

THE MAIN RESOURCES OF AMAZONIA

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ABSTRACT

Amazonia has tremendous quantities of primary resources. Resources include traditional commodities such as minerals, hydropower, agriculture and ranching, timber, non-timber forest products, and tourism. In addition, benefits are obtained through cultural, scientific and environmental resources. Environmental services include biodiversity maintenance, carbon storage, and water cycling.

In many cases, exploitation of traditional commodities brings little benefit to local populations in the region. Limits of various kinds restrain the area and the intensity of resource exploitation. Use of one resources often precludes obtaining the benefits of other resources, the most widespread instance being loss of benefits of forest when it is converted to cattle pasture. Environmental services of standing forest represent a major potential source of value that is presently unrewarded by the world economy. The challenge of turning environmental services into a means of supporting the human population in the region and maintaining the forest should be the top priority in efforts to develop Amazonian resources.

I.) INTRODUCTION

A.) WHAT IS AMAZONIA?

Depending on definition, 4-7 million km² in area, including in Brazil the Tocantins/Araguaia basin (which drains into the Pará River, interconnected with the mouth of the Amazon) and the small river basins in Amapá that drain directly into the Atlantic. Forests drained by coastal rivers in French Guyana, Surinam and Guyana are also often considered as part of Amazonia, sometimes called "Greater Amazonia." The Amazon River watershed totals 7,350,621 km², of which 824,000 km² (11.2%) are in Bolivia, 4,982,000 km² (67.8%) are in Brazil, 406,000 km² (5.5%) are in Colombia, 123,000 km² (1.7%) are in Ecuador, 5,870 km² (0.1%) are in Guyana, 956,751 km² (13.0%) are in Peru and 53,000 km² (0.7%) are in Venezuela (TCA, nd [1992]: 9). In addition, "Greater Amazonia" encompasses Surinam (142,800 km²), French Guiana (91,000 km²), and the part of Guyana outside of the Amazon River Watershed (211,239 - 5870 = 205,369 km²), bringing the total area of "Greater Amazonia" to 7,789,790 km².

In Brazil, the "Legal Amazon" is a 5 million km² administrative region comprised of 9 states (Figure 1). One million km² of the region was not originally forested, being covered by various kinds of savanna (especially the cerrado, or

central Brazilian scrub savanna). The Legal Amazon was created in 1953 and slightly modified in extent in 1977. Because special subsidies and development programs apply within the region, its borders were drawn just far enough south to include the city of Cuiabá, and just far enough east to include the city of São Luis (both outside of the portion that is geographically Amazonian).

[Figure 1 here]

B.) WHAT IS A RESOURCE?

What is a "resource?" The term is usually used to refer to something that is useful to humans. The 'thing' in question normally has to be in short supply; for example, people don't think of air as a resource unless it is made unavailable, as through pollution.

An important area of inconsistency is whether items are considered resources if they are not usable now, but might become useful in the future. This condition applies to many potential resources in Amazonia today, such as much of the region's germplasm, the secondary compounds in plants and animals, presently unused timber species, and mineral deposits and hydroelectric sites that would not be profitable if exploited today. Valuation of potential resources can be based on a Bayesian approach, multiplying the monetary value of the item if used by probability of its being used, in order to obtain the expected monetary value (EMV) (cf. Raiffa, 1968). In some cases, it would be appropriate to apply discounting based on the time that monetary benefits would accrue, but in other cases the responsibility of national governments to ensure the well-being of future generations of citizens is inconsistent with a decision-making framework based on discounted financial values (as is done by corporate or individual investors)(see Fearnside, 1989a).

People often fail to appreciate that resources have value when this value is not recognized by our current market economy. Non-monetary benefits (for example for drugs) are often more important than the money that may be garnered from selling them. Environmental services performed by natural ecosystems, such as maintaining biodiversity and climate, are currently hardly recognized at all by the economy, yet represent a major resource in the case of Amazonia.

