Deforestation and Shrinking Crop Gene-pools in Amazonia

by

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Introduction

Amazonia contains the world's largest stretch of tropical forest, spanning 5,000 km from the Andes to the Atlantic, and some 4,000 km from the Guianas and the Upper Orinoco to the scrub *cerrado* (dry savanna) of the Brazilian shield and the seasonally-flooded grasslands of the Pantanal. This vast mosaic of forest communities, second-growth, natural and man-induced grasslands, and swamps, contains the richest array of plant and animal species in the world, as well as a rich storehouse of genes for crop improvement. Rampant deforestation, fuelled by development schemes and pioneer farmers, now threatens to destroy genetic resources of many economic plants and potential crops before they can be tapped for the benefit of people throughout the world. Also, loss of tribal cultures is resulting in the disappearance of unique varieties of many of these crops, as well as of special and potentially valuable knowledge about them.

Ironically, forest clearing to establish farms and plantations can eliminate genes that could be used to improve the crops which are being planted. The shrinking of wild populations of at least *c.* 50 perennial crop species is currently under way in Amazonia (Table I). Perennial crops are important to the livelihoods of most small farmers in the tropics as well as to operators of large plantations. The importance of genetic resources to the future of Rubber (*Hevea brasiliensis*), Cacao (*Theobroma cacao*), Guaraná (*Paullinia cupana*), Annatto (*Bixa orellana*), Peach-palm (*Bactris gasipaes*), Patauá (*Jessenia bataua*), and Brazil-nut (*Bertholletia excelsa*), come immediately to mind, while the importance of preserving forest environments and safeguarding the livelihoods of people who depend on the forest also need emphasis.

Wild Gene-pools and Traditional Varieties

Hunters and gatherers occupied the Northeast of Brazil and parts of Chile 30,000 years ago (Dillehay & Collins, 1988). Small, semi-nomadic groups probably penetrated Amazonia even earlier in search of fruits, nuts, fibre, and game. Starting at least 20,000 years ago, certain fruit- and nut-trees, such as Cacao, Cupuaçu (Fig. 1), Jenipapo, Peach-palm, and Muruci, were undoubtedly sown or transplanted near temporary campsites. The Kayapó Indians give us clues to this early semi-domestication as they create artificial forest 'islands' of useful species along the *cerrado*–forest boundary in southern Pará (Posey, 1988). Early farmers in Amazonia brought into cultivation several dozen perennial crops, in addition to numerous medicinal- and food-plants, and selected many unique varieties of each crop.

Wild populations of crops, and in some cases their near relatives, are increasingly sought by plant breeders for desirable traits, such as pest- and disease-resistance. To help to make farming more sustainable, research workers, development organizations, and farmers themselves, are increasingly seeking genetic solutions to agricultural constraints rather than making costly, and sometimes environmentally-damaging, chemical applications.

Caiaué (*Elaeis oleifera*), for example, is a close relative of the African Oil-palm (*E. guineensis*), and grows wild from Honduras to Amazonia. Prostrate Caiaué has been used in crosses with its African cousin, for example, to reduce the latter's height and thereby facilitate harvesting. More recently, Caiaué has been found to resist Spear-rot, a little-understood disease that has begun creating havoc in some oil-palm plantations in tropical America. Caiaué's disease-resistance and short stature should be capable of saving the oil-palm industry millions of dollars. Caiaué's oil is less saturated than that of African Oil-palm — an important trait for the export trade, as consumers in industrial countries are becoming increasingly concerned about cholesterol in their diets.

Traditional varieties are also sought for superior hardiness and nutritional qualities. Genetic erosion of traditional varieties is well advanced, due to the dramatic drop in aboriginal populations since contact with Europeans in the early 16th century (Hemming, 1987). Unique varieties continue to disappear, as the remaining Indian groups merge with national societies or themselves disappear.

Most of the perennial crops with wild populations in Amazonia, such as Rubber and Cacao, originated in the forest. Widespread deforestation is thus eliminating gene-pools even before they can be adequately assessed.

TABLE I

Some Perennial Crops with Wild Populations in Amazonia.

