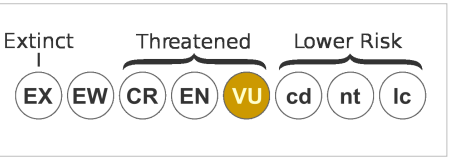
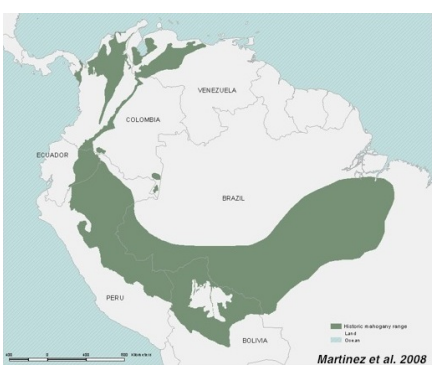
Swietenia macrophylla

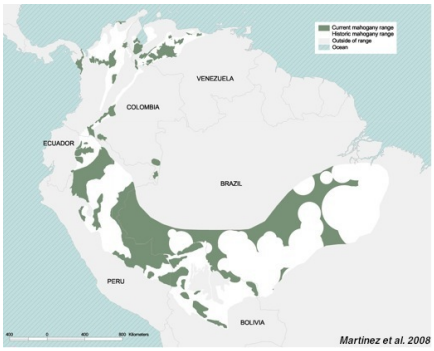
Swietenia macrophylla

Crown and trunk of an adult big-leaf mahogany tree in Brazil
Conservation status

Vulnerable (IUCN 2.3)
Scientific classification

Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Eudicots
(unranked):	Rosids
Order:	Sapindales
Family:	Meliaceae
Genus:	*Swietenia*
Species:	***S. nacrophylla***

Binomial name
Swietenia macrophylla King


Historic range of big-leaf mahogany in South America (www.swietking.org)



Current range of big-leaf mahogany in South America (www.swietking.org)

Swietenia macrophylla, commonly known as **big-leaf mahogany**, is a species of plant in the Meliaceae family. It is one of three species that yields genuine mahogany timber, the others being *Swietenia mahagoni* and *Swietenia humilis*.

The species is also known under other common names, including broad-leaved mahogany, Brazilian mahogany, large-leaved mahogany, genuine mahogany, tropical American mahogany, and sky fruit, among others.

Naming

Big-leaf mahogany, *Swietenia macrophylla* King, is one of three *Swietenias* which are the American or true mahoganies. The American mahoganies are recognized as different species principally on the basis of their allopatric or non-overlapping distributions, with the Caribbean or Cuban mahogany (*Swietenia mahagoni* (L.) Jacquin) restricted to the Greater Antilles and southern Florida, the Mexican or Pacific mahogany (*Swietenia humilis* Zuccarini) distributed along the Central American Pacific coast from southern Mexico to Costa Rica, and big-leaf mahogany occurring much more widely from Mexico's Yucatan Peninsula down the Central American Atlantic coast into South America as far south as Bolivia. First named *Cedrelus mahagoni* by Linnaeus, big-leaf mahogany was thought to be the same species as Caribbean mahogany until George King decided it was a separate species in 1886, hence the author name 'King'.[1]

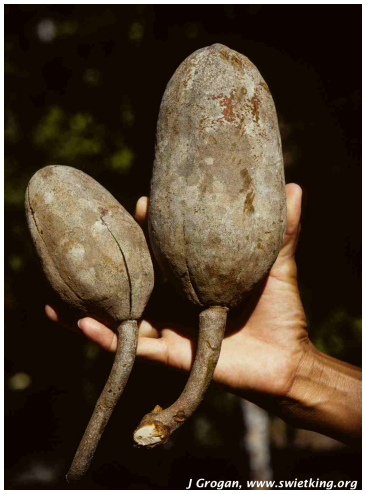
Description

Big-leaf mahogany is a large-statured canopy emergent tree at maturity. Stem diameters as large as 3.5 metres have been reported, with buttresses rising 5 or more metres up the base of the tree and crowns 70 metres tall and up to 40 metres across. Mature tree crowns tend to be irregular in shape and composed of relatively few large primary branches.[2]

Bark pattern on mahogany tree.

At maturity stem boles are cloaked in thick, deeply furrowed, nearly black bark that provides excellent fire resistance. Smaller trees have gray bark that may flake off in irregular blocks or vertical strips. Most but not all mahogany trees form buttresses, which often appear even before trees reach pole size (~10 cm diameter). Buttresses may be more prominent when a tree is growing on low ground prone to wet season flooding.[3]

Leaves on mature mahogany trees are 15–25 cm long, alternate and pinnately compound, with leaflets arranged in 3–4 pairs along a central rachis or leaf stem, and paripinnate. Interestingly, the first 4 to 6 leaves on recently germinated seedlings are simple; compound leaves appear during the second growth phase if enough light is available for vigorous growth. Saplings form huge compound leaves nearly a meter long with up to 18 oversized leaflets but form adult-sized, smaller leaves when the reach pole-size. Trees this size and larger are deciduous and reflush new crowns after one to several weeks.[4]



Mahogany fruit; cracks show suture lines where outer shell will split apart to disperse seeds.

Mahogany trees flower during the late dry season shortly after flushing new crowns; on sexually mature trees branching flower stalks emerge with new leaves during the late dry season as the rainy season shows signs of returning. Mahogany is monoecious, with axillary panicles of small (< 1 cm across), pale yellow, fragrant flowers that appear perfect but which are functionally either male or female. Small bees and moths commonly pollinate Meliaceous trees, but which species serve mahogany remains unknown. Though more than one flower per inflorescence may be pollinated, only one ripens to maturity over the course of the wet season.

Mahogany fruit are fist-sized woody capsules resembling a pear, held upright above the crown, containing a five-winged receptacle with seeds stacked in two rows within each cell. Fruit mature through the rainy season and dehisce along five suture lines the following dry season, releasing up to 60 large, winged seeds. In plantations mahogany can flower and fruit within 12 years of outplanting, when stem sizes are only 10–15 cm diameter. In natural forests, trees as small as 20 cm diameter may fruit occasionally, but generally trees must be larger than 30 cm diameter to fruit annually. As trees get larger, fruit production rates increase, with a tree 130 cm diameter capable of

producing up to 1000 fruit in a given year. Fruit production by both individual trees and by local populations may vary considerably from year to year. Fluctuations in fruiting intensity may be associated with post-disturbance conditions (for example, after large forest disturbances such as hurricanes in Central America or logging) and with atypical seasonality.