Interactions among resources are important determinants of whether the benefits of the different potential resources will be reaped. Some of the most important land uses in Amazonia represent either/or choices. Forest versus pasture is the most

important case: one can only have the benefits of one or the other, not both. Such choices do not apply to all situations: the benefits of both minerals and forest may be obtainable in some cases, although the frequency of mistaken predictions (invariably at the expense of forest) is discouraging.

The definition and evaluation of resources depends on, first of all, for whom the resources are expected to serve. The question of "Resources for whom?" is often left unasked and unanswered, leaving the implicit assumption that the benefits are from the perspective of economic actors in the national (or international) economy. The interests of native inhabitants and other forest peoples are often not well served by extraction and sale of the 'resources' identified in this way, and decisions about what is a resource would be very different if the interests of these groups were given top priority.

An important question in assessing resources is whether one counts 'resources,' such as timber, that are located in national parks, indigenous lands and other areas where exploitation is prohibited. By presenting figures and maps that imply that such 'resources' are 'available,' one is, in fact, encouraging the alteration of legislation or creation of loopholes in order to allow the 'resources' to be exploited. This concern has, in fact, led the Economic-Economic Zoning (ZEE) maps produced by the Brazilian Institute for Geography and Statistics (IBGE) for the zoning effort coordinated by the Secretariat of Strategic Affairs (SAE) to not indicate such resources within protected areas, leaving these areas blank on the maps.

II.) TYPES OF RESOURCES

A.) MINERALS

Amazonia has significant mineral resources, including iron, aluminum, copper, gold, tin and kaolin, as well as some rare minerals such as niobium. Oil and gas deposits, especially in western Amazonia, are substantial. In Brazil, the most comprehensive survey was that conducted by the RADAMBRASIL project in the 1970s using side-looking airborne radar (SLAR) supplemented by field sampling (Brazil, Projeto RADAMBRASIL, 1973-1982). A review of mineral resources in Brazilian Amazonia has been compiled by dos Santos (1981). More recent discoveries are contained in Kashida et al. (1990) and Brito (1995).

Mining, while destroying relatively little forest directly, is a significant influence in other ways. These include the building of roads to mineral-rich areas, and the processing of ores in the region in ways that consume forest. Carajás, with

the world's largest high-grade iron ore deposit, is coupled to a regional development plan that produces pig-iron from some of the ore. Charcoal, used both as a reducing agent and as an energy source, comes largely from native forest wood--contrary to the claims of the mill owners (Fearnside, 1989b). If fully implemented, supplying charcoal to this scheme would require deforesting as much as 1500 km²/year (Anderson, 1990).

B.) HYDROPOWER

Hydropower generation sites, and water resources in general, represent a major potential resource about which many key decisions are still pending. Exploitation of much of the potential would have heavy environmental costs and would flood large areas of indigenous land (Fearnside, 1989c, 1995a). The 2010 Plan (Brazil, ELETROBRÁS, 1987) suggested that 100,000 MW of installed capacity could be implanted in Brazilian Amazonia if all sites were exploited. Subsequent revisions of the plan have successively postponed the dates for given dam-building projects, but have not altered the ultimate total, which would flood 10 million ha, or about 3% of the Amazonian forest (Brazil, ELETROBRÁS, 1987: 150; see Fearnside, 1995b).

C.) AGRICULTURE AND RANCHING

The vast area of Amazonia means that the region could represent a major source of food if productive agriculture and/or ranching could be implanted and maintained in a significant part of the region. However, the vast areas are deceptive because of severe limiting factors restraining the expansion and the per-hectare yields of agriculture and ranching systems. These include poor soils, limited sources of fertilizer (especially deposits of phosphates), markets for products, and the environmental impacts of forest removal.