Family* and Scientific Name	Common Name or Names	Wild Populations' Distribution	Main uses	Habitat
ANACARDIACEAE				
Spondias lutea	Yellow Mombin, Cajá Taperebá	Amazonia	Juice, ice-cream	Forest
ANNONACEAE				
Annona montana	Mountain Soursop, Araticum	Amazonas to Rio Grande do Sul, Brazil	Fruit	Second-growth
Annona muricata	Soursop, Graviola, Guanabana	Amazonia	Juice, ice-cream	Forest
Duguetia stenantha	Jaboti	(Upper Amazon)	Fruit	Forest
Rollinia deliciosa	Biribá	W. Amazonia, Rondônia	Fruit, ice-cream	Forest
APOCYNACEAE				
Couma utilis	Sorvinha	Amazonas, Brazil	Chewing-gum, porridge	Forest
BIXACEAE				
Bixa orellana	Annatto, Urucu	Northern Mato Grosso	Food colourant, body paint	Forest
BOMBACACEAE				
Quararibea cordata	Chupa-chupa	W. Amazonia	Fruit	Forest
CARICACEAE				
Carica papaya	Papaya, Mamão	Amazonia[b]	Fruit, papain	Second-growth
CHRYSOBALANACEAE				
Couepia bracteosa	Pajurá	Amazonia	Fruit	Forest, Second-growth
Couepia longipendula	Castanha de Galinha	C. Amazonia	Nut	Forest
Couepia subcordata	Umarirana	C. Amazonia	Fruit, shade	Forest
EUPHORBIACEAE				
Hevea brasiliensis	Rubber, Seringueira	Amazonia	Latex, fish-bait	Forest
GUTTIFERAE				
Platonia insignis	Bacuri	Amazonia, Guianas, Paraguay	Fruit, ice-cream	Forest ecotone
Rheedia acuminata	Bacurizinho	Amazonia	Fruit	Forest, second-growth
Rheedia benthamiana	Bacuripari Selvagem	Amazonia	Fruit	Forest
Rheedia brasiliensis	Bacuripari liso	Amazonas, W. Maranhão, French Guiana	Fruit	Forest
Rheedia macrophylla	Bacuripari	Amazonia, Brazil	Fruit	Forest, second-growth
HUMIRIACEAE				
Sacoglottis uchi[c]	Uxí[c]	Amazonia	Fruit	Forest
ICACINACEAE				
Poraqueiba paraensis	Umari	Pará, Brazil	Fruit	Forest
Poraqueiba sericea	Mari, Umari	Amazonas, Brazil	Fruit	Forest
LECYTHIDACEAE				
Bertholletia excelsa	Brazil-nut Castanheira	Amazonia[d], Upper Orinoco	Nut	Forest
Lecythis zabucajo	Sapucaia	Amazonia[e], French Guiana	Nut	Forest
LEGUMINOSAE				
Cassia leiandra	Marimari	Pará Amazonas, Brazil	Fruit	Flood-plain forest
Inga cinnamomea	Ingá-açu	Amazonia, Guianas	Fruit	Flood-plain-forest
Inga fagifolia	Ingá cururu	Brazil	Fruit	Forest
Inga macrophylla	Ingapéua	Amazonia	Fruit	Forest
Inga velutina	Ingá de fogo	E. Amazonia	Fruit	Forest
MALPIGHIACEAE				
Bunchosia glandulosa	Ciruela	Amazonia	Fruit	Second-growth
Byrsonima crassifolia	Muruci, Nance	Amazonia, Honduras, El Salvador, Costa Rica	Fruit	Forest on sand soil
MARANTACEAE				
Calathea lutea	Cauasú	Amazonia	Leaf-wax	River banks
MENISPERMACEAE				
Chondrodendron tomentosum	Curare	Western Amazonia	Medicine	Forest
MORACEAE				
Pourouma cecropiaefolia	Puruma, Uvilla	W. Amazonia	Fruit	Second-growth
MYRTACEAE				
Campomanesia lineatifolia	Guabiraba	W. Amazonia	Fruit	Forest
Eugenia stipitata	Araçá Boi	W. Amazonia	Fruit	Forest
Psidium acutangulum	Araçá Pera	Amazonia, Guianas, Venezuela	Fruit	Forest
Psidium guajava	Guava, Goiaba	Amazonia, Tropical America	Fruit	Second-growth
Psidium guineensis	Araçá, Brazilian Guava	Amazonia, W. Indies, Tropical America	Fruit	Second-growth, grassland
PALMAE				
Astrocaryum chambira	Tucum	N.W. Amazonia	Fruit, fibre	Forest
Bactris gasipaes	Peach-palm, Pejibaye Pupunha	W. Amazonia	Fruit, palmito	Forest
Euterpe oleracea	Açaí	E. Amazonia[d]	Fruit, palmito	Flood-plain forest
RUBIACEAE				
Genipa americana	Jenipapo	Amazonia, West Indies, Tropical America	Liquor, fruit, body paint	Forest
SAPINDACEAE				
Paullinia cupana	Guaraná	C. Amazonia	Fruit	Forest
Talisia esculenta	Pitomba	Amazonia, Brazil, Bolivia, Paraguay	Fruit	Forest
SAPOTACEAE				
Pouteria caimito	Abiu	Amazonia in Peru, Brazil, Ecuador, S.W. Venezuela	Fruit	Forest
Pouteria macrophylla	Cutite	Amazonia	Fruit	Forest
Pouteria ucugui	Ucugui	Brazilian & Colombian Amazonia	Fruit	Forest
STERCULIACEAE				
Theobroma cacao	Cacao	Western and Central Amazonia, Guianas	Drink, fruit-juice, confectionary	Forest
Theobroma grandiflorum	Cupuaçu	W. Maranhão, Pará[d], Brazil	Fruit-juice, ice-cream, pudding	Forest
Theobroma speciosum	Cacauí	Amazonia, northern S. America, southern C. America	Fruit	Forest

