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CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES
OF WILD FAUNA AND FLORA

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Sustainable management and scientifically based non-detriment findings

THE SUSTAINABLE MANAGEMENT OF *SWIETENIA MACROPHYLLA*

1. This document has been prepared by a consultant under contract with the CITES Secretariat.

2. This document addresses national and regional forest management issues concerning big-leaf mahogany (*Swietenia macrophylla*, Meliaceae) across its natural range in Mexico, Central America, and South America. Mahogany's listing on CITES Appendix II at the 12th Conference of the Parties in November 2002 means that exporting countries will be required to verify that traded volumes were legally acquired and that harvests were not detrimental to mahogany's role in the ecosystem. For the purposes of this document, sustainable forest management is taken to mean continual timber production over the long term while maintaining environmental services and providing non-timber forest products (Pearce *et al.* 2003). Because this definition implies long-term maintenance of forest cover for production purposes, discussion treats both technical and public policy aspects of forest management that are prerequisite to sustainable production of mahogany. Establishment and maintenance of mahogany plantations, reviewed by Mayhew & Newton (1998), are not covered here because the CITES focus on natural populations.

TECHNICAL ASPECTS OF SUSTAINABLE MANAGEMENT

Mahogany ecology

3. Mahogany is an emergent forest tree typically growing 1 – 2 m in stem diameter and 30 – 40 m tall. It is a light-demanding species characterized by rapid vertical growth in forest canopy gaps following natural disturbances that open space for seedling establishment and growth. Disturbances said to account for mahogany population structures in natural forests include treefall gaps, floods, fires, hurricanes, and abandoned swidden agricultural plots (Stevenson 1927, Lamb 1966, Gullison *et al.* 1996, Snook 1996, Grogan 2001).

4. Mahogany is deciduous, replacing its crown annually and flowering during the dry season. Trees larger than ~50 cm diameter can be expected to fruit annually, though production varies widely from tree to tree and year to year. Up to 40,000 winged seeds may be produced in a single year by large emergent trees. Seed dispersal is by wind during the late dry season and is typically restricted to within 100 m of adult trees. Seeds may face heavy predation by rodents and insects on the ground before germination, which occurs within 3 – 4 weeks after the onset of the rainy season. Seeds cannot survive ungerminated from one year to the next (Lamb 1966, Morris *et al.* 1998, Clements 2000, Grogan 2001 & unpublished data).

5. Seedling establishment is common in the forest understory, but robust seedling growth requires elevated light conditions typical of treefall gaps. Seedling survival rates in forest shade beneath closed canopies tend to be low, with no appreciable "seedling bank" accumulating from year to year. Vigorously growing seedlings and saplings are often infested by mahogany shootborer, the moth *Hypsipyla grandella*, whose larval caterpillars consume sprouting apical meristems, disabling vertical growth and damaging stem form. Observed mean diameter growth rates by trees >10 cm range from 0.26 to 1.09 cm/year across mahogany's natural range. Estimated rotation lengths for mahogany in natural forests – the number of years required for trees to grow to commercial size under natural conditions –

range from 55 to 122 years (Lamb 1966, Gullison & Hubbell 1992, Snook 1993, Gullison *et al.* 1996, Grogan 2001).

6. Trees >70 cm diameter characteristically begin to decay from the center out, with giant stems often standing nearly hollow. The most common causes of natural mortality by adult trees are suppression by neighboring trees or vines, windthrow, and senescence from heart-rot and cumulative crown injury (Lamb 1966, Snook 1993, Grogan 2001).

Range and distribution patterns

7. Mahogany's natural range follows seasonally dry tropical forests from Mexico at 23° N of the equator down the Central American Atlantic coastal strip into Costa Rica, then along the Pacific coastal strip from Panama into Colombia, Venezuela, and south through Ecuador, Peru, Bolivia, and Brazil to points as far as 18° S (see Figures 1 and 2). 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, in a wide variety of soil types and conditions. Total original area covered has been estimated as 15 million ha in Mexico, 36 million ha in Central America, and 220 million ha in South America (Oliphant 1928, Stevenson 1928, Williams 1932, Lamb 1966, Pennington *et al.* 1981, Calvo & Rivera 2000, Conservation International 2001).

8. Mahogany was earliest known as a riverine species growing along coastal riverways on the Atlantic seaboard of Belize. In western Amazonia mahogany typically occupied drier, firmer soils slightly above seasonally inundated floodplains where floods occurred infrequently. In terra firme (upland) forests, mahogany occurs at highest densities in transition zones characterized by high rates of natural forest disturbance, where different vegetative communities grade into each other. It demonstrates no clear topographic or edaphic association on essentially flat terrain in Mexico's Yucatan Peninsula, but strong association with seasonal streambeds on gently undulating landscape in southeast Pará, Brazil. On steeper terrain from southwest Pará to the western Brazilian state of Acre, the Pando region of Bolivia, and southwestern Peru, mahogany is often found growing near first- and second-order seasonal streams (Grogan pers obs). At regional levels, drier, more disturbance-prone areas tend to have higher stockings than wetter, more stable forest environments (Williams 1932, Swabey 1941, Hoy 1946, Irmay 1949, Lamb 1966, White 1978, Pires & Prance 1985, Negreros-Castillo 1991, Gullison & Hubbell 1992, Snook 1993, Veríssimo *et al.* 1995, Weaver & Sabido 1997, Baima 2001, Brown *et al.* 2003, Grogan *et al.* 2003a).