A report on Brazil's phosphate deposits published by the Ministry of Mines and Energy indicates that only one small deposit exists in Amazonia, located on the Atlantic coast near the border of Pará and Maranhão (de Lima, 1976) (Fig. 2). In addition to the deposit's small size, it has the disadvantage of being made up of aluminum compounds that render its agricultural use suboptimal, but not impossible if new technologies were developed for fertilizer manufacture (dos Santos, 1981: 178). An additional deposit has been reported at Maicuru, Pará, but estimation of its size is incomplete (Beisiegel and de Souza, 1986). Almost all of Brazil's phosphates are in Minas Gerais, a site very distant from most of Amazonia. Brazil as a whole is not blessed with a particularly large stock of phosphate--the United States, for example, has deposits about 20 times larger

(de Lima, 1976). In Peru, the country's phosphates are located on the Pacific Coast, in the state of Piura (Fenster and León, 1979). On a global scale most phosphates are located in Africa (Sheldon, 1982). Continuation of post-World War II trends in phosphate use would exhaust the world's stocks by the middle of the next century (Smith *et al.*, 1972; United States, CEQ and Department of State, 1980). Although simple extrapolation of these trends is questionable because of limits to continued human population increase at past rates (Wells, 1976), the conversion of a substantial portion of Amazonia to fertilized pasture would greatly hasten the day when stocks of phosphate are exhausted in Brazil and in the world. Brazil would be wise to ponder carefully whether its remaining stocks of this limited resource should be allocated to Amazonian pastures.

[Figure 2 here]

Assumptions regarding the potential of Amazonia as an agricultural resource are key factors in global estimates of human carrying capacity (Fearnside, 1986a). Roger Revelle (1976) calculated that the earth could support 40 billion people, assuming large increases in per-hectare yields and use of all land that he thought "available" (including Amazonia). Revelle's assumptions regarding high input agriculture in Amazonia are at variance with a number of known limitations in the region (see Revelle, 1987; Fearnside, 1987a). The Food and Agriculture Organization of the United Nations (FAO) suggested that the earth could support 36 billion if uncultivated areas (including Amazonia) were converted to US-level agriculture (Pawley, 1971). Denevan (1973), in a reaction to the FAO estimate's assumption of an Amazonia completely converted to agriculture, raised the alarm against the "imminent demise of the Amazon rain forest." Estimates such as those of Pawley (1971) and Revelle (1976) may be the origin of former US president Ronald Reagan's belief that "farm studies" had shown that the earth could support 28 billion people (Holden, 1980: 989).

In the early 1980s, FAO, together with the United Nations Fund for Population Activities (UNFPA) and the International Institute for Applied Systems Analysis (IIASA), calculated that Brazil could support 7 billion people if Amazonia were converted to high-input agriculture (Higgins *et al.*, 1982: 104). Unfortunately, a variety of limitations are overlooked that prevent widespread conversion to high-input agriculture (see Fearnside, 1990). One of the factors leading to the high carrying capacity values the FAO/UNFPA/IIASA study ascribed to Amazonia is the assumption that land quality in uncultivated areas is equal to that in already cultivated ones. The study goes so far as to claim that "there is evidence that the

productivity of the reserves may be higher, but, for the sake of simplicity, it is assumed that the potential productivity of the unused land is the same as that of the land under cultivation" (FAO, 1984: 43). Unfortunately, as is true in most parts of the planet, the best land is brought into cultivation first, with land quality progressively declining in new settlement areas until only very marginal lands remain. In Rondônia, for example, 42% of the land in colonization projects settled in the 1970s was classified by a government soil survey as "good for agriculture with low or medium inputs;" for projects started in the first half of the 1980s, 15% of the land was so classed, while for planned areas the amount is a minuscule 0.13% (Fearnside, 1986b).

Land-use decisions based on permitting the maximum intensity that physical conditions will allow can quickly pass limits in other spheres when individual allocations are considered together. One may examine each cell in a grid in a geographical information system (GIS), comparing the soil, rainfall, etc., with the demands of a given crop, and conclude that each individual cell can be allocated to the use in question, and yet arrive at a global conclusion that is patently unrealistic. This, for example, is the main explanation of the astronomical figures mentioned earlier for human carrying capacity estimates for Amazonia and the world. The implied possibility of converting all or most of the Amazon region to high-input mechanized agriculture runs up against limits of resource availability to supply the inputs. Amazonia has virtually no deposits of phosphates; transporting them is expensive and, when the vast extent of Amazonia is considered, quickly enters into conflict with the absolute limits of this resource. The temptation is strong to view Amazonia as a potential cornucopia capable of solving population and land distribution problems; the limits of applying the intensive agriculture suggested make this a cruel illusion. These limits are best illustrated by the inviability of applying to any significant part of Amazonia the "Yurimaguas technology" for continuous cultivation (see Fearnside, 1987b, 1988; Walker et al., 1987).

