

The Impacts of Forest Degradation on Medicinal Plant Use and Implications for Health Care in Eastern Amazonia

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Over the last three decades, forest degradation in the Brazilian Amazon has diminished the availability of some widely used medicinal plant species. Results of a 9-year market study suggest that forests represent an important habitat for medicinal plants used in eastern Amazonia: Nine of the twelve top-selling medicinal plants are native species, and eight are forest based. Five of the top-selling species have begun to be harvested for timber, decreasing the availability of their barks and oils for medicinal purposes. Many of these medicinal plants have no botanical substitute, and pharmaceuticals do not yet exist for some of the diseases for which they are used. Market surveys indicate that all socioeconomic classes in Amazonia use medicinal plants because of cultural preferences, low cost, and efficacy. Degradation of Amazonian forests may signify not only the loss of potential pharmaceutical drugs for the developed world but also the erosion of the sole health care option for many of Brazil's rural and urban poor.

Keywords: medicinal plants, health care, nontimber forest products, deforestation, Amazonia

Plant-based remedies are regularly hailed by the popular media and the conservation community to support the notion that the tropics' diverse floral resources are an invaluable and largely untapped source of new pharmaceutical products. Such discussions frequently emphasize the importance of medicinal plants in the Brazilian Amazon—the largest contiguous reservoir of forest on Earth. Notably, although these discussions highlight the global consequences of biodiversity loss for pharmaceutical development, they rarely mention the local consequences of biological impoverishment for the health care of millions of Amazonians who depend on plant-based medicinals.

More than 80% of the developing world continues to rely on traditional medicines, predominantly plants, for primary health care (Farnsworth et al. 1985). In Amazonia, medicinal plants serve as the main form of health care for a majority of the populace, in part because of cultural preference and also because of the prohibitive cost of pharmaceutical products. For large numbers of rural and urban poor people in this region, medicinal plants offer the only available treatments for both minor and serious ailments (Elisabetsky and Wannamacher 1993).

Although tropical medicinal plants are lauded by the international media and used by millions of Brazilians, field research on the ecology of medicinal plants in the Brazilian Amazon has been surprisingly limited. The ethnobotanical literature on the Amazon includes a number of excellent botanical and biochemical studies of medicinal plants (Albuquerque 1989, Schultes and Raffauf 1990, van den Berg

1993, Duke and Vásquez 1994). However, with few exceptions (Phillips 1990, Martini et al. 1994), very little has been published on either the ecology of Amazonian medicinals or the implications of deforestation for individual medicinal species. The current unprecedented governmental and civic concern for sustainable land use in the Brazilian Amazon (Veríssimo et al. 2002a, 2002b) offers a timely opportunity to evaluate the links between forest conservation and national health care (Balick et al. 1995, Vieira 2002).

In eastern Amazonia in particular, the rapid expansion of logging, ranching, mining, and agricultural conversion has brought about significant changes in forest composition and structure (Hecht 1985, Uhl et al. 1991, Veríssimo et al. 1992, Cochrane et al. 1999, Gerwing 2002). Among other things, new land-use regimes place increasing pressure on many native medicinal plant species (Caniago and Siebert 1998, Cunningham 2000). To comprehend how these changes affect the availability of plant medicines and the future of

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local health care, a number of questions need to be considered: What types of medicinal plants are most widely used in eastern Amazonia? Are they native or exotic, cultivated or collected from forests? Have recent logging activities and other land-use changes threatened the continued availability of medicinal plants? Whether medicinal plants that are widely used in Amazonia are herbaceous “weeds” or native forest-based species holds clear implications for phytomedically based conservation claims (Stepp and Moerman 2001).

In this article, we examine the marketing of medicinal plants in eastern Amazonia to provide an overview of which plants are being used, where they come from, and how their relative availability is changing. By collecting basic statistics on the medicinal plant trade in the region’s main commercial center of Belém, we found that many widely traded species—at least in urban areas—are native to Amazonia and harvested from mature forests. During the last several years, deforestation has forced many of Belém’s medicinal plant traders to rely on increasingly distant sources for the roots, barks, and exudates that they sell. Could the declining availability of some native plant-based medicines in eastern Amazonia reduce access for some of the region’s population to a basic component of their health care?

To address this question, this article begins with a description of the research site, study methods, and findings regarding the most widely used medicinal plants; the illnesses for which they are used; their sources, volumes, and prices; and a brief description of consumers and collectors. Attention then turns to some factors affecting the availability of medicinal plants, including logging, expansion of secondary forests (woody vegetation regenerated after significant disturbance of the original forest), and harvesting and management. The article concludes with recommendations for conservation of locally valuable medicinal species.

The medicinal plant marketplace

Located near Brazil’s eastern coast where the Amazon River empties into the Atlantic, Belém is the capital of the state of Pará and the principal port city of eastern Amazonia. The city, which has a population of 1.7 million, is the site of the long-established open-air river market, Ver-o-Peso, where close to 100 tightly crammed booths display fresh plant material, tonics, roots, oils, tree barks, and animal parts (van den Berg 1993). In addition to their sale at the Ver-o-Peso market, medicinal plants from a wide geographic area are also sold in shops, on curbsides (figure 1), and alongside pharmaceuticals in drugstores. Offering a vast array of plant-based medicines, these outlets provide treatments for both minor and serious ailments for a significant portion of the region’s population—particularly poor people.