* Families of plants are treated in alphabetical order in this Table. — Ed.

[a] Observed growing on the Amazon floodplain near Itacoatiara, Amazonas, Brazil, in 1977. Apparently wild, but may have been planted or sprung from seed discarded by people.

[b] Occurs as a spontaneous weed on the better soils in the humid tropics of Latin America. Along Brazil's Transamazon Highway, Papaya is an early component of some second-growth communities on eutrophic oxisols (*terra roxa*) near Altamira, Pará (Smith, 1982). In Amazonia, Papaya is dispersed by such birds as the Blue-gray Tanager (*Thraupis episcopus*) and the Palm Tanager (*T. palmarum*) (Smith *et al.*, in prep.).

[c] Uxi is cultivated near Castanhal, Pará, Brazil.

[d] field notes.

[e] Sapucaia grows on eutrophic oxisols (terra roxa) near Altamira, Pará.

*Sources**: Allen, 1987; Allen & Lass, 1983; Aublet, 1775; Balée, 1986, 1987; Cavalcante, 1988; Clement, 1988; Croat, 1978; Ducke, 1946; I. Falesi, pers. comm.; Morton, 1987; Myers, 1930; Nery, 1885; Schultes, 1984; Schultes & Raffauf, 1990; Smith, 1982; Smith *et al.*, in prep.; Standley, 1930; Standley & Calderón, 1927; Vickers, 1984; Williams & Williams, 1951.

*In alphabetical sequence of first Authors' names rather than our customary chronological order. — Ed.

FIG. 1. *Cupuaçu* (Theobroma grandiflorum) *is a seasonal fruit that is planted from seed in backyards in Amazonia — particularly in Pará, Brazil. A relative of Cacao, Cupuaçu pulp is used to make ice-cream and puddings, and the beans could be used to make a new chocolate. The fruits are pendant and generally reach the size of a rugby football.*

Some fruit crops, such as Papaya, Bacuri, Guava, and Ciruela, have wild populations in more open habitats, particularly second-growth. Human activities often create light-gaps in the forest, but these do not always create opportunities for colonization by second-growth fruit species. Human population pressures and land-use practices are shortening or eliminating fallow periods in some areas.

MEGACROPS

Several of the crops with wild gene-pools in Amazonia enter global or regional trade. Two, in particular, stand out as major crops that are grown in many parts of the humid tropics: Rubber and Cacao. The ultimate fate of plantations of Rubber and Cacao in Africa or Asia may well hinge on genes in the still unexplored forests of Amazonia.

