 1977 pers. comm.).

Cacau occurs widely in Amazonia and CEPLAC is assessing that potential. Experience gained from CEPLAC's 796,000 ha. Burareiro project in Rondônia (Leão and Carvalho, 1975) should be used in planing similar projects elsewhere. From an environmental point of view, cacau is a preferred crop but only to the extent that it is consumed within Brazil. The vagaries of foreign markets over which Brazil exercises no control militates against overreliance on this non-essential agricultural luxury especially as it be cannot stored. Similarly Cupuaçu (*Theobroma grandiflorum*) may be a profitable luxury export in the short term.

The Guarana vine (*Paullinia cupana*) thrives in Amazonia, and a recent law mandates the use of 20% natural product in drinks bearing the name. This should boost the demand, since most 'Guarana' sold in Brazil has been entirely artificial. Oil palm (Dende) and other palms should also be thoroughly evaluated. The oil which can be extracted on a household scale, should be preferred in the first phases, over industrialization. IBC is assessing Robusta coffee, the suitability of which is in doubt, since the climate favors cultivation with central and south nearer the consuming centers in Brazil. Brazil nut and edible Hearts-of-Palm trees thrive widely throughout Amazonia and command high prices, so that plantations of those two crops could become highly lucrative especially since palms thrive naturally in monoculture. Since palm heart harvest kills the tree and is not a staple, its cultivation must be critically evaluated against palm fruit production Rosewood (*Aniba rosaeodora*) and other sources or valuable essential oils, cloves (cravo-da-india), Capuacu, coconut, pupunha and other similar products should all be evaluated for their commercial potential.

The tree crops which will be selected will depend upon the site. Diversity should be maximized both in varieties of crop species, number of species (polyculture) and in age of establishment (temporal diversity). The more heterogeneous the model finally adopted, the more resilient it will be with regard to soil fertility, climatic extremes, pest and disease damage, storage costs and fluctuations in demand. The remoteness of much of Amazonia precludes the routine use of fertilizers, so the crop should be adapted to the environment rather than the more widely practiced converse, where the environment is modified (by such practices as irrigation, fertilizers, pesticides and mechanization) in order to suit the crop.

Subsistence agriculture and protein supply

Sustained-yield, tree-based strategies demand a longer period to mature than do current practices, but development pioneers must be fed until harvest of these longer-term components. It may be that initially some food should be imported from elsewhere in Brazil to supply Amazonian colonists. Certainly, the destruction of forest to produce only three or four years of crops of rice and manihot — the current practice — is proving to be an expensive mistake.

Judicious planning can ensure adequate supplies of food and protein for the proposed developments if 'várzeas' are used for subsistence crops, and if fish are the main source of animal protein. Production of annuals on a sustained-yield basis is appropriate for riparian flood plains. Such várzea strips alongside rivers receive annual deposits of fertile alluvium during the wet season floods, which confer the added benefit of reducing weed and pest pressures. Appropriate várzeas, therefore, should be identified *before* colonization, and these should be designated for the production of food for local consumption (Figure 4).

Since this proposal recommends that the prime protein source now raised in Amazonia — cattle — cannot be sustained, alternate sources of protein should be provided. The most sustainable and reliable source of protein, and one that is exploitable with no environmental damage, is fish, which already is abundant throughout Amazonia (Lowe McConnell, 1975). Fish depend on planktonic and algal growth in the water, and on fruits, seeds and organic materials flushed into the water from the adjacent forest. Since nutrients are leached from upstream and from the adjacent várzea forest during the flood season, forest and flood plains must be maintained if fish are to be used as a reliable harvest. Similarly, large and abundant floating mats of vegetation — matupá — contain highly productive C4 grasses and can be used to feed draft animals or herbivorous fish.