The "Yurimaguas technology" is the project to develop continuous cultivation undertaken by North Carolina State University (NCSU), in conjunction with Peruvian institutions, at Yurimaguas, Peru (Sánchez et al., 1982; Nicholaides et al., 1985). Soil depletion is a fundamental problem that becomes increasingly expensive and problematic to correct as time proceeds under continuous cultivation. All nutrients removed in harvested crops or lost through erosion, leaching and other processes must be replaced in the form of fertilizers. The cost of replacing them includes not only the substantial expense of purchasing fertilizers and transporting them to the site, but

also the expense of identifying which elements are missing, and in what amounts, for each field, and communicating this information to the farmer in time to allow correction of the deficiencies before yields are affected. Input limitations set strict bounds on the expansion of all fertilizer-demanding agricultural systems, including agroforestry systems (Fearnside, 1995c).

Markets for the products would restrict the expansion of many land uses (especially perennial crops, such as cacao) that might otherwise be desirable choices from the standpoints of sustainability and environmental impact. Market limits, reflected in falling cacao prices since 1977, make the advantages of cacao (e.g. Alvim, 1981; Smith *et al.*, 1995) unlikely to continue for long even in the small portion of Amazonia that is presently devoted to this land use, let alone in other areas that might be zoned for expansion of cacao plantations.

The most obvious limit to expansion of agriculture and ranching in Amazonia is the area of forest that must be maintained intact. The different forms of land use imply environmental impacts (with distinct levels of impact depending on whether the land use proves to be sustainable). The impact of converting forest to another land use depends not only on the patch of land for which conversion is being considered, but also on what has been done with the remainder of the region. As the cumulative area cleared increases, the danger increases that each additional hectare of clearing will lead to unacceptable impacts. For example, the risk of species extinctions increases greatly as the remaining areas of natural forest dwindle. The role of Amazonian forest in the region's water cycle also implies increasing risk with the scale of deforestation: when rainfall reductions caused by losses of forest evapotranspiration are added to the natural variability that characterizes rainfall in the region, the resulting droughts would cross biological thresholds leading to major impacts (Fearnside, 1995c). These thresholds include the drought tolerance of individual tree species and the increased probability of fire being able to propagate itself in standing forest. Fire entry into standing forest in Brazilian Amazonia already occurs in areas disturbed by logging (Uhl and Buschbacher, 1985; Uhl and Kauffman, 1990). During the El Niño drought of 1982/1983, approximately 45,000 km² of tropical forest on the island of Borneo burned when fires escaped from shifting cultivators' fields. Of the 35,000 km² of this area in the Indonesian province of East Kalimantan, at least 8,000 km² was primary forest, while 12,000 km² was selectively logged forest (Malingreau *et al.*, 1985). In Amazonia, 'mega-El Niño' events have caused widespread conflagrations in the forest four times over the past 2000 years (Meggers, 1994). The effect

of large-scale deforestation is to turn relatively rare events like these into something that could recur at much more frequent intervals. How these dangers are incorporated into land-use decisions greatly influences the carrying capacity of the region for humans. If one assumes that the entire region could be converted to agricultural use without unacceptable consequences, then the carrying capacity one would calculate would be much higher than if one assumes that enough forest must remain intact to keep the risk of environmental catastrophes within defined limits.