Population structures

9. Mature trees are typically found scattered through the forest matrix at low densities, usually <1 adult tree/ha. In the Petén district of northern Guatemala densities of 12/ha were once found over large areas. Nearly pure stands of limited extent with densities up to 55 – 70/ha have been reported from Panama, Nicaragua, Guatemala, Belize, and Mexico. Richards (1991) reported from the community forest Noh Bec in Quintana Roo, Mexico occurrence of 6.1 trees/ha ≥15 cm diameter in 20,700 ha. Gullison *et al.* (1996), working in the floodplains of lowland Bolivia, reported that mahogany occurs in forest areas up to several hundred hectares in size, with 0.1 – 0.2 merchantable (>80 cm diameter) trees/ha and corresponding densities of sub-merchantable stems. Outside these areas mahogany may not reappear for distances up to 10 km. Densities ranging from 0.05 – 2.8/ha have been reported from terra firme forests in Brazil (Lamb 1966, Veríssimo *et al.* 1995, Baima 2001, Grogan 2001).

10. Mahogany population structures vary at regional and local scales according to disturbance regimes and physiographic conditions that influence regeneration processes. Two types of population structure have been described: uni- or bimodal, where most individuals within an aggregation of adult trees are roughly the same stem diameter or size, or fall into two general size classes, having established together following some large-scale or catastrophic disturbance such as fire, hurricane, or flood; and amodal, where all stem diameter size classes are represented more or less equally up to larger size classes when natural mortality causes declining stem numbers (Gullison *et al.* 1996, Snook 2003, Baima 2001, Grogan 2001; see Figure 3). These different scenarios require different management strategies if long-term timber production is to be sustainable, as will be addressed further below.

History of exploitation

11. Mahogany's commercial exploitation began in the late 17th Century along coastal riverways in Belize. Trees were felled either directly into rivers or skidded short distances to them, first by slave labor from about 1700 and then from greater distances by oxen beginning around 1800. For centuries mahogany extraction was highly selective due to high quality standards and technological constraints on felling and transport. Only the most valuable trees could be taken: those large enough to off-set extraction costs yet not so large as to be too difficult to hand-fell above buttresses reaching up to 5 m height. Hollow trees were left standing. Thus very large "seed trees" typically survived harvest along with trees smaller than the minimum commercial diameter. This allowed mahogany populations to recover between harvest cycles through growth and natural regeneration where forests were not converted to other uses. This pattern characterized mahogany logging in Mexico and Central America until World War II when mechanized logging equipment began extending access into upland forests, and until the early 1970s in southeastern Amazonia when overland roads began penetrating previously unexploited terra firme forests (Lamb 1966, Veríssimo *et al.* 1995, Weaver & Sabido 1997, Snook 1998).

Logging impacts on mahogany populations

12. Table 1 summarizes impacts of logging on various phases of mahogany's life cycle.

13. Mahogany logging as practiced during recent decades across much of its range represented a one-time harvest of old-growth timber that cannot be matched during future cutting cycles. Without technological constraints on the maximum stem diameter that could be felled, loggers fell all trees larger than the minimum diameter that could be profitably transported (as small as 20 cm in Belize and 26 cm in southeast Pará, Brazil), a practice known as high-grading, creaming, or mining the resource. Large hollow trees are felled on the chance that some portion of the upper bole might be merchantable. This contemporary extraction pattern decimates adult populations, leaving few seed-producing trees in its wake. Surviving trees are generally too few and too small to recuperate population structures through growth and natural regeneration within years or even decades between first and second cutting cycles on largely unregulated logging frontiers (Weaver & Sabido 1997, Grogan 2001, Kammesheidt *et al.* 2001).

14. As a light-demanding species requiring canopy disturbance for successful regeneration and recruitment, mahogany seems suited to thrive in the post-logging forest environment characterized by treefall gaps, log landing yards, and extraction roads. Yet surveys of seedling regeneration following conventional logging operations have generally demonstrated re-stocking rates inadequate for population recovery. Regeneration failures may result from the lack of seeds, seedlings, and or adequate growing conditions for seedlings and juvenile trees in the post-logging forest environment. These problems arise from three principle sources: the seasonal timing of logging operations, minimum diameter cutting limits, and unplanned logging practices (Stevenson 1927, Quevedo 1986, Gullison & Hubbell 1992, Snook 1993, Veríssimo *et al.* 1995, Gullison *et al.* 1996, Dickinson & Whigham 1998, Grogan *et al.* 2003b). Evaluating logging practices and life history factors, Martini *et al.* (1994) rated mahogany as "susceptible to population reductions" by current logging practices in a survey of 305 Amazonian timber species.

Management practices past and present

15. Management of mahogany in Mexico and Central America until the early 1900s simply involved retention of non-merchantable trees: those too large to fell, hollow, of poor form, or too small to meet processing standards. Successive harvests at 30 – 40 year intervals were possible because surviving populations could re-stock forests through growth and seedling regeneration (Weaver & Sabido 1997). This "passive" management and subsequent practices described below are summarized in Table 2.