Each smallholding and village should have a fish pond, particularly where access to a river is difficult. Such ponds are far more productive than are crops which could be raised on similar terrestrial areas. A closed cycle and enormously productive ecosystem can be established in which herbivorous fish eat grass and other lake-edge vegetation, as well as some crop residues. The pond is fertilized by sterilized leachate from treated human and pig manure, and by ducks and geese. Such aquatic life is a small but

Figure 4. Várzea crop candidates

International name	*Family*	*Portuguese*	*English*
Arachis hypogaea	Leg. Papilionoideae	Amendoim	Peanuts
Boehmeria nivea	Urticaceae		Ramie
Cicer arietinum	Leg. Papilionoideae	Grao-de-bico	Chick peas
Corchorus capsularis	Tiliaceae	Juta	Jute
Glycine max, spp.	Leg. Papilionoideae	Soja	Soya
Manihot esculenta	Euphorbiceae	Mandioca	Manihot
Nicotiana tabacum	Solanaceae	Tabaco	Tobacco
Oryza sativa	Gramineae	Arroz	Rice
Phaseolus spp.	Leg. Papilionoideae	Feijao	Beans
Psophocarpus tetragonobolus	Leg. Papilionoideae		Winged bean
Sesamum indicum	Pedaliaceae	Gergelim	Sesame
Urena spp.	Malvaceae		Urena
Vigna unguiculata	Leg. Papilionoideae		Cow pea
Zea mais	Gramineae	Mais	Maize

reliable source of protein, and can be augmented by a sty of pigs using wastes from the family milch cow. A few chickens and local fauna such as Agouti, Paca and Cavy also can be raised. Breeding preferred game species, especially Tartaruga (*Podocnemis expansa*), Veado (*Mazama* sp.), Anta (*Tapirus terrestris*), and Porco-do-Mato (*Tayassu sp.)*, for example, could be developed into a source of income if sustained-yield is achieved (Wetterberg *et al.*, 1976).

Section 3. ENERGY FLOW AND ECOSYSTEM CYCLING: APPROPRIATE TECHNOLOGY

"*Mechanization is good when hands are too few for the work intended to be accomplished. It is an evil when there are more hands than required for the work Dead machinery must not be pitted against the millions of living machines represented by the villagers. Machinery to be well-used has to help and ease human effort*"

Mahatma Gandhi, 1934

The enormous compass of Amazonia — more than five million square kilometers — and its infertile soils, combined with the inability of most settlers to invest large amounts of capital on mechanization and fertilizers, dramatically emphasize how essential is the need for 'appropriate technology'. The necessity of using the forest as a sustainable source of both energy and commodities is the primary and the most important issue. Secondary issues of appropriate technology are the employment, wherever possible, of local, solar-generated energy, the use of vernacular materials (wooden houses, for example rather than imported metal sheeting) and the reduction of nutrient leakage from the ecosystem to the point at which it is balanced by natural imports such as those brought by rivers, weathering, dust and rain.

Energy farming

World annual production of terrestrial biomass is estimated at 100 billion tons (dry weight), an energy equivalent six times greater than the world's current total energy consumption. The Amazonian forest is the world's greatest terrestrial solar energy collector. However, the diffuse nature of biomass plus increasing transport costs mandates many small conversion plants, thereby reducing transport costs and facilitating the return of nutrients to the land. Woodfuelled steam power, biological fermentation to alcohol, destructive distillation to charcoal and alcohol, hydrolysis to sugars and in the future, pyrolysis and hydrogenation of wood into liquid fuels, are all means by which the forest can be converted into energy. Amazonia, using sustained-yield methods, could become a major exporter of energy on a global scale. Would a billion dollars be better invested importing one modest nuclear power plant with all its appalling problems, or would it be wiser to invest that same amount of money to establish one thousand integrated forestry projects of one million dollars each? Since land capability surveys will reveal that Amazonia is most heterogeneous, the models will be flexible in size and design, and as diverse as the environment in which they are to fit. The billion dollars of the simile therefore may more appropriately be apportioned for example into 100 one million dollar projects and 500 projects each of a $500,000 and $100,000 size. Investment in 1000 steamships and 1000 steam engines of $50,000 each supporting the above 1100 projects would still leave half a billion dollars for research!

Local energy requirements can be met by the use of wood in direct combustion, or for the generation of steam and for the production of charcoal for example. Oligotrophic, wood-based derivative fuels can be exported. Circumstances in which wood is plentiful and fossil fuels are rare indicate wood-fuelled energy systems: steam power is one of the most useful. Wood-fuelled steam power plants are widely known throughout Amazonia (e.g. Smith, 1971). The techonology is simple, entirely obtainable in Brazil, low in capital costs and even lower in maintenance. The three main examples of such power plants are locomotives, saw mills and steamships.