D.) TIMBER

Amazonia has a substantial fraction of the remaining tropical timber resources in the world. The number of sawmills and level of timber extraction activity has increased dramatically in recent years, but is still much less than in forest areas in Asia. This is because southeast Asian forests are characterized by a higher density of commercially valuable trees. Southeast Asian forests are dominated by a single plant family (Dipterocarpaceae), making it possible to group the vast number of individual tree species into only a few categories for the purposes of sawing and marketing. In addition, most Asian woods are light in color, making them more valuable in Europe and North America where consumers are accustomed to light woods such as oak and maple. Amazonia's generally dark colored, hard-to-saw, and extremely heterogeneous timber has therefore been spared the pressure of large multinational timber corporations. Asian woods are usually of lower density than Amazonian ones, making them more suitable for peeled veneer (Whitmore and da Silva, 1990). The approaching end to commercially significant stocks of tropical timber in Asia can be expected to change this situation radically. FAO data indicate that, as of 1985, only 2% of internationally traded hardwoods came from all of Latin America, versus 57% from Asia. Before the year 2000, Asian forests are expected to be depleted to the point where they can no longer supply global markets; it seems likely that technologies would be developed to use Amazonian woods--whether consumers like them or not. In 1996, entry of Asian firms began in earnest: Brazil's Central Bank registered the entry of foreign capital totaling US\$ 300 million during the first 10 months of 1996 for investments in the logging industry in Brazilian Amazonia, including land purchases (Amazonas em Tempo, 30 October 1996). Logging firms from Malaysia and China have purchased a total of 4.5×10^6 ha of forest land in the state of Amazonas (Amazonas em Tempo, 2 August 1996). While this author views increasing timber demand as a major threat to Amazonian forests, an alternative view holds that world demand for tropical forest timber may decline due to substitution from plantations (Vincent, 1992).

E.) NON-TIMBER FOREST PRODUCTS

What is known in Brazil as "extractivism," or the harvesting of non-timber forest products (NTFPs) without cutting down the trees, has been practiced in the Amazonian interior since the period of the rubber boom (1888-1913). These systems now form the basis for proposals for "extractive reserves" as a means of maintaining forest (Allegretti, 1990; Fearnside, 1989b). The major justification for promoting the system is its potential for safeguarding the environmental services of the forest, as the resident extractivists have a greater stake than hired guards in defending the forest against ranchers, squatters and loggers.

Non-timber forest products have commercial value, but the serious economic hardships that rubber tappers are now suffering in Brazil with the fall in prices for natural rubber latex is testimony to the limited flows derived at present. Even so, NTFPs can compare well with the dominant human use of most deforested areas in Brazil: cattle pasture. In the Rio Acre Valley in the state of Acre, 62% of deforestation is for pasture, but this produces only 7% of the tax on circulation of merchandise (ICM) collected in this area; by contrast, extractivism resulted in 8% of the deforestation and 84% of the ICM collected (FUNTAC, 1990: 177). It should be noted, however, that the value of extractive products varies tremendously among different parts of Amazonia. Acre is one of the richest places for extractive products marketed at present, such as rubber and Brazil nuts.

An atypical case is the high productivity and local marketing of wild fruits in the area of Iquitos, Peru (Peters, 1990; Vasquez and Gentry, 1989). This situation is exceptional, where a hectare of forest located only 35 km from the second largest market in Amazonia for perishable wild fruits was the source of an estimate that has been widely publicized that a very high monetary value can be obtained from presently marketed products coming from extractivist activities (Peters *et al.*, 1989). A net present value of US\$ 6,820/ha was calculated from timber and non-timber products, managed in perpetuity and discounted at an annual rate of 5%. Only US\$ 490 of this total was from wood. Unfortunately, such a high value for non-timber products cannot be extrapolated to most of Amazonia. Even so, the value of extractivism is substantial (Clay and Clement, 1993; Fearnside, 1989b). In 1980, production of 12 Amazonian extractive commodities had a combined value of US\$ 85.0 million, of which rubber and latex represented US\$ 43.5 million, piassava fibers US\$ 15.7 million, Brazil nuts US\$ 12.8 million, and hearts of palm US\$ 8.4 million (calculated from IBGE data by Allegretti, 1995: 24-26).

F.) CULTURAL RESOURCES

Human societies, especially indigenous peoples, are highly diverse in Amazonia. The cultural practices and knowledge of these groups have value, both as sources of traditional "products" (such as knowledge of medicinal and other uses of natural species) and as values that need to be protected independent of foreseeable benefits with market rewards.