Mahogany seeds are winged, up to 12 cm long, and wind dispersed. Their geometric stacking within fruit capsules leads to predictable variation in size, with the largest seeds exhibiting the highest germination rates and producing the largest seedlings. They are attached to the capsule receptacle near the apex of the wing, and require some degree of turbulence to dislodge them after the five fruit capsule valves dry and fall off. The actual seed is located at one end of the wing, creating an unbalanced weight that causes the seed to 'helicopter' as it flies from crown to forest floor. Seed weights including the wing range from 0.5–0.75 g.

Mahogany seed

Natural Range

Mahogany's natural range stretches from Mexico at 23º N of the equator down the Central American Atlantic coastal strip into South America, continuing in a broad southeasterly arc from Venezuela through Amazonian regions to points as far south as 18º S in Bolivia. Countries where mahogany naturally occurs include Mexico, Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, Venezuela, Colombia, Ecuador, Peru, Brazil, and Bolivia. Its distribution generally corresponds to forests classified as 'tropical dry' with 1000–2000 mm annual precipitation. Mahogany also grows in humid and subtropical zones, at elevations ranging from sea level in Central America up to 1400 m in the Andean foothills of Ecuador, Peru, and Bolivia, in a wide variety of soil types and soil conditions.

Historic distribution of mahogany from Mexico to southeastern Amazonian according to Lamb (1966). From Martinez et al. 2008.

FB Lamb's 1966 estimate of mahogany's historic range in South America was based on anecdotal reports and his wide travels during the first half of the 20th Century rather than on structured inventories. In a study by Martinez et al. (2008)[5] and later published by Grogan et al. (2010),[6] expert respondents revised Lamb's estimate for South America downward by 19% to 278 million hectares, roughly equivalent to the total land area of Colombia, Ecuador, and Peru combined. Reductions were most pronounced in Venezuela, Bolivia, and Brazil, where Lamb's range overlapped extensive areas of savanna, cerrado, and scrub woodland that are unsuitable for mahogany. Brazil alone accounts for 57% of the revised historic range in South America, most of this occurring along the seasonally dry southern rim of closed Amazon forests. Nearly 7% of mahogany's revised historic range in South America is under legal protection, and an additional 15% lies within legally recognized Indigenous Lands.

The following country-level descriptions of big-leaf mahogany's natural range in South America are excerpted from Martinez et al. (2008).

Brazil

In Brazil, mahogany originally occurred in natural forests covering an estimated 159 million hectares along the southern and southeastern rim of legal Amazonia, an area equivalent to mahogany's historic range in all other South and Central American countries combined, including Mexico. Known in Brazil as mogno (except in Acre where the common name is aguano), mahogany's range extended as far north and east as the Transamazon Highway (BR-230) at Altamira and the Tocantins River valley east of Marabá. From these limits mahogany occurred in a broad southwesterly swath across the states of northwest Tocantins, south Pará, north Mato Grosso, southeast Amazonas, and most of Rondônia and Acre.[7]

Just as forest types grade continuously in structure and composition across Brazil's southern Amazon, mahogany occupied a wide range of habitats at highly variable densities. Before industrial logging, high-density populations occasionally exceeding one tree per hectare at landscape scales occurred along perennial rivers and seasonal streams in the southeastern corner of the state of Pará. Mahogany is reputed to have occurred at similar densities in parts of the mid-western state of Rondônia, but those populations were logged before they could be rigorously inventoried. Moving west and north from these high-density zones, population densities declined to near zero at the geographical limits of mahogany's range in Brazil. Western populations in Acre and Amazonas occur at low densities compared to southeastern populations, on the order of 1 tree in 5 to 20 hectares, in both *terra firme* and riverine forests.

Bolivia

In Bolivia, mahogany's historic range covered an estimated 30 million hectares of tropical and subtropical wet and seasonally dry forests in the Departments of El Beni, Cochabamba, La Paz, Pando, and Santa Cruz. Known in Bolivia as mara, mahogany occurred at highest densities along the margins of perennial rivers draining the Andean foothills. Mahogany occurs or occurred at lower densities in *terra firme* ('high ground') forests, often associated with seasonal streams as in Brazil. Though expert respondents reported isolated regions where mahogany populations may persist at high densities (1–10 per hectare), most surviving populations are expected to occur at densities well under one commercial tree per hectare.

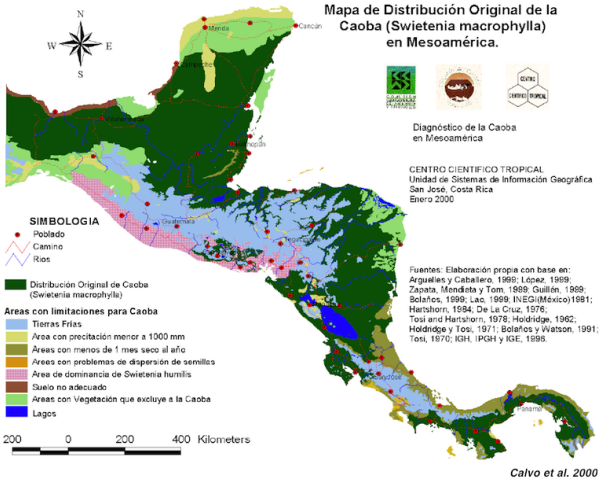
Revised historic distribution of mahogany in South America based on expert surveys. From Martinez et al. 2008.

Peru

Mahogany's historic range in Peru covered an estimated 55 million hectares across most of the country's eastern Amazon region. Known in Peru as caoba, mahogany was found along riverbanks and in *terra firme* lowlands including mixed bamboo forests, as well as in terraced foothills at the base of the Andes mountains. Little is known about abundance patterns of riverine populations that had largely vanished by the early 1970s, but United States import volumes from 1908–1960 reported by Lamb suggest that these populations occurred at relatively low densities. Based on the densities of surviving populations and trade statistics, it is probable that *terra firme* populations seldom exceeded one commercial tree per hectare at landscape scales.