Three wood-fuelled steam railroads in Amazonia (Figure 5) all served for many years and only recently were abandoned in each case and replaced by petroleum-fuelled road transport. The Madeira railroad, built under the Treaty of Petrópolis (1903), provided Bolivia with an Atlantic access. Ironically, the wooden sleepers for this line were imported from Australia by the U.S. construction company which spurned the more readily accessibly Amazonian timbers. The Belém-Bragança route serviced the first large agricultural region in Amazonia that was carved out of the forest. The soils were mined and today lie depleted and unproductive. The Tocantins railroad was built so that river cargoes could be transported around the great Itaboca rapids and transshipped. The railroad performed well until about 1974, when a spur of the Transamazonian highway duplicated the route. Today even this recently-completed highway is to be relocated because the Tucuruí reservoir will harness the same rapids. A fourth, the modern Amapá railroad started in 1957, annually carries more than 1.5. million tons of manganese ore 194 km from Serra do Navio to the coast. Although diesel powered, this railroad is much more rational than a highway.

Figure 5. Wood-fuelled steam railroads in Amazonia

Railroad	*Year abandoned*	*Length (km)*	*Route*
Madeira-Mamoré	1971	366	Porto Velho-Guajará Mirim
Belém-Bragança	1965	265	Belém-Castanhal- Capanema-Bragança
Tocantins	1974	118	Tucuruí-Jatobal

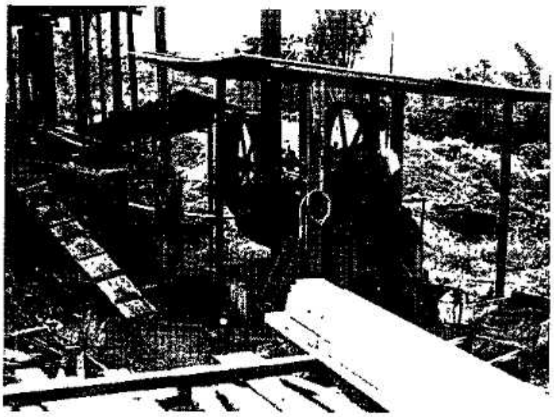
The far-sighted Plano de Viação Nacional (decreto 24.497 of 29 June 1934) proposed three Amazonian railroads:

1. Pirapora — Formosa — Carolina — Belém: almost precisely the route of the present Belém — Brasília highway.
2. Cuiabá — Santarém, paralleling the modern BR 163.
3. Cuiabá — Abunã — Rio Branco — Cruzeiro do Sul: the route of today's BR 364.

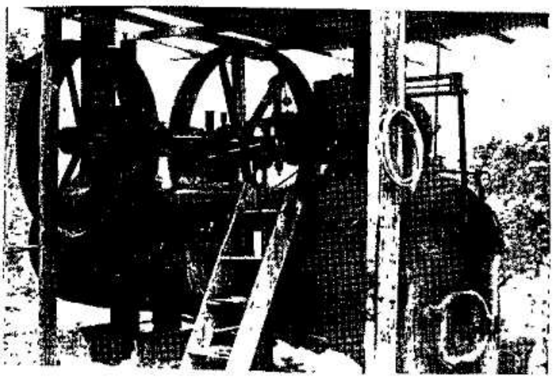
These three routes all would have been wood-fuelled eventually from trackside plantations. Ironically, such a system would have been self-sustaining in fuel and inflation-proof in addition to requiring low maintenance. Hence the three proposed railroads would have been more appropriate than the Transamazonian Highway network is at present.

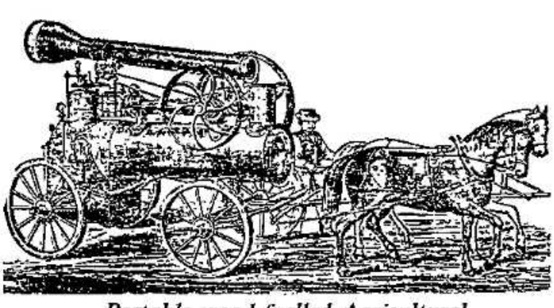
Reliable low-technology steam sawmills are highly appropriate for Amazonia, and their numbers, although small, may actually be increasing as the Araucaria forests of southern Brazil finally vanish. Such sawmills use sawdust rather than wood for fuel and are the only energy systems, except for the fast-breeder nuclear reactor, to produce more fuel than they actually consume! The venerable sawmill shown in Figure 6 worked for about 100 years in Santa Catarina until transported to its present location at Ituporanga, Pará, in 1975. This machine saws round logs into planks, beams, posts, etc. and relies on no imported energy. For a modest initial outlay, a small electrical lighting take-off could illuminate the entire village with no extra fuel necessary. A mechanical take-off is available for planing or turning lumber, for

Figure 6. Steam engines



Centenarian English Steam Sawmill Phoenix, from Santa Catarina, Reborn in Ituporanga, Pará in 1975.