Rubber

Over 97% of the world's natural Rubber is now produced in Southeast Asia. Rubber has prospered in tropical Asia primarily because it is free there from most of the diseases that afflict Rubber plantations in tropical America. But Asian Rubber plantations largely trace their origin to only 26 Rubber trees in the Tapajós Valley near Santarém, Pará* — a narrow genetic base, indeed, for such a large-scale industry (Schultes, 1984). Furthermore, the best types of *Hevea brasiliensis* are found in western and southwestern Amazonia (Schultes, 1987), and nearly nothing has yet been done genetically with the other 9 species of *Hevea.*

The greatest threat to Rubber plantations is South American Leaf-blight (*Microcyclus ulei*), a fungal pathogen that occurs on wild and planted Rubber in Brazil. South American Leaf-blight has effectively checked Rubber plantations in the home of Rubber and could eventually reach Asia. A precautionary programme of breeding resistance to the four known races of the disease is called for. Single-gene resistance to the disease is unlikely to hold up for long, so multiple-gene resistance will be needed to combat effectively the highly variable pathogen. Wild populations of Rubber in Amazonia are likely to contain genes for resistance to South American Leaf-blight, but screening has hardly begun (Schultes, 1977).

Several near relatives of Rubber are known to resist South American Leaf-blight, but breeders have been wary of using the nine wild relatives of Rubber because of concern for yield and latex quality. However, *Hevea benthamiana* produces an acceptable latex and shows some resistance to South American Leaf-blight. Several rubber hybrids containing *benthamiana* germ-plasm, such as IAN 6158, are undergoing trials in a 'hot spot' for South American Leaf-blight at the Amazonian Agroforestry Research Center (CPAA — Centro de Pesquisa Agroflorestal da Amazônia) near Manaus, Brazil.

Disease-resistance is only one of several desirable attributes contained in Rubber's near relatives. The development of high-yielding Rubber varieties that thrive on diverse soil-types is a high priority, and *Hevea nitida,* which grows on sandy soils along the Upper Rio Negro, might provide tolerance to nutrient-poor soils. In addition, the diminutive *H. nitida* var. *toxicodendroides* could be crossed with Rubber to make the latter less prone to wind damage than it currently is (Schultes, 1988).

Cacao

This is a major foreign-exchange earner for Brazil, Côte d'Ivoire, Ghana, and Malaysia. These countries are also heavily indebted to banks in industrial nations, so the health of Cacao plantations has wider implications

* Hence the widely-used connotation of 'Para Rubber'. — Ed.

than just the price which consumers pay for chocolate bars in North America and Western Europe. Cacao is an understorey tree in the forest of western Amazonia and is highly variable, thus offering a rich source of germ-plasm for breeders.

Several major diseases and insect pests of Cacao defy chemical control. Witches'-broom (*Crinipellis perniciosa*) has depressed Cacao yields in Amazonia, where the disease is native, and in the late 1980s reached Bahia, Brazil's main Cacao-growing area. In 1937, F.J. Pound collected wild and domesticated Cacao in the Amazon portion of Ecuador and Peru, and obtained several clones with varying resistance to Witches'-broom. One of his resistant selections, SCA 6, has been used in crosses that have led to commercially useful Cacao varieties (Purseglove, 1974). But the work of breeders never stops. Cacao with SCA 6 germ-plasm became susceptible to Witches'-broom in Ecuador by 1973, and in Brazil by 1982 (B. Bartley, pers. comm.; Laker & Sreenivasan, 1987). At least five pathotypes of Witches'-broom attack Cacao, and more races are likely to evolve. Few aces can be drawn in the incessant combat against pests and diseases; a flush of resistance genes is the only long-term answer to Witches'-broom.

Field gene-banks are an important resource for Cacao breeders looking for pest and disease resistance. Some 4,000 to 5,000 distinct Cacao genotypes are held in germ-plasm collections, but more collecting and evaluation are urgently needed. During the early- and mid-1980s, the far-sighted London Cocoa Terminal Market funded collecting missions for wild Cacao in Ecuador. These collections are now being evaluated in a field gene-bank of four hectares containing 245 accessions at San Carlos in Ecuador (Allen & Lass, 1983; Allen, 1987).

Brazilians are also making regular Cacao-collecting trips in Amazonia, to obtain wild material and Cacao from old, small-scale groves planted by 'traditional' farmers. These materials are taken to a field gene-bank of 240 hectares that is maintained by the National Cacao Research Program (CEPLAC — Commissão Executiva do Plano da Lavoura Cacaueira) near Benevides, Pará, for evaluation.