Taugnya, shelterwoods, group selection

16. Active natural forest management began in the 1920s in Belize when it became clear that increasing logging intensities would deplete the mahogany resource if seedling regeneration was not artificially encouraged. Attributing exceptional mahogany densities to natural regeneration following slash and burn agriculture, earliest forest managers focused on

taugnya systems interplanting mahogany by seed into swidden cornfields. This yielded good results where cleanings were possible during the first few years after seedling establishment. Shelterwood systems – canopy thinnings with retention of mahogany seed trees to encourage establishment of natural regeneration – yielded increased seedling densities but experienced high mahogany shootborer infestation rates and proved too expensive to manage over the long term. Line plantings in secondary forests yielded poor results due to inadequate canopy openings (Stevenson 1927, Weaver & Sabido 1997). According to Lamb (1966), best seedling growth performance and lowest shootborer attack rates requires establishment in large openings where secondary vegetation can shield growing seedlings from the shootborer. He recommended management by group selection during logging: creating multiple treefall gaps through removal of mahogany and secondary species, with either direct seeding on drier sites or outplanting nursery-grown seedlings on wetter sites. Lamb further suggested fire treatments to reduce competition by advance regeneration of other primary forest species.

Minimum diameter cutting limits, forest concessions

17. In recent decades natural forest management of mahogany has relied on minimum felling diameter limits and, in Mexico, Belize, and Venezuela, on division of forest concessions into annual compartments corresponding to projected felling cycles ranging from 25 to 40 years. Minimum felling diameter limits have declined from 106 to 58 cm in Belize since the 1920s, and currently vary from 55 cm in Mexico to 75 cm in Panama. However, this practice is equivalent to high-grading and leads to depletion of adult populations without management of regeneration. As well, minimum felling diameter limits are rarely respected where government regulatory control is weak or non-existent, as is the case across most of Amazonia. Enrichment plantings begun in the early 1970s in Venezuela were abandoned due to costs (Lamprecht 1989, Weaver & Sabido 1997, Snook 1998, Kammesheidt *et al.* 2001, Weaver & Bauer 2003).

Polycyclic rotations

18. The most extensive forest management for mahogany is currently being practiced by forest communities (*ejidos*) in the state of Quintana Roo, Mexico. There, mahogany is harvested with selected high-value timber species on a polycyclic schedule in three 25-year cutting cycles within a 75-year rotation period. Forested areas are divided into 25 compartments that are harvested sequentially on an annual basis; second and third cutting cycles are meant to remove today's "reserve trees" 35 – 54 cm and 15 – 34 cm diameter, respectively. Some communities augment natural regeneration through enrichment plantings in logyards and logging gaps. However, growth rates by sub-merchantable trees indicate that harvest intensities are too high for sustained yields, that is, the minimum felling diameter limit may be too low (Snook 1998, 2003).

Certification, forest legislation

19. Recent efforts to shift conventional or predatory logging practices towards sustainable management have emphasized forest certification, that is, Forest Stewardship Council-standard management practices conferring "green seal" market advantage. Certified management areas harvesting mahogany exist in Mexico, Belize, Guatemala, Honduras, and Bolivia, involving forest communities, non-profit land trusts, and industrial concerns. However, total annual production from certified management areas remains small compared to total annual volumes traded, and it remains unclear whether certified areas are managing mahogany on a sustainable basis, FSC standards notwithstanding (Brokaw *et al.* 1996, Calvo & Rivera 2000).

20. National forest legislation across mahogany's natural range requires that timber yields be sustained within demarcated management areas, but technical and regulatory capacity is rarely equal to the level of logging activity and land area involved. This has led to systematic depletion of supply and, in Brazil, to a moratorium on mahogany logging in 2001 until industry practices could be brought under control. New federal regulations published in August 2003 specified management practices for mahogany in Brazil. These include: cutting cycles based on site productive potential; 100% inventory of merchantable mahogany trees >20 cm diameter; density estimates of juvenile trees and natural regeneration; minimum diameter cutting limit of 60 cm; retention of 20% of merchantable trees as seed trees; and

seedling enrichment planting where natural regeneration is insufficient for population recovery (Ibama 2003).

Guiding principles for sustainable management

21. As can be seen from Table 2, sustainable management of mahogany in natural forests has yet to be achieved at significant scales. However, economic, social, and political reasons for this aside, technical aspects of sustainable management are relatively straightforward. Timber volumes provided by merchantable trees harvested during the first cutting cycle must be replaced during the time interval before the second harvest by growth of sub-merchantable trees, that is, those too small to remove at the time of first harvest. Subsequent harvests must be provided by seedling growth into merchantable size classes, whether naturally occurring or artificial (i.e., from enrichment planting). Tree growth and regeneration rates must be understood at local scales in order to calibrate current harvest levels and investments in regeneration management that will ensure future harvests (Grogan *et al.* 2002).

22. Generic principles for sustainable management outlined below are shown schematically in Table 3; these guidelines will require adjustments according to local densities of adult trees, site growth potential, and stocking rates of natural regeneration. Where densities of adult trees are relatively high (>1/ha), natural processes favoring regeneration – disturbance regimes, competitive environment, and physiographic factors influencing growth – may assist management efforts, reducing investments necessary to ensure sustainability. Where adult densities are low (<1/ha), conditions favorable to successful regeneration and growth may occur rarely, and management investments necessary for sustainability may be higher – paradoxically where timber yields will be low during the first harvest. In general, unlogged stocks across mahogany's natural range fall into the latter category because they have been inaccessible until recent years.

