Natural Resources Defense Council

1350 New York Ave., N.W.
Washington, DC 20005
202 783-7800
Fax 202 783-5917

4 October, 1993

Rainforest Action Network
Rua Afonso Vaz, 202
Butanta
GP: 05580
Sao Paulo - SP
BRAZIL

Dear ~~Colleague~~: Beto Borges:

The Natural Resources Defense Council (NRDC) thought you would be interested in the attached material substantiating a proposal to list bigleaf mahogany (Swietenia macrophylla) in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). We also enclose a summary of key points contained in the proposal. We regret that this material is available only in English at this time.

We hope that you will wish to request that Brazil propose mahogany for such protection. The deadline for a country officially making a proposal to list a species at the next Conference of the Parties to CITES (which will take place in November 1994) is December 1993.

If you are interested in promoting the listing of Swietenia macrophylla, you should contact:

Management Authority,
Diretoria de Ecossistemas
Departmento de Vida Silvestre - DEVIS
I.B.A.M.A.
SAIN - Av. L4 Norte
70.800 BRASILIA - DP
Telephone: (5561) 2253241: 2258150

Scientific Authority
Jardim Botanico de Rio de Janeiro
Rua Jardim Botanico 1.008
22.460 Rio De Janeiro - R.J.
Telephone: (021) 2743798

Bigleaf mahogany clearly qualifies for listing in Appendix II as overexploitation threatens to drive it to ecological and commercial extinction throughout its range within a few decades. Furthermore, national parks and reserves for indigenous peoples have been invaded by loggers seeking this beautiful and high-priced wood. Exporting countries have both economic and ethical reasons to ensure that mahogany is better managed so as to provide sustainable ecological and economic benefits.

NRDC would be pleased to assist you or others in preparing for the up-coming meeting of CITES. Please do not hesitate to contact us if you are interested in protecting mahogany or other flora.

Yours truly,

Faith Thompson Campbell

Faith Thompson Campbell, Ph.D.

<u>Regeneration and Future Mahogany Supplies</u>
(A summary of Portions of the Request
by Natural Resources Defense Council
that *Swietenia macrophylla*
be listed in Appendix II of CITES)

Mature mahogany (*Swietenia macrophylla*) trees produce large quantities of seed (Lamb 1966), but Rodriguez *et al*. 1992 (in Snook 1993) reported that the seeds from a relatively small mahogany 23 m tall in Quintana Roo seeded an area of approximately 3 ha. Human planting could greatly expand the areas seeded. Indeed, many planting programs have been started or are in initial stages (for example, the "Johnny Mahoganyseed" project of the (U.S.) International Hardwood Products Association).

However, total areas planted within the natural range of *S. macrophylla* remain small relative to that range -- in **Brazil**, 49,214 ha in Para and Amapa (Barros *et al*. 1992), a mere 1,200 ha in Rondonia (Matricardi & Abdala 1993, draft); and unknown areas in other states within the range.

And in light of the agreement by all sources that there are few if any examples of mahogany being managed on a sustained-yield basis -- either in natural forest or in plantations of various types (Whitmore 1983, 1992; Stevenson 1927; Lamb 1966; Johnson & Chaffey 1973; Finol 1971; Quevedo 1992) -- these plantings must be regarded as experimental. Their success is by no means assured, as most continue attempts to apply in different settings methods which have to date not proved to overcome the many biological, technical, and economic barriers which have prevented success in the past.

<u>Barriers</u>

1) *S. macrophylla* has been found to regenerate poorly, if at all, following logging operations using current management practices in closed forests (Quevedo 1986, Verissimo et al. 1992, Snook 1992, Stevenson 1927, Lamb 1966, Johnson & Chaffey 1973, Finol 1971). The tree does not sprout from cut stumps (Verissimo et al. 1992). Seedlings cannot tolerate shade.

The tree grows best after major disturbance providing freedom from competition and access to loose, mineralized soil. In Mesoamerica, particularly favorable conditions occur after the combination of hurricane damage followed by fire (Snook (1993). In the Bolivian Amazon, river course changes apparently provide the needed major disturbance (Gullison & Hubbell 1992). Light fire stimulates sprouting by several species, suppressing *S. macrophylla* seedlings (Snook (1993). Matricardi & Abdala observed that mahogany seedlings planted in pastures grew poorly, apparently due to soil compaction and competition for nutrients (1993, draft).