Ecuador

Mahogany's historic range in Ecuador covered approximately 7 million hectares of Amazonian forests east of the Andes mountains. Mahogany most commonly occurred on alluvial terraces in nutrient-rich, deep, well-drained soils adjacent to major rivers draining the Napo, Pastaza, and Sucumbíos Provinces, and within tributary watersheds in Andean foothills up to 500 m elevation. Possibly due to the relative aseasonality of Ecuador's Amazon region, natural populations occurred at low or very low densities (fewer than 0.1/ha). One indication of this is the fact that no forest inventory in the Amazon region during the period 1942–1980 registered mahogany's presence; it was not until 1985 that mahogany was first recorded in Ecuador. Mahogany's frequent association with rich alluvial soils means that gradual conversion of riverine forests to agriculture by Amerindian communities during the past century has likely reduced natural range and population densities through habitat loss.



Historic distribution of mahogany in Mexico and Central America. From Calvo et al. 2000.

Colombia

In Colombia, mahogany's historic range covered an estimated 18 million hectares and included three or more disjunct regions corresponding roughly with seasonally dry lowland or piedmont (upland) forests flanking the lower slopes of Andean and northern mountain ranges. These include: 1) the Pacific-side, northwest Darién region adjacent to Panama (Chocó Department), extending to the lower dry zones of the Mulatos and San Juan River watersheds; 2) the northern Caribbean-side lowland plains and foothills of the Cordillera Oriental that continues into Venezuela, extending south into mountain valleys drained by the Cauca and Magdalena Rivers; and 3) seasonal foothill forests flanking the eastern Andean slopes above the Amazonian lowlands draining towards Brazil. Commercial logging has also been reported from the southwestern corner of Colombia in the Puré and Purite River watersheds. No information is available regarding abundance patterns, but Colombia's minor historic role as a mahogany exporter indicates that natural population densities were, on average, low to very low.

Venezuela

In Venezuela, mahogany's historic range was split by coastal mountains that connect with the Andean Cordillera in the southwest. Mahogany occurred north of these mountains in the region surrounding the Maracaibo Lake depression, and on the south side in the plains region stretching across the western states of Barinas, Portuguesa, and Cojedes. The revised natural range in Venezuela covers an estimated 9 million hectares. According to experts, mahogany was most abundant in rich alluvial soils in lowland riparian forests, but was also widely distributed in semi-evergreen upland forests and in foothill gallery forests up to 900 m above sea level. Though inventory data are scarce, what sources are available indicate that mahogany occurred, on average, at densities well below one commercial tree per hectare.

Mexico & Central America

In Mexico and Central America, mahogany's natural range is estimated to have covered 42 million hectares or 17% of this region from the Yucatan Peninsula to Panama. See Calvo et al. (2000)[8] for an update to Lamb's 1966 treatment of mahogany in Mesoamerica.

Exploitation

Big-leaf mahogany is the premier timber species of the American tropics. Two closely related timber species, West Indian mahogany (*Swietenia mahagoni*) and Pacific Coast mahogany (*Swietenia humilis*), have been logged so intensively since the European conquest in the 1500s that commercially viable populations of these two species were extirpated by the early to mid-1900s. *Swietenia macrophylla* is the only true or New World mahogany with substantial populations surviving in natural forests.[9]

In South America, industrial logging in the Amazon rapidly depleted commercial stocks in previously inaccessible regions as overland transportation networks expanded during recent decades. Conventional logging practices are unsustainable because natural mahogany seedling densities are generally low before harvesting, while silvicultural

practices necessary to ensure future production are rarely implemented. Shrinking supply and a steady strong demand for old-growth tropical timber, particularly from the United States, combine to drive mahogany's value up. High value in turn drives continued exploitation, both legal and illegal.

The following country-level descriptions of big-leaf mahogany's exploitation in South America are excerpted from Martinez et al. (2008).

Brazil

The first documented sales of mahogany from Brazil were recorded during the 1920s, with small volumes extracted from the state of Mato Grosso and exported through the Atlantic port of Santos. In the western state of Acre, the earliest exploitation occurred during the 1930s and 1940s along the margins of principal western rivers such as the Juruá, Tarauacá, Envira, and Purús. A second phase of exploitation began in the late 1970s in the eastern portion of Acre as overland access improved through completion of the Porto Velho (Rondônia)–Brasília highway (BR-364).

Limited exploitation began in the 1940s along the eastern limits of mahogany's range in Brazil, particularly in the state of Tocantins. In Pará, difficult access impeded exploitation until the mid-1960s, when the opening of the Belém–Brasília highway (BR-010) facilitated logging along the margins of the Araguaia River and its tributaries. These stocks were quickly exhausted, forcing loggers to shift west into southeastern Pará in the early 1970s to mahogany-rich forests along the newly opened state highway PA-150. These stocks were in turn depleted by the mid 1980s and the logging frontier pushed farther west from the major processing center of Xinguara along state highway PA-279 towards São Félix do Xingu on the Xingu River. Throughout this vast region loggers invaded untitled federal land (terra devoluta) and Indigenous Lands through a variety of access arrangements, both legal and illegal, in search of mahogany. Commercial stands were often located by spotters in small planes.

A separate logging front opened in the state of Rondônia during the early 1980s as the southern Transamazon highway (BR-364) provided access to vast tracts of previously inaccessible forests. A federal export subsidy program sparked a 'mahogany rush' on terra devoluta and in protected areas and Indigenous Lands, essentially liquidating Rondônia's mahogany stocks by 1985. Another logging frontier spread north across Mato Grosso and into southwestern Pará via the Cuiabá–Santarém highway (BR-163). From the early 1990s loggers entered the region between the Xingu and Iriri Rivers from São Felix do Xingu in the east, from entry points along the Transamazon highway across the northern limits of mahogany's range in Pará, and from the new logging center of Novo Progresso in southwestern Pará.

Harvesting a mahogany tree using best felling practices in Acre, Brazil.

The logging industry's extraordinarily rapid advance across mahogany's range in Brazil was fueled by expansion of regional transportation infrastructure, technological advances in logging equipment, an enormous expanse of unexploited timber, insufficient public funds for land management and regulation by state and federal authorities, government subsidies, and rising market prices due to declining supply from Central America. Production statistics vary widely according to source. The Brazilian NGO Imazon estimated that 4 million cubic meters of sawn mahogany were exported from Brazil from 1971–2001; the majority (75%) went to the United States and England, while ~1.7 million cubic meters were consumed domestically during this period. This corresponds to approximately 10 million cubic meters in logs or more than 2 million mahogany trees felled. By comparison, IBAMA, the Brazilian ministry responsible for regulating forest management, reported 2.1 million cubic meters of sawn mahogany produced between 1992–2000, with 1.3 million cubic meters consumed domestically.