Inventory data

23. Empirical information regarding stocking densities is essential for planning resource use at both macro- and micro-scales. At national levels, annual harvest quotas can only be rationally determined if stocking data is current and periodically updated. Within management areas, spatially explicit inventory data is necessary in order to plan harvest levels and management practices necessary for sustained-yield production.

Merchantable trees: 1st harvest

The management plan

24. Planned extraction should include mapping of all merchantable trees and pre-harvest design of road and skidding networks. This reduces operational costs and damages inflicted on forest structure by logging, lowering risk of post-harvest forest fires where climate is strongly seasonal (Holdsworth & Uhl 1998).

Rotation length, cutting cycle, and minimum diameter cutting limit

25. Rotation and cutting cycle lengths[1] should be derived from regional or site-specific diameter growth and regeneration rates. Where active management of sub-merchantable trees and regeneration are planned (e.g., vine cutting, canopy thinning to reduce competition), rotation lengths will be shorter than indicated by mean natural growth rates. Minimum diameter cutting limits will vary according to adult density, population structure, and regional or site-specific potential growth rates. Limits should be set so that sub-merchantable trees are retained at sufficient densities to provide second harvests under planned cutting cycles (and third harvests where three cutting cycles per rotation are planned). Minimum diameter cutting limits must be strictly enforced.

[1] Rotation length indicates the number of years it takes for a tree to grow to merchantable size. The cutting cycle indicates the number of years a given management area will lie "fallow" or uncut between harvests. In polycyclic management systems, trees are divided into merchantable (generally large) and sub-merchantable (generally small) categories, with future cutting cycles supplied by trees that are sub-merchantable at the time of first harvest.

Seed tree retention and selection criteria

26. Seed trees should be retained as sources for seed dispersal by wind where natural regeneration will provide future harvests, which may be the case where adult densities are high (>1/ha). Seed trees should be retained as sources for seed collection and re-distribution across management areas where artificial regeneration will be necessary. This will be the case where adult densities are low (<1/ha) because seed dispersal areas downwind of any given tree will be small relative to the total area requiring seeds after logging. Large hollow unmerchantable mahogany trees may be perfectly healthy otherwise and capable of producing high-quality seeds. Where adult densities are low, seed trees may need to be retained in groups to maintain reproductive capacity.

Directional felling and seed collection

27. Where possible, trees should be felled directionally to open canopy gaps where seeds and seedlings are most likely to occur naturally, that is, in the direction of prevailing dry season winds. If tree felling occurs before seed dispersal, unopened fruit should be removed from crowns for seed collection.

<u>Sub-merchantable trees: preparing the 2nd harvest</u>

Thinning competing crowns and vine cutting

28. The second harvest should be identified and treated at the time of first harvest (year 0 in Table 3, by cutting vines and thinning neighboring tree crowns competing for canopy space with sub-merchantable mahogany trees (35 – 60 cm diameter where the minimum diameter cutting limit is 60 cm). Suppressed trees may be capable of accelerating diameter increments in response to canopy thinning operations. Sub-merchantable trees should be ready for harvest approximately 30 years following the first cut.

<u>Regeneration: treating and establishing the 3rd harvest</u>

29. The third harvest should also be anticipated at the time of first harvest by treating trees 10 – 35 cm diameter and pre-established natural regeneration. Where population densities are low, artificial regeneration – enrichment plantings in logging gaps – will be necessary. Operations should include:

Thinning competing crowns and vine cutting

As in paragraph 28.

Opening clearings for natural regeneration

30. Canopy gaps should be opened downwind of logged and retained mahogany trees where seeds are likely to disperse. Prior knowledge of fruiting rates and patterns by individual trees could indicate trees with highest fecundity for treatments; or, gaps could be opened wherever trees are confirmed to fruit heavily.

Enrichment planting

31. Seeds (or seedlings) should be planted directly into artificial gaps opened where site quality increases the likelihood of sustained growth and recruitment. Planting densities should be low to avoid pest build-up (the mahogany shootborer*, Hypsipyla grandella*); for protection from the shootborer, seedlings should grow within the matrix of secondary vegetation that rapidly colonizes logging gaps. Site preparation could include soil scarification and burning within gaps to enrich soils and reduce above- and belowground competition. Burns should be strictly monitored to avoid escaped forest fires (Lamb 1966, Newton *et al.* 1993, Snook 1993, Grogan 2001).

Silvicultural treatments

32. Periodic silvicultural treatments will be necessary during the first years following seed or seedling outplanting. The precise sequence of tending operations (cleaning around growing saplings and poles, occasional gap enlargement) will depend on local site

conditions and should be determined experimentally. The hypothetical scenario illustrated in Table 3 anticipates tending operations 1, 3, 6, and possibly 10 years following establishment.

Second and 3rd harvests

33. Sub-merchantable trees 35 – 60 cm diameter treated during the first cutting cycle should be ready for harvest after approximately 30 years; this time-period will depend on site-specific growth rates. At the time of the second harvest, trees 10 – 35 cm diameter, natural regeneration, and enrichment plantings that were treated or established in logging gaps in year 0 will likely require tending operations to stimulate growth rates. Harvest of these trees, assumed to have grown to 35 – 60 cm during the time since the first harvest, occurs during the third harvest or 60 years after the first cut. At the time of third harvest, natural regeneration should be treated and enrichment plantings established in logging gaps. That is, each harvest should be accompanied by regeneration treatments ensuring establishment of future harvests.