As the center of the region’s medicinal plant trade, the Belém market offers unique opportunities to gain information from both harvesters and sellers about the diversity, sources, and volumes of plants being bought and sold; about urban consumers and their medicinal plant preferences; and, to a limited extent, about the possible consequences of

deforestation and overharvesting for widely used species (Bye 1986, Martin 1992). A major constraint in obtaining information about medicinal plants in the marketplace, however, lies in the difficulty of identifying many of the species being sold. In many medicinal plant shops, piles of barks, roots, and herbs are unlabeled and lack identifying characteristics of fruit, flower, or leaf. When labels are present, they denote the plants’ common names, some of which are used for a variety of species. Although customers from rural areas are often familiar with the colors, textures, and smells of plant material, accidental errors in plant identification as well as deliberate deception do occur. For instance, bark or root material from common plants may be intentionally misrepresented as that from less abundant, costlier species. The true identity of the species can be determined only by obtaining voucher specimens of individual plants.

Gathering data on plant sales and buyers’ preferences

To assess the range of plants sold in downtown Belém, at the outset of the study we conducted a baseline survey of 23 medicinal plant establishments. We recorded the common names of more than 200 medicinal herbs, shrubs, and trees and asked two regional botanical authorities to check them to determine the origin of the plants. We then interviewed store managers and vendors to gather information on plants in greatest demand, prices, sources, volumes, numbers of



Figure 1. Sidewalk sale of widely used medicinal barks and herbs in Belém, Brazil. Photograph: © 1993 Patricia Shanley.

employees and customers, and changes in demand and sourcing. Intermittent inventories of sales at leading medicinal plant outlets provided an indication of customer demand, sales trends, and composition of the consumer population.

To determine which species of plants were in particularly high demand, we tabulated plants occurring with greatest frequency in all 23 establishments and cross-checked this list with the list of plants that store managers indicated were most popular. To ascertain the genus and species of the resultant list of leading medicinal plants, we followed a team of commercial collectors into the forest and obtained voucher specimens, which are now housed in the herbarium of EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), Belém. Because consumers obtain medicinal plants from a multitude of formal and informal venues, we conducted a socioeconomically stratified survey of 200 households in Belém to gauge the extent of nonmarket sourcing of medicinal plants.

Biennial interviews over the course of 9 years (1994–2002) with owners and vendors of three leading medicinal plant outlets and two wholesalers permitted us to detect trends in plant sales and determine those species for which demand remained stable. Furthermore, Belém's phytomedical industry grew markedly throughout the study period, and manufacturers began processing highly sought-after plants into capsules and pills. The subset of medicinal species selected for such processing provided an additional indication of which species were widely used.

Despite these indications of high demand, the ranking of species in this study has shortcomings because medicinal plants are procured in a multitude of outlets, whereas this study focused specifically on medicinal booths and shops. For example, herbs, teas, and plants that have both culinary and medicinal uses are commonly purchased in food outlets, which were not included in the inventory. In addition, the study focused on sales venues in the center of the city. During the course of our research, dozens of small medicinal plant shops, homeopathic stores, and outdoor vendors marketing botanical remedies sprang up throughout Belém.

Widely used medicinals

An inventory of medicinal plants in 23 establishments in downtown Belém revealed 211 different common names of medicinal herbs, shrubs, and trees. This is less than the 352 species recorded in van den Berg's 1965–1984 study (1984), in part because our study records only plants whose principal use is medicinal and thus excludes the substantial number of edible and ornamental plants possessing secondary uses as medicinals.

Of the 211 medicinal species sold, we found that approximately half (45%) are native to the Amazon. The specific parts of plants being sold included leaves, fruits, flowers, seeds, inner and outer barks, and exudates. Of the twelve leading species sold (table 1), nine are native to Amazonia. Eight of these occur in primary forests, and five are also extracted for timber.

Barks, roots, and oils for sale in Belém's markets are harvested principally from native tree and shrub species. Many of these occur in northern Brazil, especially in the states of Pará, Maranhão, and Amazonas. By contrast, fresh herbs sold in the medicinal markets in Belém are often nonnative, cultivated species supplied by small producers from nearby islands and suburbs.

Despite the difficulties associated with identifying medicinal plants, taxonomists verified 11 of the 12 top-selling plants obtained by one pair of commercial collectors. The one that was hard to identify was *barbatimão*. The name *barbatimão* is used for a variety of plants possessing different morphological characteristics. Although different species, genera, and families are called *barbatimão*, the barks of these varied species are widely believed to have curative properties for internal inflammation. This belief may be founded in the use of a special-purpose folk classification system (Balée and Daly 1990) and in the fact that many popularly sold barks are rich in tannins and therefore have anti-inflammatory properties (Brito 1992).