Portable wood-fuelled Agricultural Steam Engine.

mixing clay and for other uses. The last illustration in Figure 6 shows a portable steam engine suitable for agricultural processing, sawing lumber, etc.

It is our considered opinion that integrated systems of woodfuelled steam power and reforestation represent one of the most promising activities for all of Amazonia and one which should form the nucleus of all future settlements. The steam engine should be the first major item do be installed when any Amazonian colonization project is being established. Raw materials for the construction of settlers' dwellings will thus readily become available, rather than being imported from Japan, as is presently the case. Fine timbers and veneer woods can be exported from the colony to raise capital.

Distillation of wood: charcoal and alcohol

Wood heated to 400-500°C in a closed kiln without access to air decomposes into combustible gases and a condensable distillate, containing about two-thirds acetic acid and one-third methanol. The residual yield — charcoal (20%-30% of the dry weight of the wood used or 50% of the original volume) has a calorific value greater than coal. Charcoal is an excellent smokeless fuel for crop processing and domestic uses, producing twice the heat content of a similar weight of wood.

Techniques for producing charcoal range from simply covering burning wood with turf and soil to the use of sophisticated automatic retorts. Uncomplicated portable steel kilns are an appropriate low technology investment (Earl, 1975). Distillation in retorts produces acetic acid, creosote, pitch and methanol (wood alcohol). Methanol is a valuable commodity when used as a raw material for many industrial processes, either as a solvent or as a fuel. Up to 10% methanol may be added to gasoline without any modification to the automobile. Gasoline engines with modest modification will function efficiently on 100% methanol. Methanol can be produced on a small scale and is transported readily. Since quality and concentration are either immaterial or can easily be rectified by the consumer, it is a promising product for Amazonia. The products of wood distillation with approximate yields are tabulated in Figure 7.

Gasification

Wood, charcoal and agricultural wastes (husks, shells, cobs, seeds, stalks, etc.) may be gasified into producer gas and water gas. Producer gas, largely carbon monoxide and nitrogen, is evolved by burning any form of carbon in a supply of air insufficient to oxidize the carbon completely to carbon dioxide:

$$2C + O_2 = 2CO(+2 \times 26.8\ \text{kcal})$$

Water gas, a mixture of carbon monoxide and

Figure 7. Average products from tropical woods
(after Earl, 1975).

Product	*Yield (per 100 kg dry wood)*	*Uses*
Charcoal	300 kg	Crop processing; domestic; lime and cement kilns; steel industry; pollution control
Gas (1)	140 m^3	Largely recycled to energize the reaction
Methanol	14 lt	Fuel; solvent; raw material
Acetic acid	53 lt	Basis of acetone; textile industry; pickling
Esters (2)	8 lt	Chemical industry
Acetone	3 lt	Industrial solvent
Wood oil and light tar	76 lt	Raw materials
Creosote oil	12 lt	Timber preservation
Pitch	30 kg	Waterproofing; road surfacing; boat caulking

(1) Calorific value approximately 2500 kcal/m^3.
(2) Mainly methyl acetate and ethyl formate.

hydrogen, is liberated from incandescent charcoal by steam:

$$C + H_2O = CO + H_2 \ (-28.0 \text{ kcal})$$

These two fuel gases can be mixed, because it is more economical to alternate the exothermic and endothermic reactions — colloquially known as 'blow and run' (Earl, 1975). These two processes require somewhat greater capital investment and technology than kilning and retorting, so that gasification will only be appropriate where fuel gases are required, as for example at the Itaituba limestone deposit. Producer units, eminently suitable for heavy transport such as trucks and buses, are discussed in the transportation section.