In spite of a series of logging moratoria for mahogany from 1996 to 2003, Brazil exported more than 100,000 cubic meters of mahogany between 1999 and 2001. Brazilian officials estimated in 1998 that 80% or more of mahogany production originated from illegal sources. Given widespread illegal logging, in 2001 Brazil suspended all forest management plans for mahogany approved by IBAMA in the states of Pará, Mato Grosso, and Acre. In 2003 the Brazilian federal government revised forest legislation targeting mahogany production from natural forests, implementing stringent harvest regulations in an effort to protect remaining populations from unsustainable logging practices. Since 2003, only two forest management areas containing mahogany have been approved for commercial harvesting in Brazil.

Bolivia

Mahogany tree with forked stem above logyard, Acre, Brazil.

In Bolivia, a United Nations Food and Agriculture Organization (FAO) mission arrived in eastern Bolivia in 1966 and recommended the extraction of forest products for the international market. As a result, industrial exploitation began in 1967 when Brazilian logging equipment arrived in the Chore, Guarayos and Bajo Paragua Reserves in the Department of Santa Cruz. The first species logged was high-value mahogany. The mahogany frontier in Bolivia has been retreating ever since. As the most accessible regions were commercially exhausted, the logging industry opened new frontiers. Logging companies entered the Ixiamas zone during the mid-1970s, the Chimanes zone of the Department of Beni during the 1980s, and the Riberalta and Cobija zones of the Pando in northern Bolivia during the mid-1990s. A drastic decline in national mahogany production occurred from the late 1980s to 2000 in spite of a sharp increase in the number of sawmills. Lack of supply was the primary cause of reduced production.

Peru

In Peru, commercial exploitation of mahogany along tributaries of the Amazon River began during the first decade of the 20th Century and accelerated after construction of sawmills in Iquitos during the 1920s, following the collapse of the rubber industry. This earliest exploitation targeted trees growing along riverbanks or within manual hauling distance of flowing water for ease of transport to sawmills downriver. As annual production gradually increased, the mahogany frontier retreated from Iquitos as loggers had to travel ever further afield to obtain sawlogs. An estimated 50,000 hectares of riverine forests were logged annually from the 1920s through the 1940s from watersheds surrounding Iquitos and along principal tributaries of the region such as the Ucayali River.

Mahogany logging in the western Amazon before 1950 depended on transporting logs by river.

The first trans-Andean road from Lima reached Pucallpa during the 1950s, allowing overland log transport and export via the Pacific coast. This spurred expansion of the logging frontier to adjacent watersheds and the upper Ucayali region, including the Tamaya River and Alexander von Humboldt Forest, with an estimated 150,000 hectares exploited annually during this period. A road reached San Martin Department in the 1970s, opening a new logging front for mahogany and again expanding exploitation to an estimated 250,000 hectares annually within the Biabo, Saposoa, Sisa, and Huallabamba River watersheds. During this period, loggers expanded their search area into *terra firme* forests as riverine populations were extirpated.

The export market expanded dramatically during the early 1980s as mechanized logging made it profitable to log mahogany from increasingly remote areas. This encouraged illegal activities. Loggers exploited mahogany in protected areas using banned techniques such as cuartoneo (quartering sawlogs with chainsaws to facilitate overland transport). In the mid 1990s, with mahogany supplies declining from Bolivia and Brazil, logging pressure on remaining stocks in Peru further intensified. A spike in exports during the second half of the 1990s led the Peruvian government to ban logging from some watersheds suffering severe over-exploitation, including the Tamaya River watershed. By 2010 the situation had deteriorated further with the CITES Standing Committee providing the Peruvian government with a six month ultimatum to address the critical issues facing the mahogany trade within the country.[10]

Ecuador

Heavy truck transporting logs (not mahogany) in the southwest Amazon.

Mahogany's late 'appearance' in Ecuador may be attributable to a number of related factors. Industrial logging was slow to develop in Ecuador's Amazon region due to the challenge of moving timber over the Andes to processing centers and ports on the Pacific coast. For this reason, forestry authorities were unfamiliar with the species, and the common Quichua name for mahogany, ahuano, apparently failed to register as high-value mahogany. In fact, the Spanish-language name for mahogany, caoba, refers in Ecuador to other commercial timber species, including *Platymiscium* spp. (Fabaceae), *Caryodaphnopsis theobromifolium* (Lauraceae), and *Guarea cartaguenya* (Meliaceae). However, a commercial boom occurred during the decade after mahogany was first recorded in 1985. Ecuadorean mahogany was illegally harvested and exported through the northern Sucumbíos Province into Colombia via the San Miguel River, ending up, among other uses, as ornate doors at luxury hotels. No production data are available for Ecuador.

A large logged mahogany tree with hollow interior, rendering it unmerchantable.

Colombia

Along with Peru, Venezuela, and Central American colonies, Colombia supplied Spain with mahogany during colonial times. Records of sales from Colombia date from 1786 through the 1800s. From 1900 until the beginning of World War II, colonization of the agricultural frontier led to extensive deforestation of piedmont and central mountain forests. Forest products such as rubber, balata (a natural gum), quinine, and mahogany were in high demand during this period. From 1940–1952, industrial logging centered on the Pacific region and the central Cauca and Magdalena River valleys. Mahogany was exported from Colombia to the United States from 1953 through the late 1960s. The start of mechanized logging in *terra firme* forests coincided with federal laws issued in 1959 establishing forest reserves for the management and economic development of forest resources. Widespread deforestation associated with selective logging and the expanding agricultural frontier continued into the 1980s. No production statistics are available for Colombia aside from minor export volumes to the United States beginning in 1954 cited in Lamb (1966).

Venezuela

Quartered mahogany timber stacked for eventual transport in Acre, Brazil.