G.) TOURISM

Tourism is one way that intact natural ecosystems can generate monetary flows. Although the flows can be substantial, the fact that most tourists can be satisfied by seeing only relatively small areas of forest poses a limit to this use for vast areas of Amazonia.

H.) SCIENTIFIC RESOURCES

The value of rainforest as a resource for fundamental scientific research has been argued (Budowski, 1976; Jacobs, 1980; Janzen, 1986; Poore, 1976). Like a number of other values of natural ecosystems, this value is only partially reflected in potential market rewards.

I.) ENVIRONMENTAL RESOURCES

1.) Environmental Services as Resources

At present, economic activities in Amazonia almost exclusively involve taking some material commodity and selling it. Typical commodities include timber, minerals, the products of agriculture and ranching, and extractivist products like natural rubber and Brazil nuts. The potential is much greater, both in terms of monetary value and in terms of sustainability, for pursuing a radically different strategy for long-term support: finding ways to tap the environmental services of the forest as a means of both sustaining the human population and maintaining the forest. Estimates of areas of forest in Amazonia are for each country in Table 1.

[Table 1 here]

At least three classes of environmental services are provided by Amazonian forests: biodiversity maintenance, carbon storage, and water cycling. The magnitude and value of these services are poorly quantified, and the diplomatic and other steps through which such services might be compensated are also in their infancy. These facts do not diminish the importance of

the services nor of focusing effort on providing both the information and the political will needed to integrate these into the rest of the human economy in such a way that financial forces act to maintain rather than to destroy the forest (Fearnside, 1997a).

2.) Biodiversity Maintenance

Biodiversity has many types of value, from financial value associated with selling a wide variety of products, to the use value of the products to existence values unrelated to any direct 'use' of a species and its products (Ehrenfeld, 1976). People disagree on what value should be attached to biodiversity, especially those forms of value not directly translatable into traditional financial terms by today's marketplace. While some may think that biodiversity is worthless except for sale, it is not necessary to convince such people that biodiversity is valuable; rather, it is sufficient for them to know that a constituency exists today and is growing, and that this represents a potential source of financial flows intended to maintain biodiversity. Political scientists estimate that such willingness to pay already surpasses US\$20/ha/year for tropical forest (Cartwright, 1985).

3.) Carbon Storage

Carbon storage, in order to avoid global warming through the greenhouse effect, represents a major environmental service of Amazonian forests. The way that this benefit is calculated can have a tremendous effect on the value assigned to maintaining Amazonian forest. As currently foreseen in the Framework Convention on Climate Change (FCCC), maintaining carbon stocks is not considered a service--only deliberate incremental alterations in the flows of carbon. Even considering only this much more restrictive view of carbon benefits, the value of Amazonian forests is substantial. In 1990 (the year to be used as a baseline for assessing changes in greenhouse gas emissions), Brazil's 13,800 km²/year rate of deforestation was producing net committed emissions of 263 million metric tons (t) of CO₂-equivalent carbon per year (Fearnside, 1997b). The benefit of slowing or stopping this emission is, therefore, substantial. For comparison, the world's 400 million automobiles emit 550 million t of carbon annually (Flavin, 1989: 35).

Although a wide variety of views exists on the value of carbon, already enacted carbon taxes of US\$ 45/t in Sweden and the Netherlands and US\$ 6.1/t in Finland indicate that the "willingness to pay" for this service is already substantial. This willingness to pay may increase significantly in the future

when the magnitude of potential damage from global warming becomes more apparent to decision-makers and the general public. At the level indicated by current carbon taxes, the global warming damage of Amazon deforestation is already worth US\$ 1.6-11.8 billion/year. The value of the global warming damage from clearing a hectare of forested land in Amazonia (US\$ 1,200-8,600) is much higher than the purchase price of the land today (see Schneider, 1994). The calculations in the present paper use US\$ 7.3/t C as the value of permanently sequestered carbon (the "medium" value from Nordhaus, 1991).