Genetic resources also offer hope in combating a serious pest of Cacao in Southeast Asia. This is Cocoa-pod-borer (*Acrocerops cramerella*), a moth larva that bores through Cacao husks and disrupts bean develop-

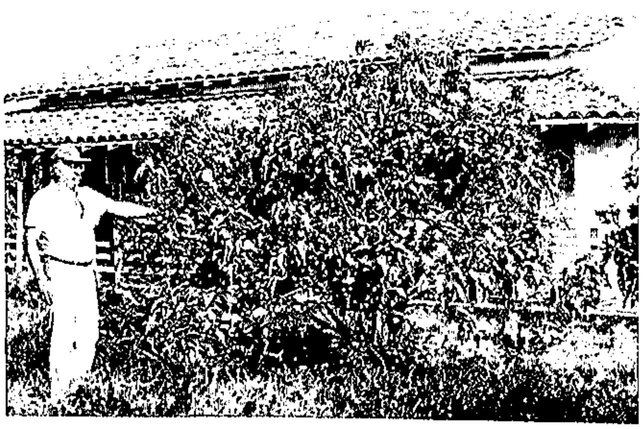

Fig. 2. *A small plantation of Annatto* (Bixa orellana) *in the Bragantina zone near Belém, Pará, Brazil. The scale is indicated by the figure of the 2-m-high farmer.*

Fig. 3. *Açaí* (Euterpe oleracea) *has long been harvested for its frui Açaí is planted in 'dooryard' gardens and occurs wild along wate courses in eastern Amazonia. This graceful palm has recentl come under pressure from the palmito industry.*

ment, making extraction and fermentation difficult. Th volant pest was formerly confined to the Philippines an Indonesia; but by 1980 it had gained a foothold in Sabal Malaysia (Entwistle, 1985). Cocoa pod-borer reached th Malayan Peninsula by the mid-1980s. Chemical contr is difficult, because the larvae are concealed inside th pod. A hard-husked Cacao from a backyard nea Benevides, Pará, prevents penetration of Cocoa pod borer — a discovery that emphasizes the value of su veying old Cacao orchards.

A search is now under way for genetic resistance t another insect pest that bores into Cacao pods. This is th larva of a curculionid beetle, *Conotrachelus humeroptic tus*, which was first reported as attacking Cacao planta tions near Cacoal, Rondônia, in 1981. The beetle is als infiltrating a new germ-plasm collection at Ouro Pret d'Oeste, Rondônia (Mendes *et al.*, 1987). This new an highly destructive pest threatens to undermine attempt to establish Cacao as a viable, and ecologically suitable cash-crop for pioneer farmers in Amazonia.

Crops in Ascendancy

An impressive number of crops, domesticated i Amazonia or with wild populations there, are becomin ever-more-important for commerce and subsistence. Guaraná, for example, was domesticated by the Maué Indians of the Central Amazon and is proving a popular soft-drink in some of the larger urban markets in Canada and the United States. Concern about the relatively high caffeine content of Guaraná has somewhat deflated sales prospects, but a search of wild and domesticated germ-plasm might turn up some low- or even no-caffeine germ-plasm. Some wild coffees, for example, contain no caffeine.

More and more small- and medium-scale farmers in Brazil are planting Annatto in response to growing demand for this natural red food colourant, traditionally used for body paint by Amazonian Indians (Fig. 2).

Most of the world's palmito comes from wild palms, such as *Euterpe edulis* and *E. oleracea* in Brazil, harvesting of which often leads to the destruction of natural stands. Populations of *E. edulis* have been virtually wiped out in southern Brazil by the palmito industry. Unlike *E. edulis*, Açai (*E. oleracea*) can sprout again after cutting, but stands of Açaí in the lower Amazon are under heavy pressure from the palmito trade (Fig. 3). Burgeoning demand for palmito, both for domestic and international markets, dictates a more rational approach. Açaí plantations would provide local employment, food, and possibly foreign exchange. Precocious growth would be a desirable trait for Açaí selections for plantations.

Peach-palm, long an important source of starch and vitamin A in parts of the humid tropics of Latin America, is receiving increasing attention for palmito production. Like Açaí, Peach-palm is a ratoon crop, which means that it does not need to be replanted after it is cut down. Peach-palm plantations for palmito export have been operating successfully in Costa Rica since the early 1970s, but as such operations proliferate, the danger increases of widespread disease and pest problems. Several quick-growing, but genetically different, varieties need to be deployed to reduce disease pressure.