Little is known about early exploitation patterns in Venezuela. Lamb noted exports to the United States as early as 1908. Exports to France and Germany began before World War I. With Spanish cedar (*Cedrela odorata*), mahogany was logged beginning in the 1920s from Cojedes and Portuguesa near the cities of Valencea and Cardeas, and from Barinas further southwest beginning in 1939. The 1955 Forestry Law of Soils and Water established four permanent Forest Reserves within mahogany's range with the objective of building a national wood-processing industry based on sustainable timber production. However, the concession system implemented in Forest Reserves began as simple annual logging permits, and has been poorly regulated; logging practices essentially high-graded high-value species, and future harvests will yield mostly low-value low-density timber. Experts report that commercial mahogany stocks today occur in only two of the original four Forest Reserves. Sawn timber production of mahogany from Venezuela peaked in 1971 at 23,764 cubic meters, falling to 1,919 cubic meters by 1999. This decline was due to reduced supply. Production statistics are unavailable for the period before 1969.

Mexico & Central America

In Mexico and Central America, 64% of mahogany's historic range had lost forest cover by the mid-1990s, with remaining forest populations severely depleted by logging.

CITES Status

Big-leaf mahogany was granted international regulatory protection by its listing on CITES Appendix II in late 2002.[11]

By the early 1990s, international concern was growing over the commercial and conservation status of big-leaf mahogany throughout its natural range. Both *Swietenia mahagoni* and *Swietenia humilis*, the other two Neotropical mahoganies, were listed on Appendix II by 1992 in recognition that commercial supplies of these species no longer existed in the wild. A growing body of reports indicated that industrial logging of big-leaf mahogany was in turn pushing *Swietenia macrophylla* to commercial extinction across large portions of its natural range. Field studies in Mexico, Bolivia, and Brazil provided evidence that mahogany's regeneration strategies were incompatible with conventional selective logging practices, leading to regeneration failures after logging. Government regulatory capacity in remote Amazonian regions where most supplies originated after 1970 was too weak to control the logging sector specializing in locating and extracting mahogany from previously unlogged primary forests. Underlying these 'facts on the ground' were mahogany's extremely high export value relative to other internationally traded tropical timber species, and consistently strong international demand, especially from the US and Europe.[12]

The first proposal to list big-leaf mahogany on CITES Appendix II, submitted by Costa Rica and the USA, was considered at the 8th Convention of the Parties (CoP8) in 1992 in Kyoto, Japan. The proposal failed to garner two-thirds majority support necessary for listing from voting members at CoP8 and thus failed. At CoP9 in 1994 in Fort Lauderdale, USA, a second attempt to list mahogany on Appendix II, this time proposed by the Netherlands, also failed, as did a third attempt in 1997 at CoP10 in Harare, Zimbabwe. Costa Rica unilaterally listed mahogany on Appendix III in 1995, followed by Mexico, Bolivia and Brazil in 1997 and Colombia and Peru in 2000.

These listing proposals were fiercely contested. Mahogany's vast natural range and logistical difficulties associated with studying natural populations in remote regions where the logging industry had not yet eliminated commercial

populations made it difficult for the scientific community to reach a consensus on mahogany's status. The logging industry and range nation governments, especially in South America where most international supplies originated after 1970, exploited this lack of consensus to defeat each listing proposal. Meanwhile a series of international conferences, publications, and CITES-sponsored Working Groups convened to debate the merits of international regulation.

In the meantime, pressure mounted for mahogany's inclusion on Appendix II as the Appendix III listings failed to ensure that internationally traded volumes of mahogany represented legal supplies. Mahogany's Appendix III status required that listing nations issue CITES Export Permits through their Management Authorities verifying that exports were obtained in accordance with national forest legislation. The original Appendix III listing by Costa Rica in 1995 additionally required mahogany exports from other range nations to be accompanied by certificates of origin identifying the country where shipments were harvested. As well, CITES Authorities in consumer nations had to verify that imported volumes were accompanied by appropriate documentation, depending on the country of origin. The Appendix III listings by six range nations between 1997 and 2000 improved monitoring of trade data, and compliance was apparently widespread among range and consumer nations.

However, a crisis in Brazil in late 2001 demonstrated that illegal harvests continued. There, the Brazilian government banned the harvest, processing, and export of mahogany after discovery of widespread fraud within both the logging industry and regulatory agencies responsible for enforcing forest legislation and verifying legality of supply. Some shipments of Brazilian mahogany to the USA in 2002 were returned after successful legal challenges to the authenticity of CITES Export Permits accompanying them. The decline in Brazilian and Bolivian supplies during the late 1990s, and the shutdown of Brazilian exports in 2001, were mirrored by a dramatic spike in exports from Peru, where weak regulatory capacity was unable to stem a tide of illegal extraction in the Amazonian administrative department of Madre de Dios.[13]

At the 12th Convention of Parties (CoP12) held in November 2002 in Santiago, Chile, CITES member nations voted 68–30 to include mahogany on Appendix II. The Appendix II listing requires cooperation between producer and consumer nations to verify that internationally traded individuals or volumes of listed species are harvested legally and in a manner non-detrimental to their role in ecosystems where they naturally occur. Though 12 other timber species had already been listed on Appendix II by 2002, mahogany was the first heavily traded species to receive this level of protection under CITES before commercial extirpation of natural stocks could occur. The decision recognized that international intervention was necessary to control illegal harvests and to maintain viable populations across mahogany's natural range from Mexico to Bolivia. The listing went into full effect in November 2003.

The Appendix II listing interposed an additional layer of regulatory control, beyond the issue of legality, between mahogany and international markets. It requires each range nation's CITES Scientific Authority to verify through 'non-detriment finding' (NDF) that mahogany's export as sawn timber would not be detrimental to its survival "at a level consistent with its role in the ecosystems in which it occurs" (CITES Art. IV.3). Export is possible only when NDF has been made and the exporting nation's CITES Management Authority determines that specimens or volumes of listed species were obtained in a manner consistent with national laws for the management and protection of flora and fauna, as under Appendix III. Protocols for determining NDF and legality are established by individual range nations. CITES Authorities in consumer nations must in turn verify that imports are accompanied by valid Appendix II documentation. In mahogany's case, logs, sawn wood, veneer sheets, and plywood were covered by the 2002 Appendix II listing; domestic consumption within range nations, and plantation production from countries outside its natural range – principally Fiji and Indonesia – were not.

Of course, listing mahogany on CITES Appendix II did not magically solve all the problems with overexploitation and illegal international trade. While Brazilian supplies remained essentially shut down while the forest products industry adjusted to new federal regulations monitoring mahogany harvests established in 2003, the flood of mahogany exiting Peru since the listing raised questions about the legality and sustainability of harvests there.