From 1994 to 2002, 11 of the 12 species remained leading sellers. In 2000, sales of one species, *Croton cajucara*, declined sharply as the result of publicized claims that excessive use could lead to toxicity. During the 9-year period, sales of the other leading medicinal plants increased, in part because of changes in the form in which products were sold. To meet increasing demand and satisfy customers who prefer processed medicinals, each of these plants became widely available not only in its crude form but also as more costly capsules (pão d'arco, sacaca, guaraná, copaíba, andiroba, barbatimão, quebra pedra); powders (pão d'arco, guaraná, marapuãma, quebra pedra, barbatimão, verônica); liquid medications (verônica, andiroba, sucúba, barbatimão, marapuãma); shampoo (amor crescido); and drinks (mastruz, guaraná). Sales venues for these products expanded to include the Internet, gas stations, supermarkets, and increasing numbers of pharmacies, sidewalk vendors, and homeopathic shops.

Illnesses treated

A closer examination of the purported utility of some of the top-selling plant species may help explain why certain species are highly prized and habitually used. In the course of our interviews, users maintained that these species effectively treat commonplace illnesses (e.g., worms, urinary infections, burns, coughs, cuts, sprains, fatigue) at relatively low cost. Worms are routinely treated with *Chenopodium ambrosioides* (mastruz), kidney and urinary problems with *Phyllanthus niruri* (quebra pedra), burns with *Portulaca pilosa* (amor crescido), and fatigue and lack of energy with *Paullinia cupana* (guaraná). Locally called "nature's antibiotic," copaíba oil from *Copaifera* spp. is used for cuts and abrasions, acting as a cicatrizant (i.e., promoting scar formation) and anti-inflammatory (Mors 1982). Andiroba oil from *Carapa guianensis* is topically applied to treat sprains and rheumatism (arthritis) and to repel insects (figure 2; Shanley et al. 1998,



Figure 2. Oil from *Carapa guianensis* (*andiroba*) seeds is used as an insect repellent and to alleviate sprains and arthritis. Oil is extracted from seeds and processed longer than a month to produce the oil. Photograph: © 1994 Patricia Shanley.

Shanley and Medina forthcoming). In both rural and urban areas, gynecologically related problems such as vaginal infections are commonly treated with *Dalbergia subcymosa* (*verônica*).

Some of the leading plants are used not only to heal common ailments but also to treat diseases for which effective pharmaceutical medications do not yet exist (Vieira 1991). *Tabebuia impetiginosa* (*pãu d'arco*) is taken to treat gastric ulcers and internal inflammation and to arrest the growth of tumors. *Himatanthus sucuuba* (*sucuúba*) is used against herpes. *Ptychopetalum olacoides* (*marapuãma*) is locally (Amazonia) employed against impotence and diseases of the nervous system. In studies in rodents, extracts from *Pt. olacoides* have shown encouraging results against experimentally induced tremors (Elisabetsky et al. 1992, Siqueira et al. 1998). *C. cajucara* (*sacaca*) is taken for diabetes and to lower cholesterol and promote weight loss, and loss of hair is treated with *Po. pilosa* (*amor crescido*).

Sufficient phytochemical and pharmacological research has not been conducted to verify the efficacy of most of the native species (*guaraná*, *marapuãma*, *pãu d'arco*, *sucuúba*, *sacaca*, *copaíba*, *andiroba*, *verônica*) mentioned above, in

Table 1. Twelve leading medicinal plants sold in Belém, Brazil, 1994–2002.

Scientific name (family)	Common name	Collection number	Plant part used, plant habitat	Principal uses
<i>Carapa guianensis</i> Aublet (Meliaceae)	Andiroba	435	Seed oil, native tree	Sprains, bruises, insect repellent, rheumatism
<i>Chenopodium ambrosioides</i> L. (Chenopodiaceae)	Mastruz	471	Leaf or seed, nonnative herb	Worms, bronchitis
<i>Copaifera reticulata</i> Ducke (Caesalpiniaceae)	Copaíba	452	Oleoresin, native tree	Wounds, sore throat
<i>Croton cajucara</i> Benth. ^a (Euphorbiaceae)	Sacaca	440	Bark or leaf, native tree	Diabetes, cholesterol
<i>Dalbergia subcymosa</i> Ducke (Fabaceae)	Verônica	442	Inner bark, native vine	Vaginal infections, uterine inflammation
<i>Himatanthus sucuuba</i> (Spruce) Woods. (Apocynaceae)	Sucuúba	454	Bark or exudate, native tree	Worms, herpes, uterine inflammation
<i>Paullinia cupana</i> Kunth. (Sapindaceae)	Guaraná	473	Seed, native shrub	Stimulant, diuretic, weakness
<i>Phyllanthus niruri</i> L. (Euphorbiaceae)	Quebra pedra	472	Root, nonnative herb	Urinary infections, kidney stones
<i>Portulaca pilosa</i> L. (Portulacaceae)	Amor crescido	470	Leaf, nonnative herb	Burns, wounds, diuretic
<i>Ptychopetalum olacoides</i> Benth. (Olacaceae)	Marapuãma	474	Root, native shrub	Nerve diseases, impotence
<i>Stryphnodendron barbatiman</i> Mart. (Mimosaceae)	Barbatimão	437 450	Bark, native tree	Hemorrhage, uterine and vaginal infections
<i>Tabebuia impetiginosa</i> Standley (Bignoniaceae)	Pãu d'arco Ipê roxo	475	Bark, native tree	Inflammations, ulcers, skin ailments