The greatest diversity of Peach-palm is found in western Amazonia, where the crop has long been domesticated and wild forms of *Bactris gasipaes* have recently been found (Clement, 1988). Transmigration schemes — from the overcrowded altiplano in the Andes down to the foothill forests of the Amazon — logging, and oil operations, all pose threats to primitive forms of Peach-palm and other crops.

Most trunks of Peach-palm bristle with stiff, black spines, making harvesting of the heart of the palm a painful proposition. The spines serve a useful purpose, however, by keeping rodents and other mammals away from the fruit. But when the objective is to generate palmito, the spines confer no advantage. A spineless Peach-palm, held in a germ-plasm collection of the National Institute for Amazonian Research (INPA — Instituto Nacional de Pesquisas da Amazonia) near Manáus, Brazil, promises to facilitate palmito operations. Other spineless forms of Peach-palm are cultivated by indigenous groups along the Apaporis River in the Colombian Amazon, and a small proportion of planted Peach-palms in Costa Rica have virtually no spines (Johannessen, 1966).

Perennials on the Threshold of Domestication

Only a handful of crops have been domesticated since Biblical times, and the world would undoubtedly benefit from a wave of new crops. The humid tropics is a logical region in which to search for new food, fibre, beverage, and medicinal, plants. Two Amazonian forest trees, Patauá Palm (*Jessenia bataua*) and Brazil-nut, are on the crest of the surge to develop new crops.

Patauá Palm

Graceful Patauá is a creekside palm that is harvested for its purple, damson-sized fruits which are pounded to make a refreshing drink. The fruit-pulp is also rich in oil, rivalling olive oil in quality (Balick, 1979; Pesce, 1985; Lleras & Coradin, 1988). Forest populations of the solitary Patauá are too disperse to support a commercial refinery, so plantations will need to be established to meet growing market interest in this fine oil. In anticipation of a commercial future for Patauá, the Brazilian agricultural research system (EMBRAPA — Empresa Brasileira de Pesquisa Agropecuária) recently started a field gene-bank for the forest palm at its Belém research facility. As of 1988, EMBRAPA had established 169 clones in the Patauá gene-bank. To improve the chances of Patauá providing a viable cash-crop option to farmers in the region, varieties will have to be developed that are high-yielding and mature quickly.

Scientists in Colombia and Malaysia are collaborating to improve the yield and other characteristics of Patauá. Some 30,000 seeds of *Jessenia* have been collected thus far, divided equally between Colombians and Malaysians. This initial collection was made from 60 trees at 8 locations. Variation in Patauá populations is pronounced in western Amazonia, and particularly fine stands of the palm are found there.

Brazil-nut

This is further along the path to domestication than is Patauá. Virtually all Brazil-nuts come from wild stands, but within fifty years or so, most marketed Brazil-nuts will probably come from plantations in Southeast Asia, Africa, and Latin America. Towering Brazil-nut trees are giving-way rapidly to reservoirs, cattle ranches, farms, and illegal lumbering. Tens of thousands of Brazil-nut trees probably drowned in the 2,000 km² reservoir that formed after the Tucuruí dam was completed on the Tocantins River in 1984 (Fig. 4).

Two main concentrations of Brazil-nut trees occur in Amazonia, both of which are partly due to the agency of early hunters and gatherers or farmers who probably enriched stands artificially. The major concentration of majestic Brazil-nut trees is in the Tocantins valley, the scene of many development activities since the 1970s — ranging from pioneer highways and the 4,000 MW hydroelectric dam at Tucuruí, to the Grande Carajás mining and agro-industrial projects. The 890-km railroad that links Carajás to the port of Itaguí in Maranhão, slices through some of the richest Brazil-nut country in southern Pará.

The Grande Carajás scheme calls for 238,000 hectares of mechanized soybean production, 12,600 hectares of sugar-cane, 417,000 hectares of pasture for beef cattle, and 3.6 million hectares of *Eucalyptus* plantations to supply charcoal for smelting iron-ore (Hall, 1987). Between 90,000 and 200,000 hectares of forest will need to be cut down every year for seven years until the *Eucalyptus*