Management of mahogany in logged forests

34. Where forests have been logged for mahogany only once, it may be possible to manage surviving populations. These practices would emphasize treatments favoring second- and third-harvest trees, including:

Thinning competing crowns and vine-cutting

35. These treatments should free surviving sub-merchantable mahogany trees 35 – 60 cm diameter from competition by neighboring crowns and vines, as described in section 1.7.3.1. This stock could be harvested during the second cutting cycle approximately 30 years following treatment.

Establishing the 3rd harvest

36. Treatments described for unlogged forests are appropriate for establishing trees to be harvested during the third cutting cycle. However, enrichment planting would occur in logging gaps created by extraction of secondary timber species and by removal of intermediate-sized surviving mahogany trees with low growth potential (for example, with damaged crowns). Removal of secondary species serves the dual purpose of opening growing space for outplanted mahogany seedlings and subsidizing treatment costs (Snook 1993, Gullison *et al.* 1996). Where logging secondary species is not economically viable, it may be necessary to open growing space by felling non-commercial trees. In this case, incentives for loggers and landowners interested in forest management are greatly reduced, as they are forced to return to previously logged forests to implement silvicultural treatments without benefit of short-term returns on their investment.

Adaptive management approaches and research needs

37. Guiding principles for sustainable management of mahogany in natural forests outlined in section 1.7 encapsulate knowledge accumulated over many decades by forest managers and researchers across mahogany's natural range. These guidelines will require adjustments in emphasis and timing according to local and regional population density patterns, growth and regeneration rates, and site conditions including socio-economic factors. For lack of general experience with mahogany in natural forests, forest managers must have access to the best possible information about its regeneration ecology and local growth rates. Improved management prescriptions will depend on collection of site-specific information critical to projecting rotation lengths and to modifying silvicultural practices. In most regions this information does not exist and must be collected as management efforts proceed. This information must in turn be locally coordinated and disseminated among forest managers.

38. Table 4 summarizes research needs at both local and regional scales.

National and regional resources

39. Table 5 outlines mahogany-related resources by producer and importer companies. This table is by no means complete, but represents what we have at our disposal at the time of writing.

It is expected that this table can be expanded based on country reports presented at the Mahogany Working Group in Belém, and based on other information as it comes available.

NON-TECHNICAL ASPECTS OF SUSTAINABLE MANAGEMENT: ECONOMIC COSTS AND PUBLIC POLICY

Economic opportunity costs

40. Sustainable management of mahogany requires that extraction intensities be controlled and cutting cycles respected. However, in many cases other land-use options – for example, predatory extraction of mahogany and other high-value timber species, and forest conversion to agriculture and pasture – return higher short-term profits. Sustainable management of mahogany would then depend on economic mechanisms reducing or eliminating opportunity costs associated with forest management, that is, the cost of foregoing higher immediate profits that could be invested in alternative investment opportunities.

Regulation and control

41. Regulatory control of logging is required to ensure compliance with management plans and to provide information towards improved practices (adaptive management). Control could be improved through investment in technical capacity and adoption of new technologies and auditing procedures within government agencies responsible for environmental protection. Management areas should be periodically audited by independent technical consultants. Independent audits could reduce transaction costs for regulatory agencies including operational costs and the time necessary to obtain resource use authorization. Mahogany's inclusion on CITES Appendix II creates opportunity for such audits to become a routine control mechanism within regulatory agencies, improving oversight of forest practices beyond the specific case of mahogany.

42. Recently developed methodologies make it possible to demarcate management areas and rural property boundaries on satellite images, and to identify recently logged areas. Control of log transport could be improved by installing georeferencing devices on transport vehicles that would allow trucks loaded with mahogany to be tracked between points of embarkation and delivery, alerting authorities when vehicles stray from authorized routes or when suspect operations are registered. The government of Brazil is now testing the use of such technologies. Results from these studies should be made available to other range nations (Souza Jr. & Barreto 2000, Barreto & Souza Jr. 2001).

Market policies

43. Forest management could become more financially attractive where the market pays a premium for sustainably produced supplies or for other goods and services provided by management areas. To date, market options have played a minor role in stimulating forest management. Some options include:

<u>Forest certification</u>

44. Independent certification verifying timber origin via chain of custody has been used to promote forest management. In general, certified timber enjoys two principle market advantages: a price premium and maintenance or expansion of market share. It is possible that effective CITES Appendix II implementation could reduce or render irrelevant demand for certified supplies since it was the lack of credibility by government regulatory efforts that created demand for certified products in the first place. In this case, the principle factor driving price increases would be reduced supplies resulting from export controls.

<u>Payments for environmental and other services</u>

45. Payments for environmental services such as carbon storage, soil protection, and biodiversity represent alternative incentives that could make forest management more attractive. However, revenues generated by these markets have proven limited so far, principally for lack of global mechanisms for collection and transfer of payments (Richards 1999). The first major advance in this type of arrangement would have been inclusion of avoided deforestation as an activity complying with the Kyoto Protocol's Mechanisms for Clean Development. Unfortunately, avoided deforestation has been discarded as an eligible activity under the Kyoto Protocol.