Note: Plant specimens were collected by Patricia Shanley and identified by Nelson A. Rosa and José Maria de Albuquerque.
a. *Croton cajucara* remained a leading seller only until 2000.

part because of their extremely complex biochemistry. Nevertheless, urban and rural Amazonians routinely use particular plants for specific illnesses and staunchly maintain claims of their effectiveness.

Although 11 of the 12 species remained leading sellers throughout the 9-year study period, changes in both supply and demand occurred. Whereas every shop owner interviewed said that demand for medicinal plants had increased steadily, some reported that the availability of particular roots, barks, and oils harvested from native tree species such as *Tabebuia* spp. had decreased, a possible result of diminishing access caused in part by deforestation. Collectors and vendors note that local sources of copaiba oil have markedly declined and the root of *Pt. olacoides* (marapuãma), a species occurring in low densities in mature forest, has become more difficult to obtain.

Although access to some medicinal plant products obtained from native trees may have diminished in recent years, cultivation of one of the species naturally occurring in forests, the shrub *Pa. cupana*, has allowed producers and vendors to meet surging demand for this internationally recognized “energy booster.” Cultivation of herbaceous medicinal plants such as *Ch. ambrosioides*, *P. niruri*, and *Po. pilosa* has also created significant employment in the peri-urban area of Belém. To meet increasing demand from urban consumers, smallholders in Belém environs cultivate and sell fast-growing herbaceous species, many of which are naturalized exotics.

Demand increased not only for locally cultivated plants and native tree species; during the study period, popular radio and television programs featuring “miracle” cures for cancer and other ailments began to fuel sales of less familiar, exotic species. After one such program, feverish demand swept the city for leaves of *Aloe vera*, a plant introduced from Africa. In 1999, when individual leaves sold for the equivalent of about US \$1, even impoverished mothers scraped together enough change to offer the prescribed daily dose of leaf, honey, and sugarcane alcohol to their sick children.

Price and volume

Prices that consumers, particularly poor people, are willing to pay for medicinal plants offer one indication of the plants’ perceived value. In the Belém market, the price of medicinal plants varies widely, depending on the sellers, species’ availability, and demand. As a general rule, collectors receive half or less of the final selling price of crude medicinals, with wholesalers and middlemen largely dictating the transaction price. Price also varies widely according to species, as some select species cost two to three times more than other medicinal species. Currently, most packets of herbs or bark, which weigh about 200 and 700 grams, respectively, cost the consumer the equivalent of between US \$0.40 and US \$1.00. However, prices have risen for some species that have become difficult to find as a

result of overharvesting or pressures from other forms of land use, such as logging. Between 1994 and 2000 in Belém, the price of good quality copaiba oil doubled to reach roughly US \$8.00 per liter, reflecting its growing scarcity.

Prices and demand for particular plants also change as species come in and out of fashion. For example, although *Pt. olacoides* costs twice as much per unit as many other plants do (US \$1.20 for a small piece of root), it remains tremendously popular as “Amazonian Viagra.” *Tabebuia* spp., which have been used for many years by rural peoples in the region, have recently gained an international following for the treatment of gastric ulcers and tumors. As a result of rising popularity in 1999, 1 kilogram of *C. cajucara* bark cost approximately twice as much as the same quantity of other medicinal barks. However, sales plummeted and stocks were pulled from shelves in 2001 after a television program alleged that collateral effects contributed to the death of habitual users. Although *C. cajucara* bark was one of the top-selling plants until 2000, it is now absent from many of Belém’s medicinal plant outlets.

Despite conflicting claims of efficacy and fluctuating prices, consumers continue to seek out select medicinal plants. Although some plants are costlier than others, customers insist (and their spending patterns indicate) that other, less costly plants may not serve as substitutes. In most cases, however, medicinal plants are significantly cheaper than pharmaceuticals. Research conducted as part of this survey revealed that, on average, some herbaceous plants with pharmacologically demonstrated effectiveness—such as *Ch. ambrosioides* (for expulsion of intestinal worms) (Okuyama et al. 1993), *P. niruri* (for urinary tract infections) (Melo et al. 1988), and *Bryophyllum calycinum* (for burns) (Nassis et al. 1991)—cost four times less per unit than their pharmaceutical counterparts.