Although ethanol is not generally produced from trees, its manufacture may be appropriate for special circumstances in Amazonia. Ethanol already is widely manufactured on both a large and small scale in Brazil from sugarcane, manihot, sweet potato, etc. Though cane requires better soil and more careful treatment, it produces over 100 tons/ha. Manihot thrives on poor soils and demands little attention but it produces only 16 tons/ha. Each ton of raw material can be distilled into 100-150 liters of alcohol. The technology is well known and widespread elsewhere in Brazil where it is more appropriate; it is relatively inexpensive; the process is self-sustaining; and the product is relatively valuable. Ten experimental ethanol-fuelled vehicles have been running in Brazil for over a year. The different advantages and markets should be considered when choosing between retorting, kilning, fermentation-distillation and gasification.

Wood ash: fertilizer and soap

Ash, the remains of the sawdust or wood fuel, is a valuable by-product of the energy system and one which is especially important to retain in the Amazonian ecosystem, recycled in tree nurseries or in horticultural enterprises.

The 1-4% ash content of wood is rich in the mineral nutrients of plants, particularly potassium and calcium, which are so often in short supply in Amazonia. Wood ash is easily converted into fertilizer on tis own and is even better when mixed with organic materials as available such as crop or domestic residues including sewage, more sawdust or with soil. Such materials may be decomposed where feasible into a nutrient-rich mulch and possibly biogas on a farm or village scale (Penagos-G., 1967; Makhijani, 1975). In this way, infertile soils and the unavailability of fertilizers need not be restraints to development.

Ash is readily converted into soap by boiling and steaming with plant oils (e.g. coconut, *Cocos;* dendê, *Elaeis*; buriti, *Mauritia*; babaçu, *Orbygnia*) and animal fats. When the mixture has cooled, the soap is separated from the lye (glycerol) by the addition of salt. Petrobrás has discovered 150.000 Km^2 of rocksalt deposits between the Madeira and Tapajos Rivers, especially near Fordlândia, Oriximiná and Areiro, and a caustic soda industry may be feasible there using Itaituba limestone. Nitrogen, frequently a limiting factor to agriculture in Amazonia, is deficient in most soils and is lost to the atmosphere when vaporized by burning biomass. Emphasis on nitrogen-fixing legumes with which Brazil is so richly endowed, will mitigate the shortage of nitrogen. Firebreaks, shelterbelts, hedges, living fence-posts, trackside verges, nurseries, etc. all should contain a large proportion of leguminous nitrogen fixers. Brazil leads the world in the discovery of nitrogen-fixing grasses and recently common capoeira plants have been found to fix nitrogen, Pan Chumbo (*Trema micrantha*) for example (Kerr, 1976). Finally, plants tolerant to low nitrogen requirements can be bred. Emphasis in research and utilization of nitrogen-fixers — plants, algae, mycorrhiza — can ensure that the lack of nitrogen need not limit successful sustained-yield.

Steam transportation

Petroleum-fuelled road transport, as now promoted by the 14,000 km Transamazonian highway system, is less rational than wood-fuelled fluvial transport along the 80,000 km of navigable waterways. Steamboats are ideally suited to Amazonia since they are inexpensive to manufacture and maintain, and rely on wood or charcoal, a renewable indigenous fuel. Steamers of all sizes integrated with fuelwood plantations afford a sustainable, inflation-proof and economic mode of transportation for Amazonia.

Where no rivers run in the required directions and where draught animals are too slow or impractical to use, heavy transport — trucks, tractors and buses — may be powered by producer gas. Charcoal or wood-fuelled producer gas runs slightly-modified internal combustion (e.g. gasoline) engines. Since one ton of charcoal for producer gas is the equivalent of 720 liters of gasoline, such units will become increasingly competitive with petroleum.

The use of petroleum-based transport and tractors binds this system to dependence on imports of foreign fuels and spare parts. Buffalo, donkey, mule or bullock-carts should therefore be used wherever possible as soon as the animals' food supply is ensured in each colony — from marsh, pond and riparian vegetation at the outset to be augmented subsequently from ruderal sources (50 km of roads provide 100 km of ruderal fodder belts) and abandoned fields, if they are permitted in the model which is finally adopted. Firebreaks in forest plantations can be a valuable grazing — browsing resource in which 3-D agriculture may be appropriate. In the future, wood-fuelled traction engines or biogas-driven tractors may replace some bullock power.