Current Status

Consumer demand for big-leaf mahogany has driven boom-and-bust logging cycles for centuries, depleting local and regional supplies from Mexico to Bolivia. Approximately 58 million hectares (21%) of mahogany's historic range in South America (278 million hectares total) had been lost to forest conversion by 2001. Commercial populations had been logged from at least 125 million more hectares, reducing the current commercial range to 94 million hectares (34% of historic). Surviving mahogany stocks are extremely low-density populations in remote regions of Amazonia representing a smaller fraction of historic stocks than would be expected based on estimated current commercial range.

The following country-level descriptions of big-leaf mahogany's current commercial range in South America are excerpted from Martinez et al. (2008).

Brazil

In Brazil, commercial mahogany populations survive across an estimated 35% of the revised natural range, or in 55 million hectares of natural forest. Most remaining populations are located in remote regions where transportation infrastructures remain incipient, or where terrain is steep, or where seasonal rains impede access. These populations occur mostly along the northern and western limits of mahogany's range in the country, at low or very low densities compared to high-density populations that were once common in Rondônia and southeast Pará. The true extent of logging impacts in Brazil is likely even more extensive for reasons given in Martinez et al. (2008).

Approximately 30% (16.4 million hectares) of mahogany's estimated remaining commercial range in Brazil falls within protected areas and Indigenous Lands. However, while protected areas and Indigenous Lands have been shown to slow deforestation rates across southern Amazonia, neither have afforded effective protection to mahogany populations within their borders. Only the current stringent regulatory environment can enforce the conservation status of these and other unprotected surviving mahogany populations in Brazil.

Bolivia

Decades of selective logging in Bolivia resulted in elimination of commercial populations of mahogany from 79% of its historic range by 2001. Approximately 14% of the range is protected, but densities within these areas are low. Illegal logging has occurred and continues to varying degrees in all legally protected areas within mahogany's historic range in Bolivia. The most significant surviving populations occur in areas of difficult access in the northern Amazon region along the borders with Brazil and Peru, and within protected areas. High-density populations (more than one commercial tree per hectare) reportedly survive in the Isiboro-Secure National Park, while medium-density populations remain in other protected areas such as Amboró, Carrasco, and Madidi National Parks, and the Pilón Lajas Biosphere Reserve and Indigenous Territory.

Peru

Although forest cover remains relatively intact across mahogany's historic range in Peru, decades of selective logging, especially intensive *terra firme* logging carried out since the early 1990s, had eliminated commercially viable populations from 50% of this area by 2001. The spike in mahogany exports from Peru after the 2001 moratorium in Brazil, and continued high export volumes under quotas set after the Appendix II listing when into effect, suggest that remaining stocks occupy significantly less than 50% of mahogany's original natural range in Peru. Remaining populations are located mainly in the least accessible or most remote areas of the Peruvian Amazon, which correspond in large degree to protected areas and Indigenous Lands. The most important stands, those with the highest reported densities (0.1−1 trees/ha), occur near the border with Brazil's western state of Acre within the Alto Purús Reserved Zone, a naturally isolated, roadless area located in the upper watershed of the Purús River; and in the northwestern section of Manu National Park. However, extensive illegal logging activities have been reported from these regions during the past decade.

Ecuador

Approximately 73% of mahogany's historic range in Ecuador lacks commercial populations as a result of over-exploitation. There are presently no forestry concessions for mahogany in Ecuador and harvests are illegal. The most important remaining populations are probably located in the headwater region of medium-sized tributaries of the Napo River, that is, in adjacent watersheds of the Cusano, Nushiño, and Sotano Rivers. The lower slopes of the Sumaco volcano adjacent to the Sumaco-Galeras National Park may also harbor natural populations.

Colombia

Roughly 50% of mahogany's historic range in Colombia has lost forest cover. Despite the lack of detailed inventories, substantial deforestation and the absence of any significant trade contribute to the belief that mahogany is commercially depleted throughout the country. The most significant remaining natural populations of mahogany probably occur in the northern Pacific region of the Department of Chocó on the Panamanian border, encompassing the municipalities of Bahía Solano and Juradó; and in Indigenous Reserves located along the Domingodó, Opogado-Guaguando, Napipi, Alto Río Cuta, Uva and Pogue Rivers, particularly in the upper watershed areas which serve as buffer zones for Ensenada de Utria Natural National Park. Outside these areas, commercial stocks probably no longer exist, though mahogany may be present in logged forests or surviving forest fragments at extremely low densities.

Venezuela

As of 2001, 74% of mahogany's original estimated range of 9.3 million hectares had been deforested in Venezuela, while decades of selective logging had eliminated commercial stands from 89% of mahogany's range. Densities are estimated to be very low (fewer than 0.01 trees/ha) in approximately 87% of areas where mahogany can still be found, low (0.01 − 0.1 trees/ha) in 13%, and medium (0.1−1.0 trees/ha) in less than 1%. A little over half (51%) of the area where mahogany reportedly occurs is private property, with the remainder in National Parks (21%) and Forest Reserves (28%) under concession management. In general, it is difficult at present to locate unlogged natural mahogany populations in Venezuela.

Mexico & Central America

In Mexico and Central America, 64% of mahogany's historic range had lost forest cover by the mid-1990s, with remaining forest populations severely depleted by logging.

Regulations

While mahogany has been commercially logged for centuries in Mexico and Central America, state-administered forest management regulations are a relatively new phenomenon, dating back only to the early 1900s. The earliest attempt to manage the mahogany resource at a national level occurred in Belize (then British Honduras) in the 1920s and 1930s. There a Forest Trust (subsequently Forest Department) was established with the aim of improving harvests and management practices for mahogany.[14]

As transportation infrastructures and heavy machinery advanced ever deeper into previously inaccessible primary forests, harvest intensities increased. The main regulatory 'tool' available for restricting harvest intensity has historically been the minimum diameter cutting limit, that is, the minimum stem size that could be legally harvested. Paradoxically, instead of increasing over time to reduce harvest pressure, the minimum diameter cutting limit has consistently fallen to allow ever more intensive harvests driven by rising consumer demand for the world's premier tropical hardwood. In Belize, the minimum diameter cutting limit fell in stages during the 20th Century from 106 cm to 58 cm; currently it is 60 cm diameter. In Mexico, the current minimum diameter cutting limit is 55 cm.