To meet the needs of the very poor, bark can be purchased in small quantities and oils and honeys are sold by the spoonful. Although such small volumes might seem trivial, a great number of sales occur on a daily basis. Modest stores and laboratories may attend to more than 50 clients an hour. According to store records and interviews in seven leading medicinal plant outlets in Belém (one wholesaler, five shops, and the Ver-o-Peso market), in 1994 their collective annual sales of the bark called pãu d’arco exceeded 9 metric tons, while combined sales of five medicinal barks totaled approximately 30 tons (table 2). By 2002, combined sales of these medicinal barks in seven principal downtown outlets doubled to

Table 2. Annual volume (in kilograms) of five medicinal plants sold by seven principal outlets in Belém, Brazil, 1994 and 2002.

Common name	Possible species	1994	2002
Barbatimão	<i>Stryphnodendron barbatiman</i>	6130	17,100
Marapuãma	<i>Ptychopetalum olacoides</i>	4215	9200
Pãu d’arco, ipê roxo	<i>Tabebuia impetiginosa</i> or <i>T. serratifolia</i>	9355	13,900
Sacaca	<i>Croton cajucara</i>	6270	2225
Sucuúba	<i>Himatanthus sucuuba</i>	3920	16,250



Figure 3. *Copaíba* and other medicinal oils and tree exudates for sale at a medicinal plant shop in Belém. In rural areas, where cuts and abrasions are common, *copaíba* serves as “nature’s antibiotic.” From 1999 to 2000, sales of phytotherapeutics in Brazil rose 15%, as compared with a 4% increase for synthetic medicines (John 2002). Photograph: © 1995 Patricia Shanley.

reach close to 60 tons. Combined sales of the regionally popular oils andiroba and *copaíba* in principal outlets reached an estimated 10,000 liters in 1994 and tripled to 30,000 liters in 2002 (figure 3).

Buyers, sellers, and collectors

Within the city of Belém, store records, interviews, and direct observation suggest that the principal medicinal plant outlets in the downtown area conduct more than a million sales per year. However, this figure does not include the substantial sales occurring throughout the greater metropolitan area or the significant nonmarket consumption of medicinal plants. In a survey of medicinal plant usage undertaken as part of this research, we surveyed 200 households in different neighborhoods of Belém representing three socioeconomic classes (lower, middle, and upper). We found that 45% of city households surveyed obtained medicinal plants by direct collection, cultivation, or swapping with friends and neighbors. This high degree of subsistence use of medicinal plants within the city represents only a small fraction of the nonmarket sourcing of plants by millions of rural Brazilians who prefer plant-based medicines or have little or no access to alternative treatments.

Interviews and observations of both buyers and sellers confirmed that members of all strata of Brazilian society—including rural immigrants, poor city residents, and wealthy

urban merchants—commonly use medicinal plants. In addition to their widespread use within Amazonia and Brazil, increasing numbers of locally valued medicinal plants have existing or growing markets outside the region and overseas, primarily in the herbal or botanical medicine markets (ten Kate and Laird 1999). Native Amazonian species currently capturing an international market include *pão d’arco*, *marapuãma*, *jatobá*, *guaraná*, and *copaíba*. Reliable export statistics are unavailable for many of the marketed medicinals, but according to vendors in Belém, international export of medicinal plants is intermittent and for most species does not yet compete with domestic supply. However, increased export of forest-based medicinal plants, specifically barks and exudates of long-lived tree species that are not currently managed, could affect their future availability for local and domestic health care (Silva et al. 2001).

With growing demand for medicinal plants, high unemployment rates, and a weak health care system, the socioeconomic contribution of medicinal plant collection and sale in Belém is significant. Hundreds of men and women make part of their living collecting, planting, transporting, processing, or selling medicinal plants. Because of the scattered distribution, low densities (Clement et al. 1999), and lack of domestication of many native medicinal plants, collecting forest-based medicinals remains largely an individual and family-based activity. Commonly, men collect forest medicinals and women process them into medications. Collectors bring their products to the city on trucks, boats, buses, and bicycles, where they sell their wares to wholesalers and retailers.

Close to the city, individual collectors have created bicycle and walking trails through secondary forests located on the fringes of the suburbs. Experienced collectors claim that 15 years ago, in secondary forests within 50 kilometers (km) of the city, it was possible to secure many species of bark within a half day, whereas it now takes a full day or more just to locate individual plants of some of the top-selling species. To meet demand, collectors report that they must constantly seek the bark of *sucuúba*, *copaíba*, *andiroba*, *barbatimão*, and *pão d’arco*. As native species within a few hundred kilometers of the city disappear because of deforestation, collectors are left with only one, temporary source of certain valuable medicinal barks—sawmills.

Changing land use and factors affecting the availability of medicinals

Recent transformations of eastern Amazonian forests through fire (Uhl and Kauffman 1990, Cochrane et al. 1999), selective logging (Martini et al. 1994), ranching (Hecht 1985, Uhl et al. 1988, Nepstad et al. 1991), and shifting agriculture (Vieira et al. 1996) have caused accompanying changes in forest composition and structure (Uhl et al. 1991, Gerwing 2002). These changes have affected the availability of medicinal plant products as well as other economic plant species. Members of many forest-based communities relate that trees producing medicinal oils and exudates and barks of certain timber species that have been extracted from area forests are

particularly difficult to find. Slow-growing mature forest species that occur in low densities and have preferred habitat requirements are especially vulnerable (Peters 1994, Cunningham 2000).