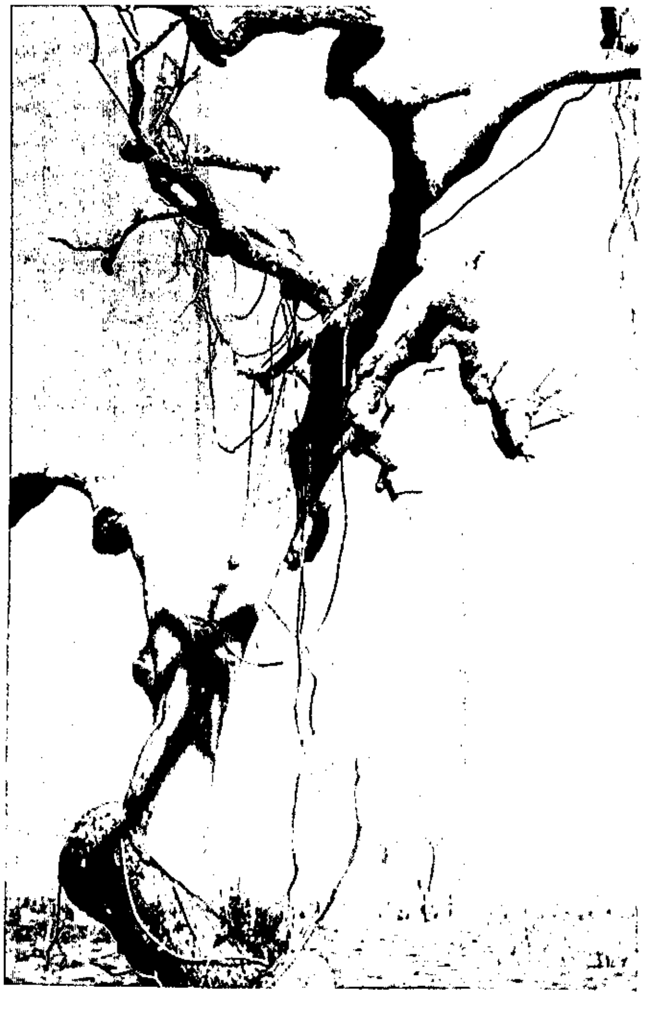

FIG. 4. *A Brazil-nut tree* (Bertholletia excelsa) *killed by the Tucuruí reservoir, 1988. The trees frequently reach a height of 40 metres.*

plantations are old enough to supply charcoal for the 15 projected pig-iron smelters (Mahar, 1989).

Brazil-nut trees are also particularly densely packed in the forests of the Madre de Dios in Peru. The latter region may be opened up by a road to the Pacific coast, to export lumber to Japan. The Manú National Park in the Madre de Dios is currently the only safe haven for Brazil-nut trees in Peru.

The United States alone imports approximately $16 millions worth of protein-rich Brazil-nuts each year (Caufield, 1984), so several *entrepreneurs* in the Brazilian Amazon have recently started large-scale plantations of the upland tree. Malaysians have also established plantations of the exotic tree, and Malaysia may well end up by dominating Brazil-nut production as they have that of Rubber. Brazil-nut trees can be grafted; this will permit the rapid dissemination of high-yielding clones. Several such clones will be needed, though, to facilitate successful pollination and to help to avert catastrophic disease and pest outbreaks. Diverse germ-plasm is also needed to 'tailor' Brazil-nuts to varied soil and drainage conditions.

For Brazil-nut plantations to succeed, provision must be made for the large bees that pollinate the tree. In Amazonia, euglossine and anthophorine bees pry c the hooded, marble-sized flowers to reach the ne reward. Upon leaving, they carry pollen to the next t In Malaysia, other large bees perform the same serv At least some of the pollinators of Brazil-nut req forest, or old second-growth, to provide food for t after the Brazil-nut tree's short flowering-season enc the early part of the rainy period. Male euglossine l depend on flowers of certain forest orchids to ga odours to attract their mates (Prance, 1984). Substa tracts of forest or advanced second-growth will be n ed close to Brazil-nut plantations to sustain those spe pollinators.

A two-pronged strategy is needed for safeguarding genetic resources of Brazil-nut, involving *in situ* anc *situ* conservation. Most importantly, sizeable 'extrac reserves' need to be established, particularly along Tocantins and Madre de Dios, for the benefit of l people to gather Brazil-nuts and other resources. S extractive reserves will need to accommodate some c ring for agriculture, as dependence on forest prod alone is unlikely to raise living standards for the r population, at least in the near term. Countries with ter ry in Amazonia have made commendable moves to e blish parks, extractive reserves, and ecological preser but these cover only a tiny fraction of the vast region.