2) In natural forests, *S. macrophylla* grows in widely-scattered, even-aged clumps (Snook 1993, Quevedo 1986, Gullison & Hubbell 1992, Verissimo *et al.* 1992), providing little opportunity for a prompt second cut (Verissimo *et al.* 1992, Gullison & Hubbell 1992) which would return economic value to landowners.

3) Snook (1993) and Verissimo *et al.* (1992) consider the seed supply for regeneration to be a limiting factor. First, the tree produces fruit irregularly and the seeds experience high levels of insect predation (Verissimo *et al.* 1992). Second, mahogany seeds do not remain viable beyond one season (Snook 1992). The removal of seed trees during logging -- which are usually felled before the seeds are dispersed -- further reduces the potential for natural regeneration. These impacts are exacerbated by the even-aged clumping growth pattern described above and scarcity of young trees. Finally, the size limit in Quintana Roo and Belize is already set so low that Gullison & Hubbell were concerned that the trees might not produce much of a seed crop (see below).

On the other hand, Gullison & Hubbell (1992) do not consider seed supplies to be a limiting factor in Chimanes, **Bolivia**, because of the large number of seedlings found around mature trees. Based on data from one year of a three-year study, Gullison & Hubbell hypothesized that natural regeneration would occur even if trees were cut before the current seed crop matures. However, Gullison & Hubbell were concerned that if trees were cut at 60 cm dbh (~70 years of age), they may not be sufficiently large to produce much of a seed crop. (See below for other constraints.)

4) The barrier most often mentioned is the susceptibility of *S. macrophylla* to insect attack which ruins the tree's value for timber.

Despite an enormous amount of effort over the last 100 years, no practical control methods have been developed for the mahogany shoot borer *Hypsipyla grandella* (Zeller), Lep. Pyralidae (Martorell 1943, Strong 1940, Whitmore 1992, 1976a,b, Grijpma 1974, 1976, Betancourt 1987, Lamb 1966, Newton *et al.* 1992, Cock 1985). The larvae destroy the shoot apex and cause branching, forking or deformation of the bole. The resulting multiply-branched stems "seriously reduce the stand value and utility at maturity" (Liegal & Venator 1987).

In U.S. Forest Service experimental "line plantings" in **Puerto Rico**, shoot borer damage was found on 58, 11, and 18% of the trees planted in 1974, 1979, and 1980 respectively (Weaver & Bauer 1986). In **Brazilian** trials, Yared & Carpenezzi (1981) reported that shoot borer damage was virtually absent four years after planting in the line enrichment system employed. This was attributed to low initial planting densities, the presence of lateral shade, and the maintenance of some of the ecological conditions of the original forest (such as floristic diversity and microclimate). However, note that USFS levels of attack increased significantly for the 12-year old plantations compared to the 6- and 7-year old plantations. Furthermore, both Sullivan (1991) and Verissimo *et al*. report significant levels of shoot borer attack in plantations in Para.

In Rondonia, Matricardi & Abdala (1993, draft) observed shoot borer damage on 100% of trees planted in pastures, in mixed plantings with coffee or cacao, in "line plantings" on areas which had been burned, and in mixed plantings with other timber trees (one site was not attacked in the first year). Plantings in clearings in primary forest or in relatively open (but unburned) second growth suffered much lower levels of shoot borer attack.

Shoot borer attacks apparently occur at similar levels among trees naturally regenerating in cleared areas (in **Mexico**, Snook 1993) as in "line planting" plantations (U.S. Forest Service in **Puerto Rico**, Weaver 1986). The absence of adult mahoganies with borer-deformed stems from natural forests is attributed by Snook to damaged trees' inability to compete for scarce light resources (Snook 1993).

5) *S. macrophylla* requires, on average, more than a century to attain current commercial diameter limits (Snook 1993, Gullison & Hubbell 1992). The average annual volume increment is maximized by cutting at 73 years in Chimanes, **Bolivia** (diameter 62 cm -- however, this may reduce the seed supply; see above) (Gullison & Hubbell 1992). The mature, often canopy-emergent trees now being logged may be one to several centuries old (Gentry & Terborgh 1990, Betancourt 1987, Mabberley 1983, Snook 1993).

<u>Apparent Positive Attributes</u>

1) *S. macrophylla* has good regenerative capacity in well-lit areas (Verissimo et al. 1992) -- as long as attacks by the shoot borer can be controlled, soil conditions are favorable, and competing vegetation removed.