One consequence of the high biodiversity characteristic of Amazonia is the low density of any one species. Many widely employed medicinal tree species occur in densities of less than one individual per hectare (e.g., *Hymenaea courbaril*, *Tabebuia* spp., *Copaifera* spp., *Dipteryx odorata*) (Clay and Clement 1993, Clement et al. 1999). Copaíba oil marketed in Belém comes from ever-increasing distances because of its naturally low densities and a decline in local sources as a result of logging and destructive harvesting techniques. The copaíba oil sold in one of Belém's largest medicinal plant establishments is harvested from the neighboring state of Amazonas, 1200 km away. However, in some cases, local management of preferred species can increase their abundance. For example, rural residents often guard stands of the medicinal oil tree *Ca. guianensis*, plant the tree in their home gardens, and tend it when it sprouts spontaneously (figure 4).

Logging. In terms of overall volume, the raw material most often exported from medicinal species in the eastern Amazon is not medicinal bark, roots, or oil, but wood. Indeed, the eastern Amazon has emerged as Brazil's dominant source of sawn timber during the last three decades, with production increasing from 4.5 million cubic meters in 1976 to 28 million cubic meters in 1998 (Veríssimo et al. 2002b). Of the 300 species logged in eastern Amazonia, one-third are also valued for food, medicines, and gums and resins (figure 5; Martini et al. 1994). Of the five leading primary forest tree medicinals sold, three are exported for timber. *Ca. guianensis* (andiropa), of the mahogany family, and *Tabebuia* spp. are especially prized: Between 1987 and 1997 approximately 140,000 cubic meters of *Ca. guianensis* and 75,000 of *Tabebuia* spp., respectively, were exported from Belém (AIMEX 1994, 1999). Moreover, export statistics represent only a small fraction of what is actually logged; domestic consumption accounts for approximately 86% of the roundwood produced in Brazil (Smeraldi and Veríssimo 1999).

Although this rapid expansion of the timber industry has brought about a decline in the availability of some medicinal species that are also harvested for wood, it has also produced concentrated, albeit short-term, sources of medicinal barks. Bark of timber species no longer found standing within a 200 km radius of Belém, therefore, are often "harvested" as byproducts from the region's many sawmills. These medicinal barks include those of *Hy. courbaril*, *T. impetiginosa*, *Ca. guianensis*, and *Copaifera* spp. (figure 6).

Forests transformed to fallow. As mature forests within reach of Belém have been logged, collectors relate that they have increasingly turned to secondary forests to supply native medicinal plant material. Studies throughout tropical and temperate regions show that medicinal species can be well represented in disturbed landscapes, successional areas, and



Figure 4. The seeds of *Carapa guianensis* (andiropa) yield a valuable medicinal oil used widely throughout Amazonia. Dubbed "bastard mahogany" because of the color and grain of its wood, the species is heavily logged. Photograph: © 1996 Patricia Shanley.



Figure 5. One-third of the 300 species logged in eastern Amazonia are also valued for food, medicines, and gums and resins. When rural communities sell timber, they often lose valuable fruit, medicinal, and game-attracting species. Photograph: © 1997 Patricia Shanley.



Figure 6. Community members stripping medicinal bark from a log of *Hymenaea courbaril* (*jatobá*) prior to shipping the logs downriver to the sawmill. The bark and exudate of *jatobá*, a species considered to be threatened, are used medicinally as a restorative tonic and to combat flu. Photograph: © 1996 Patricia Shanley.

managed vegetation (Alcorn 1984, Balick and Mendelsohn 1992). In eastern Amazonia, the occurrence and densities of popular medicinal species in secondary forests vary, depending on factors such as their sprouting response following cutting or burning, their ability to invade disturbed areas, and their presence or absence in soil seed banks. In a study of secondary vegetation near Belém, Vieira and colleagues (1996) found that 64% of native species of eastern Amazonia do not regenerate readily after repeated cycles of cutting and burning (e.g., *Ca. guianensis*, *Copaifera duckei*) and that approximately 40% are at risk or threatened because they occur at low densities and undergo little or no regeneration in forests. In a study examining the vulnerability of tree species to intensive logging based on their ecological characteristics, the widely used medicinal oil species *Copaifera reticulata* and *Co. duckei* were found to be potentially susceptible to population reductions (Martini et al. 1994).

Results of studies conducted in tropical forested regions of Brazil differ regarding the relative medicinal importance of primary versus secondary forest and weeds. Indigenous groups (Prance 1972, Cavalcante and Frikel 1973, Balée 1986, 1987) use more primary forest species than do nonindigenous rural Brazilian communities, which show greater use of secondary vegetation, cultivated plants, and weed species (Branch and Silva 1983, Amorozo and Gély 1988, Voeks 1996). This difference may reflect environmental degradation, increased availability of secondary and weed species, and inaccessibility

of primary forests (Voeks 1996). It may also reflect the fact that weeds, for both biochemical and bioecological reasons, represent a significant part of traditional pharmacopoeias throughout the world (Stepp and Moerman 2001) and that disturbed vegetation may constitute a preferred habitat for collectors and users of medicinal plants (Voeks 1996).