Parks and Nature preserves will ultimately cap only a portion of the wild gene-pools of crop-plants other species. Extractive reserves, accessible to l people for non-destructive use, could cover much la sections of Amazonia. Unlike many parks and reser which are designed to shut out people, extractive reser would be compatible with the needs of locals, and cc secure large segments of forest for wild gene-pool Brazil-nut, Rubber, Cacao, and other important cr Local control of extractive reserves would, however, necessarily safeguard the genetic resources of Brazil and other economic plants; a community could dec that more money can be made by converting fores pasture or a sugar-cane plantation.

As a complement to *in situ* conservation, field ge banks for Brazil-nut are needed, so that breeders can e ly accession a wide assortment of germ-plasm. EMBI PA is wisely planning to establish a 1,000-hectares ge bank for Brazil-nut along the Mojú River near Belém.

IMPLICATIONS FOR CONSERVATION

Conservation of genetic resources and regional de lopment in Amazonia are intertwined. More studies needed, however, to document genetic variation in v populations and domesticated gene-pools of Amazor crops. Also, hard economic data are needed to convi policymakers of the value of preserving forest habitat resources for development.

Another salient lesson from global efforts to conse crop genetic resources is the need to maintain the cult integrity of indigenous groups. People with a long hist of interaction with the forest have much to teach us ab sustainable agricultural practices. Rural folk are parti larly knowledgeable about the location and natural his ry of wild populations of crops and their near relativ Biodiversity and cultural heterogeneity are vital to sus nable development.

The notion that debt-for-Nature swaps (now sometimes recast as debt-for-development, to incorporate a broader range of socio-economic issues) can help to save vast areas of tropical forest, is attracting much attention in the press and scientific literature (Neumann & Machlis, 1989). But it remains to be seen how much forest will be effectively safeguarded by such means. A small portion of the external debt of Costa Rica and Bolivia, for example, has been purchased at a steep discount to acquire tropical forest reserves. A total of 1.5 million hectares of forest and grassland has been set aside in the Beni region of Bolivia with the help of the San Francisco-based Frank Weeden Foundation. The philanthropic Foundation provided $100,000 to relieve Bolivia of $650,000 of external bank obligations (Walsh, 1987).

Debt-for-Nature swaps are a good idea, but only a fraction of the hundreds of thousands of millions of US dollars of debt owed by tropical countries is likely to be used for setting aside Nature reserves. Even at a steep discount, debt-for-Nature swaps will be expensive. And when once such reserves are set aside, the questions of long-term management and protection remain. A country could accept a debt-for-Nature deal, then turn around a few years later and clear the forest for mining activities. Only if countries are motivated to conserve resources, rather than just escape a debt burden, can such deals be useful over the long haul.

The conservation of crop genetic resources can be difficult to sell, but the stakes are high. It is difficult for developing countries, besieged with economic woes and rapidly-growing populations, to set aside vast tracts of forest because they contain crop genetic resources of unknown potential. Should Malaysia compensate Brazil for safeguarding Brazil-nut and Rubber germ-plasm, and should Brazil help Ethiopia and Sudan to protect forests containing wild Arabica Coffee? A consortium of donors, including Third World governments, multilateral development banks, commercial banks, private foundations, commodity groups, and bilateral aid agencies, is needed to help conserve and improve the use of crop genetic resources in the dwindling tropical forests.

Summary

Deforestation in Amazonia is eliminating wild gene-pools of many crop-plants. Wild or spontaneous populations of at least 50 perennial crops are at risk, including the Rubber tree and Cacao, as well as several crops emerging from relative obscurity, such as Peach-palm (which is now being planted extensively for palmito production), Annatto (which produces a natural red dye), and Brazil-nut.

Numerous minor crops, such as Cupuaçu (a relative of Cacao), and many locally-important fruits, could become more important in future if enough of the genetic reservoirs of these plants are safeguarded in forest environments. Indigenous communities have much to teach us about the natural history of wild populations of crop-plants and potential new domesticates.

The survival of forests in Amazonia and other humid tropical forest regions is vital for sustainable agriculture. Many of the crops that originated in Amazonia are important for subsistence and commerce. Genes in wild populations and traditional varieties will be needed to upgrade crops and to develop new ones. The livelihoods of millions of rural people in the lowland tropics, and the economies of both industrial and developing nations, hinge on ways to develop Amazonia that minimize forest destruction.

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