On many fronts, one of the major challenges to finding rational uses for Amazonian forest lies in gathering and interpreting relevant information. Making environmental services of the forest into a basis for sustainable development is, perhaps, the area where information is most critical. When comparisons are made among options for combating global warming, avoiding deforestation is much less frequently the approach chosen than, for example, planting trees in silvicultural projects. Even though the potential benefit of avoiding deforestation may be many times higher and the cost per ton of carbon much lower than in tree-planting schemes, the latter is more convincing to those who make the choice, in part because of the greater certainty associated with plantations. Past experience allows reasonable assurance that investing a given amount in tree planting will sequester the promised amount of carbon, whereas no such assurance can be had that after investing in trying to slow deforestation there will be a given number of hectares less clearing in Amazonia. Providing better understanding of the dynamics of deforestation, as well as understanding of deforestation's impacts on biodiversity, carbon storage and water cycling, is a necessary starting point on the long road to turning environmental services into a basis for sustainable development in Amazonia.

4.) Water Cycling

Water cycling is different from biodiversity and carbon in that impacts of deforestation in this area fall directly on Brazil rather than being spread over the world as a whole. Several independent lines of evidence indicate that about half of the rainfall in the Brazilian Amazon is water that is recycled through the forest, the rest originating from water vapor blown into the region directly from the Atlantic Ocean (Shukla et al., 1990). Because recycled water is 50%, the volume of water involved is the same amount as one sees flowing in the Amazon River. The Amazon is by far the world's largest river in terms of water flow--over eight times larger than the second largest, Africa's Zaire River. Part of the water vapor is transported to

Brazil's Central-South Region, where most of the country's agriculture is located. Brazil's annual harvest has a gross value of about US\$ 65 billion, and dependence of even a small fraction of this on rainfall from Amazonian water vapor would translate into a substantial value for Brazil. Although movement of the water vapor is indicated by global circulation models (Eagleson, 1986; Salati and Vose, 1984), the amounts involved are as yet unquantified.

III.) TURNING RESOURCES INTO DEVELOPMENT

Total annual values of environmental services for biodiversity, carbon and water cycling are summarized in Table 2. The total value of US\$ 55 billion/year for the forests of Greater Amazonia is sufficient to serve as a basis for sustainable development, even if the amounts that can be collected and applied should be considerably lower than the value calculated here.

[Table 2 here]

The term "development" implies a change, usually presumed to be in the direction of improvement. What is developed and whom the improvement should benefit are items of widely differing opinions. This author holds that in order to be considered "development", the change in question must provide a means to sustain the local population. Infrastructure that does not lead to production is not development (such as swimming pool complexes built for small towns in the interior of Roraima prior to a recent election), nor is a project that exports commodities from the region while generating minimal employment or other local returns (perhaps Aluminum processing and export provides the best example).

Production of traditional commodities often fails to benefit the local population. Conversion of forest to cattle pasture, the most widespread land-use change in Brazilian Amazonia, brings benefits that are extremely meager (although not quite zero). High priority must be given to redirection of development to activities with local level returns that are greater and longer lasting. Tapping the value of environmental services offers such an opportunity. Keeping benefits of these services for the inhabitants of the Amazonian interior is the most important challenge in turning these services into development (Fearnside, 1997a).

IV.) CONCLUSIONS

Amazonia has tremendous resources, but, in many cases, exploitation of these brings little benefit to local populations in the region. Limits of various kinds restrain the area and the intensity of resource exploitation. Use of one resource often precludes obtaining the benefits of other resources, as when the benefits of forest are lost when areas are converted to cattle pasture. Environmental services of standing forest represent a major potential source of value that is presently unrewarded by the world economy. The challenge of turning environmental services into a means of supporting the human population in the region and maintaining the forest should be the top priority in efforts to develop Amazonian resources.

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FIGURE LEGENDS

- Figure 1 --
- A.) Amazon drainage basin, including Tocantins/Araguaia and Amapá coastal rivers.
 - B.) Amazonian forest vegetation (based on Harcourt et al., 1996 and Daily and Prance, 1989).
 - C.) Greater Amazon (based on TCA, nd [1992]) with addition of coastal region of Guyana.
 - D.) Brazil's Legal Amazon region with state boundaries.
- Figure 2 --
- Phosphate mines and deposits in Amazonian countries (based on Beisiegel and de Souza, 1986, de Lima, 1976 and Fenster and León, 1979).