Our study differs from these prior studies by measuring not plants that are used rurally but plants that are purchased in an urban setting. Purchased plants may reflect a higher number of species common to mature forests because, unlike cultivated exotics and abundant secondary growth and weed species, they are not easily accessible for harvest by city dwellers. The popularity of forest plants in Belém may also reflect a demographic shift occurring throughout Amazonia (Browder and Godfrey 1997): The city's population includes a large proportion of rural migrants who retain familiarity with forest-based remedies. Urban markets in Amazonia create easy access to forest-based medicinal plants, and cultural association fuels demand (Posey 1999). In addition, although widespread use of exotics, annuals, and cultivars for healing is common to many cultures (Voeks 1996, Stepp and Moerman 2001), preferences for familiar vegetation types appear to persist, as a large proportion of top-selling botanical medicines are native to the regions in which they are sold or are naturalized (Laird 1999).

Harvesting. In addition to habitat being a critical factor in determining species abundance, the plant parts used and the manner in which medicinal products are harvested also affect population structure and availability. Primary forest tree products, including barks, roots, and exudates, are widely used, but little is known about the sustainability of harvesting strategies currently employed. Particularly vulnerable are those species occurring at low densities, those whose roots are harvested, and those whose bark or oil is extracted unsustainably (Cunningham 2000).

Determining sustainable harvesting strategies requires basic ecological information. The ecology of even the most widely used species, however, is poorly understood (Peters 1994). For example, *Pt. olacoides* is a primary forest understory species whose root is harvested. In spite of its long history of popular use and promising findings on its pharmacological properties (Elisabetsky 1987, Siqueira et al. 1998), basic ecological work has never been conducted to determine its density, distribution, germination requirements, or growth rate (von der Pahlen and Shanley 2002). Also, in both North America and Europe, sales of the bark of *Tabebuia* spp. are strong, yet the harvesting practices and regeneration potential for this plant product have not been amply investigated. And although the medicinal oil of *Copaifera* spp. has been used for centuries by millions of Amazonians, until recently (Leite et al. 2002, Plowden 2002) only one published field study described its production and yield (Alencar 1982). *Copaifera* spp. can be sustainably tapped by boring a small hole in the trunk, collecting the oil as it drips out, and tamping after collection. However, collectors often use machetes to make a large gash

in the trunk, which weakens the tree and diminishes future oil production (Alencar 1982, Leite et al. 2002).

With scant research describing the ecology and harvesting practices of native medicinals, the persons most knowledgeable are often seasoned collectors who, as resources decline, experiment with various bark, root, and oil harvesting regimes. Harvesters can elucidate details regarding species phenology, use, collection techniques, and production trends. Unfortunately, although this detailed information is extremely useful, much local knowledge has not been documented or critically examined. For example, to maximize the volume of bark harvested from certain secondary forest species, bark is sometimes stripped in thin vertical rows, permitted to grow back, and harvested again. Depending on the trees' height and bark thickness, a secondary forest tree of median diameter may provide 100 to 200 kilograms of fresh bark. In the area of this study, for instance, one felled *H. sucuuba* tree with a diameter of 25 centimeters provided 150 kilograms of fresh bark and required four days of labor to extract, transport, and sell. In 1994, the wholesale market value of the bark of this *H. sucuuba* tree was roughly equivalent to US \$107, a stark contrast to the few dollars per entire tree that timber companies routinely offer to forest residents.

Despite problems associated with limited management and unsustainable harvesting of some native medicinal tree species, the relative impacts of harvesting medicinal plants are insignificant when compared to the impacts of deforestation over the last two decades. Approximately 15% of the Amazon has been deforested, but if tracts severely degraded by logging and fire are included, the estimated extent of deforestation in the Amazon rises to over one-third (Nepstad et al. 1999, Laurance et al. 2001).

International markets for medicinal plants

In addition to their widespread local use, plants continue to play an important role in international botanical and pharmaceutical markets. Markets for botanical and homeopathic remedies grew tremendously during the 1990s, with global sales reaching an estimated US \$20 billion in 1999 (Gruenwald 2000). Research on plants as a source of new pharmaceuticals also continues, and, despite technological advances in the industry, existing pharmaceutical products often trace their origins to the natural world. For example, more than half of all prescriptions filled in the United States in 1993 contained at least one major active compound "now or once derived or patterned after compounds derived from biological diversity" (Grifo et al. 1997). Among the South American forest species in this group are quinine (*Chincona ledgeriana*) and pilocarpine (*Pilocarpus jaborandi*) (Pinheiro 1997, Laird and ten Kate 2002).

However, drug discovery and development efforts emphasize diseases afflicting the affluent, limiting the potential for even plant-derived drugs to benefit the rural poor (Laird and ten Kate 1999). Indeed, the World Health Organization estimates that only 4% of total global research and development resources are devoted to diseases that primarily afflict

people in developing countries (Chetley 1990). Of the 1229 newly developed drugs that entered the international market between 1975 and 1998, only 11 focused on tropical diseases such as malaria (Dumoulin 1998), which remains one of the leading causes of death in the world.