46. A new mechanism that could be used to promote sutainable management of mahogany is the conservation concession proposed by Conservation International in 2000. This mechanism was designed to purchase conservation rights within forest areas that otherwise would have been exploited for timber. Under this type of agreement, the owner of a forested area receives annual payments upon demonstration that the area is being protected. This mechanism could be adapted to promote forest management in regions where mahogany population densities are low, considering that in these cases forest structural damages associated with logging and silvicultural treatments would be low, leaving the forest with high conservation value. Payments for conservation could encourage land-owners to implement silvicultural practices necessary for mahogany regeneration and forest protection. By July 2002, Conservation International had reached agreements with forest concessionaires in three countries (Guyana, Guatemala, Peru) and was conducting feasibility assessments in six others (Mexico, Bolivia, Ecuador, Indonesia, Cameroon, Madagascar) (Rice 2002).

47. This type of arrangement would probably be most attractive to private landowners in regions where alternative land-use opportunities are few. Conservation concessions would be unattractive on public lands in regions where pressure for economic growth is high. In the case of public productionn forests, the decision to grant concessions is often tied to local interests in multiplier effects associated with logging, such as employment generation, tax revenues, and consolidation of political power. Conservation concessions that do not offer opportunities to aggregate value through activities like ecotourism would not be attractive for public lands.

48. In the absence of external mechanisms to stimulate large-scale forest management, it will be necessary for individual countries to develop compensation or stimulus measures. These could include reduction of property taxes associated with forested land (currently the case in Brazil) and financial compensation for rural land-owners through reduction of income- or forest use-related taxes. See Richards (1999) for an extensive review of international financial mechanisms related to forest use, and Haddad & Rezende (2002) for review of opportunities in Brazil. However, these financial mechanisms could ultimately face restrictions due to budget difficulties within producer nations.

Land tenure

49. Investments in forest management yielding long-term benefits require clear and secure land tenure arrangements. Conflicts over land ownership and lack of clarity about property rights could have negative impacts on sustainable management of mahogany in various producer nations (see Weiss 2002 on the Brazilian case). Key countries within mahogany's natural range – Peru, Bolivia, and Brazil – are currently clarifying property rights through such measures as: creation of protected areas; demarcation of indigenous and forest-dwelling communities; and creation of production forests where forests would be used for the production of goods and services through use agreements (concessions) with the private sector.

50. Correct implementation of concession policy will require major institutional investments and administrative transparency (Gray 1999). The concession process could also be slowed by the need for public participation and consultation among the many actors involved. On the other hand, it is urgent that property rights be clarified before uncontrolled logging expands into new occupation frontiers. In the short term, the most important issues are to designate and demarcate new forest production areas while administrative capacity is being created. It is therefore critical that efforts to clarify property rights be accelerated and strengthened in order that sustainable management of mahogany within public and private forests becomes possible.

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Figure 1

Mahogany's natural range across Mexico and Central America.
Based on Lamb 1966, from Grogan *et al.* 2002.

Figure 2

Mahogany's natural range in South America.
Based on Lamb 1966, from Grogan *et al.* 2002.

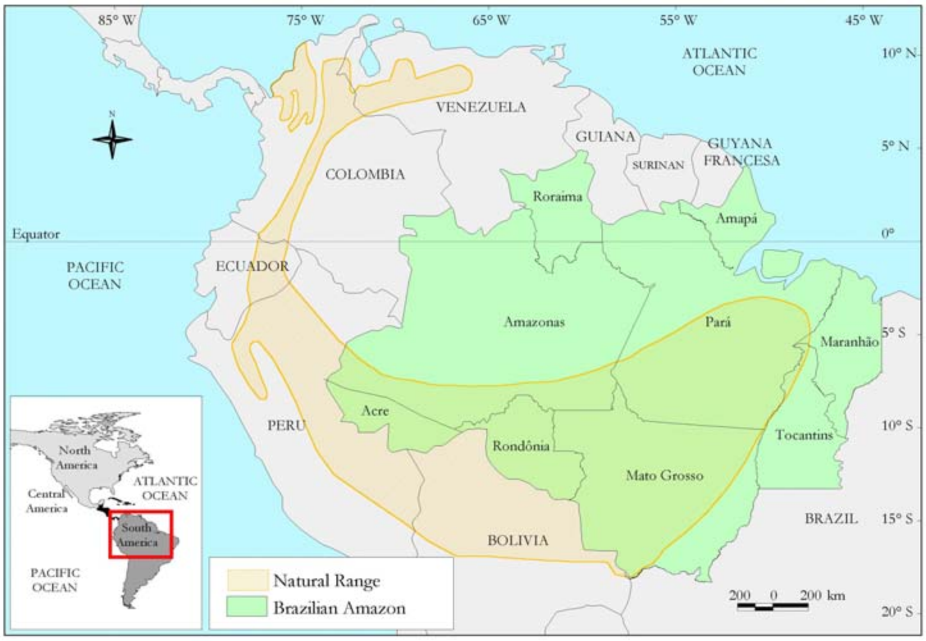
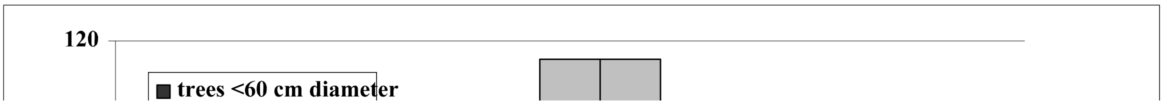


Figure 3

Two types of mahogany population structures.