2) The species' apparently great genetic variability (Lamb 1966) may include variations in susceptibility to shoot borer attack (Newton *et al*. 1992, Whitmore & Hinojosa 1977, Grijpma 1976, and Snook 1993). On the negative side, few investigations of the genetic variation in *Swietenia* species have been undertaken to date, by either forestry companies or research institutes (NRC 1991, Newton *et al*. 1992, Gullison & Hubbell 1992).

> "The potential loss of genotypes resistant to pest attack is perhaps one of the strongest arguments in favour of greater protection for remaining stands of mahogany. As described above, selection for pest resistance has great potential as a method of reducing the damage to commercial plantations caused by the mahogany shoot borer. The exploration and testing of *Swietenia* genotypes is therefore an urgent priority. If resistant genotypes and populations are identified, their *in situ* and *ex situ* conservation and utilization should become immediate objectives, on economic as well as biological grounds." (Newton *et* al. 1992).

3) In favorable conditions, mahoganies grow rapidly; they often emerge from the canopy by 70 years (Snook. 1992). In their first year of study, Gullison & Hubbell (1992) found that seedlings in gaps created by felling of **Bolivia**'s large mahogany trees is double that of seedlings in closed canopy forests - 14.72 cm/yr compared to 7.44 cm/yr.

However, growth rates in some plantations are much less. U.S. Forest Service experimental plantations in **Puerto Rico**, utilizing significant resources to optimize conditions, obtained growth averaging 0.09 to 0.65 m/yr during the first 8 years. Although this was conceded to be slow growth, "the plantation is considered to be a success in light of the innumerable failures listed in the mahogany literature" (Whitmore 1992). In Rondonia, **Brazil**, Matricardi & Abdala (1993, draft) stated that similar growth rates -- median annual increase in height 0.63 m -- for mahoganies planted in degraded primary forests were not satisfactory, probably due to light deficiencies.

At least since Lamb (1966), experts have most often recommended "line planting" of mahogany seedlings interspersed with other crops or in thinned or degraded formerly natural forests. This method is considered best for reducing shoot borer attack. However, this method reduces stand density and hence return on investment. And it still requires significant labor to ensure growth -- primarily in the form of gradually removing competing vegetation to maintain optimum light conditions for seedlings' growth.

"Line planting" has been tried in several locations, and with varying degrees of maintenance. In **Belize** in the 1920s and **Puerto Rico**, poisoning or girdling of unwanted species was tried initially, but then halted (Stevenson 1927; Johnson & Chaffey 1973; (Whitmore 1992). This approach is now being used experimentally in Quintana Roo **Mexico** (Negreros 1991). Earlier efforts to enrich forests through line planting failed in Quintana Roo (Miranda 1958, Snook 1992, 1993). Recently, local people in **Mexico** have begun collecting seeds and planting them in felling gaps, skidtrails and logyards. Snook (1992) considered it too early to evaluate the results, but in other locations (such as **Bolivia** -- see Gullison & Hubbell 1992), such practices have not been successful.

As noted above, despite significant inputs to ensure optimum conditions, the USFS on its experimental forest in the Luquillo mountains of **Puerto Rico** achieved a "slow" average growth rate of 0.09 to 0.65 m/yr during the first 8 years. In addition, shoot borer damage was found on 58, 11, and 18% of the trees planted in 1974, 1979, and 1980 respectively (Weaver & Bauer 1986). In Rondonia, **Brazil**, the enrichment of logged forests with *S. macrophylla*, in combination with the elimination of competing vegetation, resulted in similar growth rates (median annual increase in height 0.63 m), considered there to be insufficient (Matricardi & Abdala, draft 1993).

In **Bolivia**'s Bosque Chimanes area, *S. macrophylla* plantings in the period 1989-90 were done on skidding trails, where they lacked sufficient light. In 1991, experimental plantings were begun along major roads and in abandoned logyards, but results are not yet available on seedling survival at these sites (Gullison & Hubbell, 1992).

In **Rondonia**, the most successful practice was enrichment of secondary forests ("*capoeira*"), combined with the elimination secondary vegetation. This produced an average annual height increment of 1.186 m and diameter of 1.2 cm (Matricardi & Abdala, draft 1993). This growth rate greatly exceeded that for plantings in degraded forests (see above) or the growth of naturally occurring seedlings in tree-fall gaps in Chimanes, **Bolivia** -- 14.72 cm/yr in height (Gullison & Hubbell 1992).