The emphasis of pharmaceutical research and development on "northern" health issues, coupled with the cost of pharmaceuticals, suggest that traditional plant-based medical systems of the kind served by markets in eastern Amazonia will continue to function as the primary source of health care for most of the world's population. However, natural products research conducted in high-biodiversity developing countries could enhance domestic capacity to undertake research and development of products that address local health care priorities (Laird 2002). To establish meaningful links among medicinal plants, health care, and conservation, international research and development organizations must develop research agendas that focus on questions of local and regional significance and offer benefits to local communities dependent on plant-based resources.

In Amazonia, there is a particular need for strategic research on the impacts of land-use change on some of the most highly valued, forest-based medicinal plants. As these plants decline in abundance, poorer segments of the population may be disproportionately affected. Forest transformation may signify not only loss of potential remedies for people in the developed world but also erosion of one of today's primary health care options for Amazonia's urban and rural citizens.

The future of Amazonian medicinal plants

The global attention directed toward medicinal plants has not been matched by on-the-ground research in the Brazilian Amazon. After centuries of use, the efficacy of many commonly harvested plants that are consumed daily by millions of Amazonians remain "comprovado pelo povo," that is, proven by the people. Relatively little research has been undertaken regarding the ecology or management of top-selling medicinal plants that have been highly valued for centuries. This gap in research is notable because nine of the twelve most widely traded medicinal plants in Belém are native to Amazonia and five are extracted by the timber industry. Two of the top-selling medicinals are prized timber trees with strong domestic markets and growing international demand.

Home to nearly one-third of the world's tropical forest, the Brazilian Amazon is well poised to meet rising domestic and international demand for tropical timber (Uhl et al. 1997). In eastern Amazonia, logging is often an initial step in a synergistic process involving a combination of roads, fire, ranching, and agriculture that eventually leads to forest fragmentation and conversion (Cochrane and Laurance 2002, Gerwing 2002). Although forest degradation will reduce access to some forest-based medicinals, it will favor secondary growth species. In response to an increasingly degraded landscape, users may simply switch to these commonplace plants—when substitutes exist—or, if economic conditions allow, purchase pharmaceuticals.



Amazonian healer carving a canoe from a species also prized for its medicinal bark. Photograph: © 1995 Patricia Shanley.

However, cultural familiarity, growing market demand, and willingness, even by the poor, to pay higher prices for some forest-based medicinals suggest that urban Amazonians strongly value select forest medicinals and retain interest in their use. Furthermore, for several popularly used Amazonian medicinals, few allopathic or other phytotherapeutic substitutes exist. And although technical advances in the pharmaceutical industry enabling synthesis of some active compounds have eliminated the need for bulk material of certain plant species used for medical purposes, none of the 45 plant-based drugs developed from tropical rain forest species worldwide through the early 1990s is known to be synthesized (Farnsworth and Soejarto 1991). The phytochemical complexity of tropical plants has consistently eluded efforts toward synthesis, and companies continue to depend on natural sources of raw materials (Laird 1999). Little is known, however, of the distribution or density of species that are collected from wild sources to provide these drugs.

In Africa, Cunningham (1993) reports that medicinal plant collection for export and increased urbanization have resulted not in conservation but in overharvesting and devastation of select species, leaving locals without medicinal remedies. To avoid a similar scenario in Amazonia and promote better land-use management, attention is needed for traditionally used, valuable primary forest medicinal species that often occur in low densities, are slow to reach reproductive age, and are particularly vulnerable to logging, fire, or land-use change (Cunningham 2000). Secondary forest medicinal species that may serve in the restoration of degraded ecosystems also deserve study. In addition, a full cost-benefit analysis will be needed to evaluate whether and how logging of medicinally valuable species makes short-term or long-term economic and sociocultural sense.

Building on a strong foundation of medicinal plant research, Brazilian scientists are collaborating across disciplines to better understand the phytochemistry, pharmacology, and sustainable management of nationally valued species (Kanashiro 2002). Central to this effort, the Brazilian Institute of Environmental Protection (IBAMA, or Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis) and the National Center for Genetic Resources and Biotechnology (Cenargen), in collaboration with other research institutes such as EMBRAPA, have identified 221 species as priorities for conservation, 60 of which are considered threatened (John 2002). Serious efforts are under way to conserve the genetic diversity of medicinal plants through seed banks, tissue culture, and the creation of forest genetic reserves (Vieira 1999). Use of medicinal plants and pride in the rich medicinal plant heritage is so pervasive that concern about species loss is inspiring not only governmental agencies but also some forest product industries and rural and urban Brazilians to advocate conservation of locally valued species. As environmentally knowledgeable leaders assume prominent decisionmaking roles in Brazil, a well-informed citizenry and relevant research could provide strong

support for conserving valuable ecosystems to help meet local and national health care needs.

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