It was only during the 1990s in Bolivia and Brazil and in the early 2000s in Peru that regulatory frameworks were created to 'manage' mahogany harvests. Before then, mahogany was essentially mined from primary forests wherever loggers could access natural populations. To no small degree, new laws prescribing management criteria for mahogany were responses to the international debate about its commercial and conservation status culminating in mahogany's listing on Appendix II of CITES in 2002.

The concessions system in Peru and federal regulation of harvest practices in Bolivia aim to encourage best practices forest management. While management plans are not specifically tailored for mahogany, some harvest regulations create extra protections. The minimum diameter cutting limit for mahogany in Peru is 75 cm; forest management plans there typically anticipate 40-year cutting cycles. In Bolivia, the minimum diameter cutting limit for mahogany is 70 cm diameter on 20-year cutting cycles. Further, 20% of commercial-sized stems must be retained as seed trees for regeneration and future harvests, and the minimum landscape-scale retention density of mahogany trees > 20 cm diameter is 0.25 ha-1 (25 trees per 100 ha).

In Brazil, mahogany's exploitation began to be regulated in the early 1990s with the imposition of export quotas and with gradually increasing scrutiny of logging industry practices by federal and state authorities, including the requirement that production originate only from legally registered forest management areas. Export quotas fell from 150,000 m3 in 1990 to 50,000 m3 in 2000. The minimum diameter cutting limit for all timber species including mahogany during this period was 45 cm. As the logging sector specializing in mahogany continued to ignore or evade regulations governing mahogany harvests during the 1990s even while its inclusion on Appendix II was debated, the Brazilian government responded with a moratorium on new management plans including mahogany in 1996, and by suspending all commercial trade in the species in 2001.

In response to the Appendix II listing in late 2002, the Brazilian government established new and stricter management guidelines for mahogany in 2003. These raised the minimum diameter cutting limit to 60 cm; required that 20% of commercial-sized stems be retained for seed tree purposes; set the minimum landscape-scale retention density at 0.05 commercial-sized trees ha-1 (5 trees per 100 ha); and required cutting cycles of 25–35 years. Additional provisions require 100% pre-harvest commercial census with spatial planning using reduced-impact logging practices.

Ecology

Distribution Patterns

Riverine populations of mahogany tend to be logged first. Here, the Rio Envira in Acre, Brazil.

Mahogany is most commonly found in forests near water, whether along the banks of permanent (aseasonal) rivers or beside seasonal streams that stop flowing during the dry season. Although less common, it can also be found in stressed or disturbed transition zones between forest communities where canopy disturbance is frequent and light levels at ground level are persistently high.

In South America, early descriptions of mahogany's distribution patterns emphasized its association with river floodplains in the upper reaches of the western Amazon Basin. From Ecuador, Peru, Bolivia, and Brazil many observers described its tendency to grow at highest densities on drier, firmer soils slightly above seasonally inundated floodplains, where floods occurred infrequently. In lowland Peru, mahogany was reported to survive flooding but was usually found above lower areas with prolonged inundation. In Bolivia, Irmay (1949) wrote that mahogany "prefers lowlands and river margins with periodic inundation and humid soil year long… [it grows] in dense forests found on permeable, firm soil above but not near river margins".[15] Elsewhere in lowland Bolivia mahogany has been found perched atop steep erosion gullies in floodplain ecosystems.[16] Similar reports from Brazil have described mahogany's distribution in south Pará as concentrated "in low and more humid places near the streams".

Along the Rio Envira in Acre during the dry season.

In Brazil, three patterns of landscape distribution have been observed. First, riverine populations along rivers large enough to flow year-round were the first to be logged out in the 1970s when the region opened up to market infrastructures by gold miners, loggers, ranchers, and small-scale agriculturists. These mahogany populations vanished before scientists could document them and little is known about them. Second, populations in terra firme forests aggregate along the banks of seasonal streams that flow only during the rainy season. These areas are characterized by fast draining, sandy gray to white hydromorphic or 'water-formed' soils that have relatively high nutrient status compared to fine-textured soils on slightly higher ground. And third, populations occur at relatively low densities on the slopes to the tops of steep inselbergs or 'island mountains' that punctuate this region's landscape at irregular intervals. These fire-prone slopes are dry and exposed, with shallow sandy soils. Mahogany rarely grows to large stature on inselbergs but thrives there nonetheless in highly disturbed and open conditions.[17]

Mahogany can also be found growing at elevations as high as 1400 m in the Andean foothills of Ecuador, Peru, and Bolivia. Trees growing above 500 m elevations in Bolivia tend to be smaller than lowland trees, with denser, higher quality wood. This could be a function of generally drier soil conditions due to rapid subsurface drainage on steep slopes.

Population Density

Inselbergs ('island mountains') in southeast Pará, surrounded by pasture & secondary forest.

Mahogany trees are known for occurring in clumps or aggregations of tens to hundreds of mature stems, often with expanses of 'empty' forest many kilometers wide separating aggregations. Densities in Mexico and Central America tend to be higher than those reported from South America, though of course surviving populations do not necessarily reflect historic natural densities after centuries of exploitation, especially of riverine populations. In the Petén district of northern Guatemala densities of 12 trees per hectare were once found over large areas.[18] Nearly pure stands of limited extent – a few hectares – with densities up to 55–70 trees per hectare have been reported from Panama, Nicaragua, Guatemala, Belize, and Mexico. On Mexico's Yucatan Peninsula densities of 2.5–6.1 trees per hectare ≥ 15 cm diameter were reported during the 1990s in previously logged forested areas.[19]

In Bolivia and Brazil, recent large-scale inventories indicate that mahogany occurs at lower densities in both riverine and terra firme forests. In floodplains of lowland Bolivia adjacent to aseasonal rivers, aggregations of 0.1–0.2 commercial-sized (> 80 cm diameter) trees per hectare have been found. Outside areas of occurrence mahogany may not reappear for distances up to 10 km. These densities are similar to inventory results from Acre and Amazonas in west Brazil, where densities of 0.12 trees > 20 cm diameter per hectare (12 trees per 100 hectares) were observed. However, inventories in southeast Pará found 0.65 trees > 20 cm diameter per hectare (65 trees per 100 hectares), while a nearby research site in this region reported 1.18 trees this size per hectare (118 trees per 100 hectares).[20]

Reproduction

The 'pink' stage in crown replacement by a mahogany tree at the Agua Azul field site.