The drying and preservation of annual crops as now raised demands a great deal of energy. Emphasis on perennial crops will decrease this demand. Less energy is required to dry cacau (apart from the sun), to extract dendê oil, and to treat raw rubber latex, and this engine could be provided from the combustion of wood.

Amazonia is so favorably endowed with water supplies that little, if any, irrigation is necessary. Most domestic water is available from nearby creeks or wells, In cases where such sources of water cannot be found, windmills should be used instead of the customary diesel pumps.

It is now becoming an accepted fact that as regards both economics and soil structure and fertility, agriculture on bulldozed jungle sites is inferior to that on less-mechanically cleared sites. Sustained-yield practices and appropriate small-scale technology should be encouraged from the very beginning. Only in this way can the tropical wet forest support colonization without destroying both the environment and the livelihood of the colonists themselves.

Section 4. PLANNING

"Ecology is the science which
warns people who won't listen
about ways they won't follow
of saving an environment they don't appreciate."

Research and assistance

It would be perilously naive to assume that farming is an occupation for which adequate skills and training are innate. Successful smallholding in tropical wet forest is at best difficult for an affluent tropical agronomist or a person with centuries of village tradition to follow, but it is far more so for the relocated slum-dweller, urbanite or drought victim. The agro-ecosystem ultimately selected will be successful only to the extent that it can be managed by the colonist. It is therefore imperative that four activities precede the arrival of the settlers: 1) research; 2) land capability, resource inventory, and soil survey; 3) demonstration areas and extension; and 4) sources of biological components of the agro-ecosystem (Figures 8 and 9).

Figure 8. One proposal towards a rational forest-based settlement

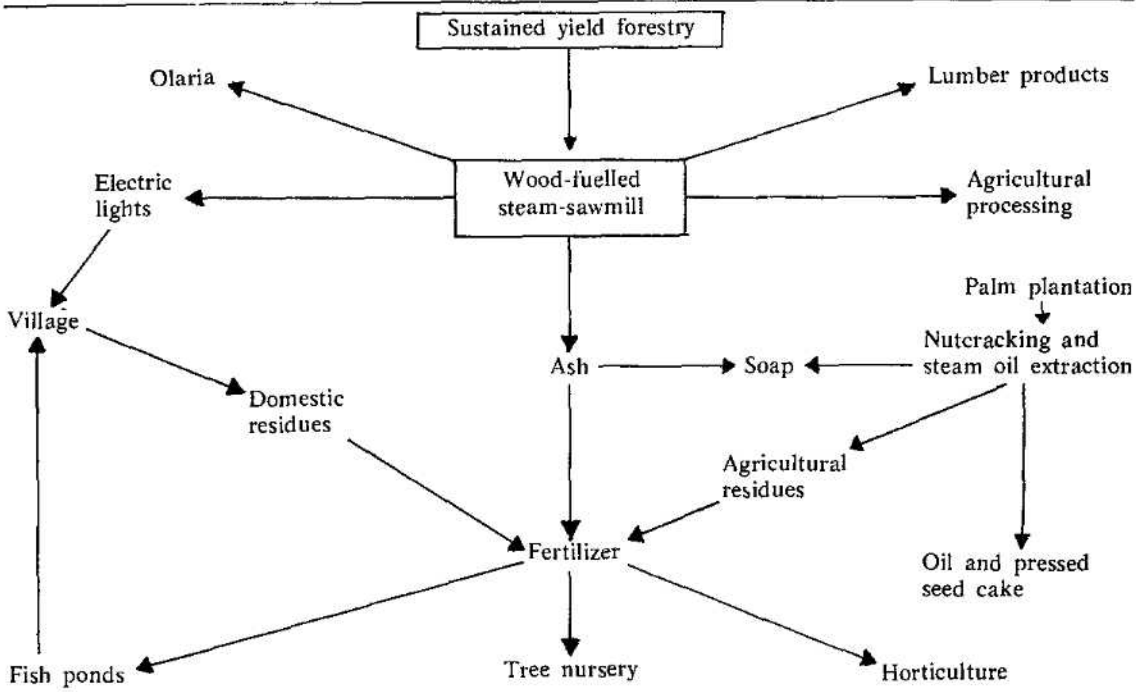


Figure 9. An Amazonian settlement process

1.0 Overall process
- 1.1 Land capability survey (e.g. proportion of varzea, mata de terra firme, etc.). Determination of carrying capacity and sustainable population density, RADAM analysis.
- 1.2 Forest inventory (e.g. proportion of valuable fine timbers).
- 1.3 Research, experimentation: sustained yield forestry, breeding.
- 1.4 Extension service, environmental education divulgation, training of colonists.
- 1.5 Overall zonation of Amazonia; mines, roads, indigenous reserves, conservation areas, parks, future reservoirs, major settlements.