A. Uni-modal population structure with a single-aged cohort (peak) of trees roughly the same size. Size classes gradually spread apart by differences in diameter growth rates over time. Bi-modal population structures would be bi-aged with two cohorts (peaks) spreading apart by size class over time. B. Amodal population structure with no peaks = multi- or all-aged. If total population sizes are equal (890 trees >10 cm diameter as shown), a minimum diameter cutting limit of 60 cm would retain fewer sub-merchantable trees for future harvests in A. (16.9% of total population >10 cm diameter) than in B. (38.4% of total). Trees retained in A. would also be, on average, smaller than in B., that is, they would represent lower potential volume available at the time of the second harvest.

A.



B.

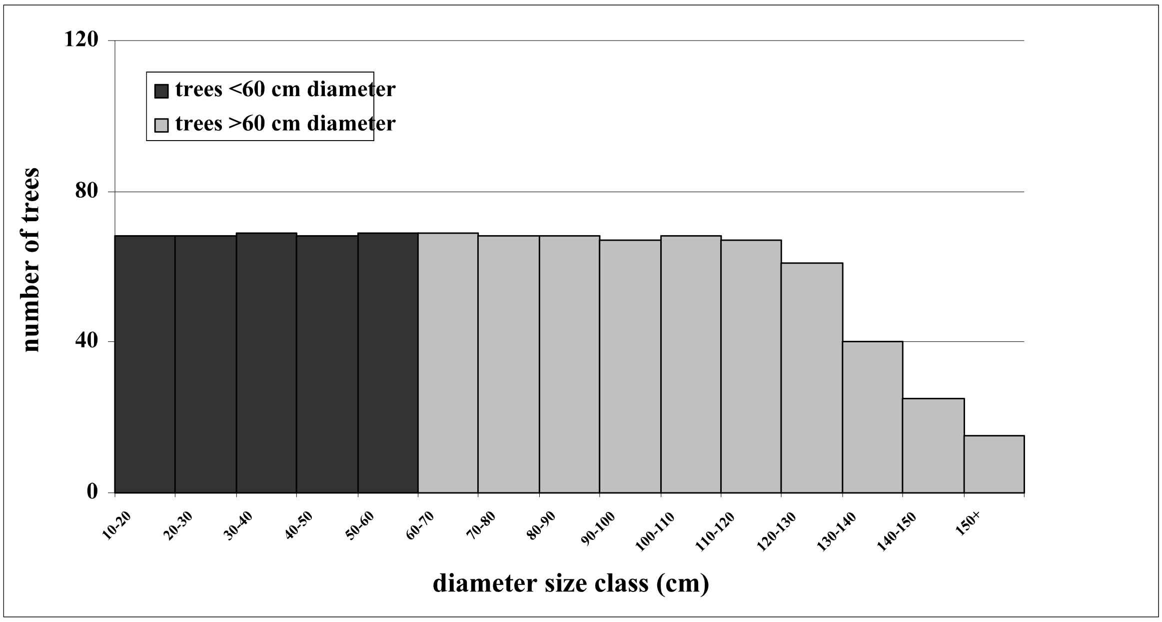


Table 1

Logging impacts on mahogany populations.
See paragraphs 13 and 14 for references.

Logging practice	Life phase / aspect impacted	Impact
Logging timing	Seed dispersal	Seeds undispersed because fruit capsules closed at time of logging (late rainy season / early dry season)
No maximum diameter cutting limit	Seed production	Depressed because no seed trees retained
Minimum diameter cutting limit	Population structure	Few small survivors (amodal) / rare small survivors (uni- or bimodal)
"	Seed production	Low population-level production because surviving trees are small
"	"	Depressed because increased distance between surviving trees
"	Seed dispersal	Reduced distance because surviving trees are small
Unplanned selective extraction	Seed availability	Few seeds available some years because annual variation is large
"	Seedlings	Low survival & growth rates because no pre-logging inventory / post-logging cleaning treatment
"	"	Low growth rates because single treefall logging gaps are too small
"	Sub-merchantable trees	Damaged during logging because unmarked
"	"	Low diameter increment rates because vines & competing trees uneliminated during or after logging
"	Population structure	Unknown recovery cycle because no inventory or growth data available
"	General	Habitat lost or degraded because logging roads provide access to small-holder agriculture, ranching, and associated fire
Repeated unplanned selective extraction	Population structure	Rare sub-adult survivors because newly merchantable size classes are removed
"	General	Increased risk of habitat loss or degradation as above

Table 2

Management experience with mahogany.
Restricted to cases where timber production was the principle objective (i.e., non-research).
See paragraphs 15-20for references.