Reproduction by big-leaf mahogany trees is a yearlong process that begins when the rainy season ends in May or early June. As the forest dries, deciduous trees like mahogany begin to their leafy crowns. By July, the middle of the dry season, most mahogany trees drop all of their leaves and within a week of the last leaf falling, begin to flush new crowns. Tiny emerging leaves are bright pink before turning lime green, expanding within a month to full size. As new leaves grow, branching inflorescences emerge from leaf axils, with each flower stalk bearing up to 100 flower buds. The new crown requires just over one month to mature. Then flowers begin to open, initiating the next annual reproductive cycle.[21]

Individual flowers are pale yellow, less than 1 cm in diameter, and mildly scented. A large mahogany tree in full flower can have several hundred thousand flowers open at one time on its crown. A diverse community of small diurnal butterflies and nocturnal moths visit the flowers, with most visitation occurring during the late afternoon and early evening. Many species of ants, thrips, beetles, flies, bees, and wasps also visit flowers, many of these feeding on the basal nectary. Large emergent trees with spreading crowns present the largest floral displays and probably attract the largest pollinator crowds.

Mahogany tree with half-sized new green leaves at the Corral Redondo field site.

Individual mahogany trees flower up to a month at a time, while local populations take up to four months to flower. This means that early-flowering trees are reproductively isolated from late-flowering trees in the sense that their flowering schedules do not allow for pollen exchange. By the time the rainy season sets in, small fruit have begun to develop on tree crowns. Woody fruit mature through the wet season, gradually becoming full-sized. Scarlet macaws break into fruit on the crown and eat seeds. Seeds developing inside fruit capsules are also susceptible to attack by the mahogany shootborer (Hypsipyla grandella), a nocturnal moth whose larval caterpillars bore into the fruit and consume the seeds.

Mahogany fruit held upside down, dehiscing from the bottom up.

Mahogany trees begin to fruit annually or supra-annually once they reach 30 cm diameter; although fruiting has been observed on trees 20–30 cm diameter, it is rare. Mahogany trees larger than 60 cm diameter produce significantly more fruit on an annual basis than trees 30–60 cm diameter (15 fruit/year vs. 4 fruit/year, respectively). In Pará, Brazil, a 'large' fruit crop may contain 25 or more capsules, while exceptional fruit crops in excess of 300 have occasionally been observed.[22] These fruit production rates are low compared to populations in Acre and Bolivia in southwest Amazonia, where large (130 cm diameter) trees have been observed to produce 900+ fruit in a single year.

As the rainy season ends in late April and May and tree crowns thin as leaves begin to fall, fruit held above the crown begin to dry out and split open. Five woody valves (pericarps) peel off of each fruit and drop to the forest floor, exposing approximately 60 winged seeds ready to disperse on the first wind capable of dislodging them from the parent tree. Most seeds land within 35 meters of parent trees, but occasional wind gusts can disperse seeds several hundred meters. Seeds disperse through the dry season as tree crowns go completely bare and then reflush new leaves. By the time a tree has a new crown and is flowering heavily, few seeds will be left to disperse, and the cycle repeats itself.

Seed Germination

Seed viability at the time of dispersal is commonly > 90%. Seeds have no long-term dormancy mechanisms, but can survive four to six months in the field under dry conditions and up to 10 months when dried and chilled. Moisture availability associated with the onset of the rainy season triggers germination. Germination generally begins within 10 days of sowing in nurseries under moist conditions, and continues for about three weeks afterwards, with an average time between planting and total germination of 28 days. Differences in germination rates between 'large' and 'small' seeds and among fruit capsules of different sizes have also been observed.[23]

Foreground mahogany seedling has 2 pair of initial simple leaves with new flush (growth) beginning (pale green stem tip).

After germination, mahogany seedlings grow to 15–25 cm height, with two to four narrow cotyledons or vestigial leaves spaced alternately along its lower length and then two pairs of nearly opposite, heart-shaped simple leaves on short petioles near the stem apex. From emergence to full-sized first leaves requires 10–14 days. Seedlings will flush new growth within two to four weeks after lignification; when conditions are ideal, especially in high light environments, the first flush may add up to eight simple leaves and 5–10 cm of stem growth, with new leaves much larger and more elongate than first leaves. Vigorous seedlings may begin to form compound leaves during the second flush four to six weeks later, setting bi- or trifoliolate leaves and then, in successive flushes as height extension accelerates, four- to eight-foliolate leaves up to 18-foliolate as saplings rise above 1.5 m tall. New leaves are set in spiraling formation along the expanding apical leader, widely spaced at first and then bunching tightly as apical growth slows, the last (highest) leaves tending to be much smaller than the first. Bunched leaf scars on stems of saplings and poles delineate successive apical flushes which occur three to four times annually.

Seedlings, saplings and poles are strongly heliotropic, capable of growing at steep angles towards the sun in open spaces as overhead canopy gaps close with secondary growth. Fast-growing saplings can add up to one meter's height in a single flush, setting 20–30 large compound leaves whose combined weight may cause the new crown and even the entire stem to flop groundwards. As saplings grow taller than 2 meters height, apical dominance weakens and lateral sprouting may occur along the upper stem. This tendency is more pronounced on plants growing in open conditions (for example, in plantation settings) compared to plants growing in dense secondary regrowth.

The transition from juvenile to adult growth patterns – from an evergreen habit with multiple annual apical flushes to complete crown loss and reflush once annually during the dry season – occurs during the early pole phase between 5–10 cm diameter. Leaf size and leaflet number also diminish once adult growth patterns are set. Whether this transition is prompted by environmental or genetic factors is unknown.

Cultivation

Since the restrictions in logging this tree in its native habitats, it has been introduced into several Asian countries in plantation environments. The mahogany timber grown in these Asian plantations is the major source of international trade in genuine mahogany today. Unlike mahogany sourced from its native locations, plantation mahogany grown in Asia is not restricted in trade. Major Asian countries which grow *Swietenia macrophylla* are India, Indonesia, Malaysia, Bangladesh, Fiji, Philippines and some others with India and Fiji being the major world suppliers.

Gallery

Young tree in Kolkata, West Bengal, India.

Young Bark in Kolkata, West Bengal, India.

Old Bark & leaves in Kolkata, West Bengal, India.

Leaves & Pond Heron in Kolkata, West Bengal, India.

Fruit with leaves at Branch Canopy in Kolkata, West Bengal, India.

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- Big-Leaf Mahogany in Brazil & South America (www.swietking.org) (http://www.swietking.org)

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