TABLE 1: AREAS OF AMAZONIAN FOREST BY COUNTRY

Country	Estimated area remaining (km ²)	Year of estimate	Source
Bolivia	454,197	1992	CDC-Bolivia, unpublished, cited by Nagashiro <i>et al.</i> , 1996: 222
Brazil	3,526,046	1994	Based on Brazil, INPE, 1996 and Fearnside, 1993
Colombia	323,493	1982	IGAC-INDERENA-CONIF, 1984; see Paez <i>et al.</i> , 1996: 251
Ecuador	30,000	1988	Cabarle <i>et al.</i> , 1989, cited in Suarez <i>et al.</i> , 1996: 265
French Guiana	81,490*	1979	Sabatier <i>et al.</i> , 1996: 271
Guyana	183,025*	1992	Brown <i>et al.</i> , 1996: 280
Peru	698,521	1991	de Freitas <i>et al.</i> , 1996: 295, based on PNAF, 1991
Suriname	133,284*	1978	Werkhoven <i>et al.</i> , 1996: 305
Venezuela	542,682*	1982	Franco <i>et al.</i> , 1996: 314
TOTAL	5,972,738		

* Whole country estimate

TABLE 2: VALUES OF ENVIRONMENTAL SERVICES IN AMAZONIAN COUNTRIES

Country	Forest area in 1990 (10 ³ ha) ^a	Average total biomass of forest (t/ha) ^b	Carbon stock at risk in biomass and soil (10 ⁹ t C) ^c	Annual value of carbon storage @5%/year (10 ⁹ US\$) ^d	Annual value of biodiversity maintenance (10 ⁹ US\$) ^e	Annual value of water cycling (10 ⁹ US\$) ^f	Total annual value of environmental services (10 ⁹ US\$)	Total annual value for Greater Amazon (10 ⁹ US\$) ^g
Bolivia	49,317	269	6.2	2.3	1.0		3.2	3.0
Brazil	561,107	339	90.0	32.8	11.2	6.5	50.6	34.2
Colombia	54,064	349	9.0	3.3	1.1		4.4	2.6
Ecuador	11,962	353	2.0	0.7	0.2		1.0	0.2
French Guiana	7,997	561	2.2	0.8	0.2		1.0	1.0
Guyana	18,416	444	3.9	1.4	0.4		1.8	1.8
Peru	67,906	423	13.8	5.0	1.4		6.4	6.6
Suriname	14,768	464	3.3	1.2	0.3		1.5	1.4
Venezuela	45,690	339	7.3	2.7	0.9		3.6	4.3

TOTAL	831,22 7	137.6	50.2	16.6	6.5	73.4	55.0
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^a FAO, 1993.

^b FAO, 1993, with adjustments in Fearnside, 1994, nd. Adjustments to above-ground biomass for dead material, trees <10 cm DBH, form factor, palms, vines, other non-tree components, and hollow trees total 48%. Root/shoot ratio = 0.31 (Fearnside, nd). Because FAO biomass data are not reported separately by forest type or political unit, values are for all forests in the country (not only the Amazonian portion).

^c Fearnside, nd, updated from Fearnside 1994. Carbon content= 50% (Fearnside et al., 1993); soil carbon loss in top 20 cm = 3.92 t C/ha converted to pasture (Fearnside, 1985, 1997b); replacement landscape average total biomass carbon = 28.5 t C/ha (Fearnside, 1996).

^d See Fearnside, 1997a.

^e At US\$20/ha/year (Cartwright, 1985).

^f Assuming 10% of gross value of Brazilian harvest depends on Amazonian water (Fearnside, 1997a).

^g Assumes forest areas in Greater Amazon (based on Table 1) have same biomass and biodiversity value per ha as the average for all forests in each country. The water cycling value in Brazil is assumed to be all Amazonian.