2.0 Individual settlements
- 2.1 Advance party (year 1-3); riverside wood--fuelled steam-powered sawmill — creates trails, provides construction materials, some export.
- 2.2 Pioneers (year 2-5); varzea — clear plots, plant subsistence crops, fisheries — fluvial and in ponds, dwelling construction villabe nucleus near varzea and port tree planting of the 2-year old 'kits', demonstration plots established, environmental education.
- 2.3 Main settlement (year 4 on); reforestation an-d plantation, silviculture, lumbering, forest, industries.

The world's leading Amazonian research institute, INPA in Manaus, with several field stations, e.g. Aripuanã — Humboldt, could convene and supervise relevant organizations such as EMBRAPA, CNPq, IBDF, SEMA, SUDAM, EMBRATER, in order to prioritize research necessary to achieve the objectives of rational forest exploitation. This group should also direct and coordinate large and small-scale zonation, land capability assessments, forest inventories and soil surveys. From this information, an appropriate model or agro-ecosystem can be designed. The establishment of demonstration plots, fisheries, farm ponds and the associated appropriate technology is necessary before settlers arrive. Equally important as accessible and functioning pragmatic demonstrations and agricultural extension, is the provision of the biological components of the recommended agro-ecosystem. Most Amazonian projects try to modify the environment to suit the crop, e.g. by replacing the forest with cattle. The more rational course is the converse — choose or adapt the crop to the existing environment with as little modification as possible. The typical present-day response to declining yields is to 'try harder' — to alter still further the environment — an action more suicidal than sapient as recent experience has shown. The provision of acclimated seed and saplings tolerant of the climate, soils, pests and diseases, and species of crop adapted to the environment is therefore most important. INPA and the inheritors of IPEAN and IPEAAOC already have found new species of food plants and different varieties of conventional species with vastly superior tolerances and yields under Amazonian conditions. Taxonomic diversity, stressed in order to reduce pest pressure and the depletion of soil fertility, means that each colonist should have more than twenty species of useful trees alone and ideally, these should be provided as a 'kit' of saplings about two years old (Figure 3) together with instructions on their management. An even more diverse array of herbaceous plants also should be available as selected seed.

The isolation and remoteness of Amazonia can be turned to advantage from a phyto-sanitary standpoint. Many sites for settlement can be maintained free of exotic plant diseases and those should be protected by phyto-sanitary checkpoints — for example, at health screening posts. Although such checks can be effective, some potentially diseased plant materials will inevitably be smuggled to the new area in unless colonists have confidence that productive and adapted varieties will be readily available to them upon their arrival.

Prevalent cattle diseases such as Foot-and-Mouth disease (Aftosa), Brucellosis, Anthracnose and Rabies should be avoided by disease check points (INCRA, 1972).

Conservation

The major legal instruments for the conservation of Amazonian forests are administered by IBDF, FUNAI, and SEMA. The Código Florestal (Forest Code) of IBDF provides for the conservation in its natural state of 50% of each property. Although theoretically effective, this law does not work in actual practice. Landowners have been known to will the forested half of their properties to an heir, who then becomes legally empowered to clear a further 50% of the inherited plot, and so on. Also, the forested half is often sold, at which time the new buyer has the right to cut 50% of his newly-purchased forested plot. Even if the law was enforced, the result would be patchwork or small, isolated conserved plots which are environmentally inadequate to conserve much of the fauna and flora this law was specifically designed to protect. Furthermore, such small forest plots become dryer than the original forest, and hence are increasingly vulnerable to complete destruction by fire, which frequently spreads from the cultivated surroundings.