Location, era	Management objectives	Management / silvicultural practices	Results	Notes
Mesoamerica Pre-Colombian	-	Swidden agricultural field abandonment	Natural regeneration at high densities from nearby seed trees in ideal growing conditions	Thought responsible for high Mesoamerican stocking densities in some regions
General Pre-20th Century	-	Seed tree retention, high minimum diameter cutting limit	Population recovery on 30-40 year cycles	Default system due to technological constraints on harvest of large trees
Belize 1920s	Artificial seedling regeneration	Taugnya agroforestry = intercropping with swidden food crops	Good establishment & growth with periodic cleaning, by seeds on dry sites & outplanted seedlings on wetter sites	Food crop pays establishment costs; abandoned during Depression
Belize 1950s	Artificial seedling regeneration	Taugnya agroforestry with corn	Good establishment & growth on some sites; 55-year rotation with 10x greater yield than selection systems	Large variation in performance among sites
Belize 1920s, Mexico from 1940s, Brazil 1990s	Artificial seedling regeneration	Line plantings in secondary vegetation, enrichment plantings along logging roads	Poor survival & growth due to inadequate canopy opening	Most abandoned or unmonitored
Belize 1920s	Natural seedling regeneration	Shelterwood = canopy thinning with retention of seed trees & understory cleaning	High seedling densities but high pest infestation & poor long-term growth rates under high shade	Abandoned due to costs
Belize 1920s	Sustained-yield production	Minimum diameter cutting limits	High-graded stocks	Minimum diameter cutting limit unenforced
Mexico 1950s-1970s	Sustained-yield production	Concessions divided into annual harvesting compartments with minimum diameter cutting limit	High-graded stocks	Replaced by community-based forest management areas
Venezuela 1950s-1970s	Sustained-yield production	Concessions as above with minimum diameter cutting limit, enrichment planting of seedlings in logging gaps	High-graded stocks; enrichment plantings unevaluated	Enrichment plantings abandoned due to costs
Bolivia 1980s-1990s	Sustained-yield production	Concessions as above with minimum diameter cutting limit, retention of large seed trees	High-graded stocks	Minimum diameter cutting limit unenforced
Mexico 1980s-present	Sustained-yield production	Annual harvest compartments, minimum diameter cutting limits, some enrichment planting	Future rotation status uncertain, probably high-graded; uncertain regeneration status	Community (*ejido*) management areas

Table 3

Management guidelines for mahogany and projected timetable.
Assumes minimum diameter cutting limit of 60 cm and mean annual diameter growth rates by managed sub-merchantable trees of ~1 cm/year.
See paragraphs 21-37 for discussion.
Based on Grogan *et al.* 2002.

Target population of treatments	Year of intervention		Treatments	Time until harvest relative to time zero (years)
Trees >60 cm diameter: 1st harvest	0	-	Plan logging	0
	0	-	Respect minimum diameter cutting limit	-
	0	-	Select seed trees & collect seeds	-
Trees >35 cm diameter: 2nd harvest	0	-	Cut vines, thin competing crowns from sub-merchantable trees	30
Trees 10-35 cm diameter: 3rd harvest	0	-	Cut vines, thin competing crowns	60
Seedlings: 3rd harvest	0	-	Accelerate growth by natural regeneration in logging gaps	60
	0	-	Establish artificial regeneration through enrichment plantings in logging gaps	60
	~1, 3, 6, 10, 30	-	Clean around natural & artificial regeneration, cut vines	60
Seedlings: 4th harvest	30	-	Establish artificial regeneration through enrichment plantings in logging gaps	90
	~31, 33, 36, 40, 60	-	Clean around natural & artificial regeneration, cut vines	90

Table 4

Research needs

Inventory of remaining stocks

1 Density (commercial volume) by region
2 Situation in conservation / indigenous areas
3 Range limits

Management: operational planning and silviculture in natural forests

1 Growth rates (diameter, volume) by region and implications for cutting cycles
2 Selection criteria for seed trees and maintenance of population structures
3 Effects of vine cutting / crown thinning on growth rates of sub-merchantable trees
4 Natural regeneration: promoting survival and growth rates
5 Artificial regeneration: establishment procedures within management areas
6 Cost-benefit analysis of management practices

Management: plantations

1 Evaluation of experience to date
2 Plantations with mixed species (e.g., pepper plantations)
3 Pest control

Reproductive ecology

1 Flowering and pollination phenology: implications for seed production
2 Seed production: variation by tree size, year, region
3 Impacts of logging on seed production

Conservation of genetic structure

1 Geographical and local variability in genetic structure
2 Impact of logging on crossing systems and genetic flux
3 Phylogeography: definition of genetic stocks

Table 5

National and regional resources

Country	Institution	Expertise
Mexico	Plan Piloto Forestal – Quintana Roo	Community forest management
Belize	Belize Forestry Department	Taugnya and line planting
	Programme for Belize – Rio Bravo Conservation Area	Forest management, research
Guatemala		
Honduras		
El Salvador		
Nicaragua	MARENA Center for Genetic Improvement & Seed Bank – León	Genetic improvement
Costa Rica	CATIE – Turrialba	Silviculture, plantation management, genetics
	Tropical Science Center – San Jose	Geographical information
Panama		
Colombia		
Venezuela		
Ecuador		
Peru	Conservation International, WWF – Lima	Geographical information
Bolivia	BOLFOR – Santa Cruz	Forest management research
Brazil	Embrapa – Belém/PA, Rio Branco/Acre	Forest management research
	Imazon – Belém/PA	Forest management research
	INPA – Manaus/AM	Genetics
	Kayapó/Conservation International – Pará	Life history research
Puerto Rico	USDA International Institute of Tropical Forestry – San Juan	Plantation management, genetics, life history research
USA	Conservation International – Washington DC	Geographical information