It is difficult to ascertain from IBDF the use to which the 50% plots may be put to legally. The assumption that such plots can be used for selective logging, hunting, etc., means that in the long term, the forest conservation plots will disappear. It would be preferable if all the colonists' 50% conserved plots in one settlement could be united into one large tract occupying half the project area. As soon as the soil survey and forest inventories have been performed, the site could then be zoned. Additional criteria should be used to zone specific areas as protective forest, on slopes steeper than a certain gradient, around sources of water, either side of water courses (as provided for by the Codigo Florestal) and so on. This proposal recommends that suitable várzeas be identified for the production of annual subsistence crops. This should be reconciled with IBDF legislation. Similarly, the capricious rule imposed by INCRA that the 200 m strip between road and property must be deforested before legal title can be confirmed, can be damagingly counterproductive.

Complete compliance with the Codigo Florestal of IBDF is unnecessary. For example, annual crop cultivation in várzea forest bordering some waterbodies is an effective environmental advantage for Amazonian projects. When soil fertility, topography, gross hydrology and forest inventory become better known — as recommended before the project begins — the entire area should be carefully zoned for land use. This should be performed by a group which included IBDF and SEMA appointees. Tracts will be included for the protection of water supply and waterways themselves (including flood prevention, maintenance of várzea alluvium, dry seasonal flow maintenance, navigation and fisheries protection) and for sustained-yield firewood lots, fire- and wind-control barriers, as well as for the more conventional designations.

Finally, tracts of protected forest should themselves be internally zoned on a primarily concentric plan. These would range from a firewood collecting and possibly selective felling zone on the outside containing limited access trails. Within this outer buffer zone would be areas with successively restricted access and use, right up to a central inviolate core in which neither paths nor any extractive activity whatsoever will be permitted.

Overall zonation of Amazonia should precede development. It is dangerous and wasteful to establish an Indigenous Reserve and shortly thereafter bisect it with a highway (e.g. Xingu Park). It is irrational to construct a town and then flood it by constructing a hydro reservoir. It is counter-productive to build a major highway two years before it will be flooded and so on. These problems can be avoided by overall zonation and advance planning. There is ample scope for Amerindians, mines, lumbering, industry, reservoirs, national parks, highways and so on — but only with judicious advance planning, since many activities are incompatible.

Environmental awareness is gathering momentum in Brazil — witness the encouraging "Brazilian Ecological Manifest" of José Lutzenberger (1976). The choices are clear for Amazonia: self-reliance and forest based development on the one hand, or convert the irreplaceable forest to pasture, export cattle and import sophisticated technology on the other. The former is rational and sustainable; the latter already is ominously deteriorating. Unfortunately, the ecological approach is boring (lengthy, modest, humble) for controllers, for the same reason destruction is fun (spectacular, immediate, vivid). Education at all levels therefore is essential.

List of Acronyms

CEPLAC	Centro de Pesquisas do Cacau Cacau Research Center
CNPq	Conselho Nacional de Pesquisas National Research Council
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária Brazilian Agricultural and Ranching Research Bureau
FAO	Food and Agriculture Organization of the United Nations
EMBRATER	Empresa Brasileira de Assistência Técnica e Extensão Rural Brazilian Technical Assistance and Rural Extension Service
IBC	Instituto Brasileiro do Café Brazilian Coffee Institute
IBDF	Instituto Brasileiro de Desenvolvimento Florestal Brazilian Forestry Development Institute
INCRA	Instituto Nacional de Colonização e Reforma Agrária National Institute for Colonization and Agrarian Reform
INPA	Instituto Nacional de Pesquisas da Amazônia National Institute for Amazonian Research
IPEAAOC	Instituto de Pesquisa Agropecuária da Amazônia Ocidental Agriculture and Cattle Research Institute of Western Amazonia
IPEAN	Instituto de Pesquisas e Experimentação Agropecuária do Norte. Northern Institute for Agriculture and Cattle Research and Experimentation
RADAM	Radar (visada lateral) na Amazônia
SEMA	Secretaria Especial do Meio Ambiente Special Secretary for the Environment
SUDAM	Superintendência do Desenvolvimento de Amazônia Superintendency for the Development of Amazonia

SUDECO	Superintendência do Desenvolvimento do Centro-Oeste Superintendency for the Development of the Center West
SUDHE-VEA	Superintendência do Desenvolvimento da Hevea Superintendency for the Development of Hevea

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