<u>projected time until harvest</u>

The U.S. Forest Service projects rotations of 40-60 years for mahogany in the Luquillo Experimental Forest in **Puerto Rico** (Whitmore 1992). Other research has estimate that a minimum of 40 years is required for mahogany plantations to reach maturity (Vega 1976, Bascope *et al.* 1957). Indonesian mahogany plantations require 50 years to reach maturity (Perum Perhutani 1991). However, Indonesian plantations report an average annual production of mahogany of 49,000 m^3 from clear cut and thinnings. Analysis of the data provided by Perum Perhutani (1991) indicates that it will take a further 25 years before even 11% of the current Perum Perhutani plantations can attain the earliest designated level of commercial maturity (Rodan *et al.* 1992).

In **Brazil**, Sullivan (1991) visited several companies and government research and management stations in Para in October-November, 1991. All the mahogany seedlings were young, the oldest being estimated at 9 years. Growth of saplings was reported as good at some sites, but Sullivan reported shoot borer damage, and that said "at present no-one seems to have an idea about how long it will take these seedlings to mature." Verissimo *et al.* (1992) reported similar preliminary findings on the mahogany plantings by the five biggest sawmills in southern Para, noting reasonable growth but frequent problems with the shoot borer.

If managers wish to rely on management/enrichment of natural forests (such as by hand seeding with weeding of competing vegetation), Verissimo *et al.* (1992) and Gullison & Hubbell (1992) both estimate the cutting cycle must be set at 70 - 100 years.

Economic constraints

The natural ecosystem has adapted to death of high proportions of *S. macrophylla* seedlings. However, a forest manager seeking to make a profit from the harvest of mahoganies cannot afford such losses.

Growth rates also must be examined from the perspectives of profibability and opportunity costs. While the U.S. Forest Service could be pleased by growth averaging 0.09 to 0.65 m/yr during the first 8 years in experimental plantations which are not expected to earn a profit (Whitmore 1992), Matricardi & Abdala (1993, draft) stated that growth rates at the higher end of this scale -- median annual increase in height 0.63 m -- were not satisfactory when viewed as an investment intended to produce income for landholders in Rondonia.

The USFS has more resources than most governmental or private entities within the natural range of *Swietenia* species. Nor is the USFS required to earn a profit on its experimental forest in the Luquillo mountains of Puerto Rico. Finally, Puerto Rico's inhabitants are not seeking to colonize forested areas to raise cattle or subsistence crops. In other words, while USFS biological findings are quite relevant to efforts to develop sustainable mahogany management, it is operating in an entirely different socio-economic setting.

Conclusions and Recommendations

In summary, Snook (1992) noted that selective logging impedes *S. macrophylla* regeneration in the following ways: 1) selective logging removes mahoganies but leaves other species behind to take over their space; 2) the openings created by a single tree fall do not provide conditions suitable for *S. macrophylla* regeneration, such as the provision of adequate light and disturbed mineral soil; and 3) logging removes seed sources.

Gullison speculated, on the basis of first-year results, that in Chimanes, the gaps created by felling the larger mahoganies found there "may be large enough to provide a suitable environment for good growth of the [naturally present] seedlings." (Gullison & Hubbell 1992)

Newton adds, "Selective logging acts as a source of dysgenic selection, whereby the best genotypes (in terms of growth or form) are selectively removed during the course of forestry operations. This results in a population depleted in its most favoured genotypes (genetic erosion). ... Genetic erosion of other *Swietenia* and *Cedrela* species has already occurred in Central and South America, where trees of good form are now rarely encountered except in isolated areas (Styles & Khosla, 1976)." (Newton *et* al. 1992).

Snook (1993) and Verissimo *et al.* (1992) recommended the following steps to assist natural mahogany regeneration following logging or deforestation:

- modify the current practice of cutting to a diameter limit (potentially removes all mature mahoganies within a region, resulting in a loss of seed production)
- encourage the early removal and use of other species
- retain appropriately spaced *S. macrophylla* seed trees
- open areas for regeneration
- await seed dispersal before harvesting
- intermittently remove other vegetation that competes with mahogany regrowth.

Gullison recommended in Chimanes, " . . . a more aggressive replanting campaign, . . . " He suggested a mixed strategy of natural and artificial regeneration to prevent probable future decline in mahogany stocks as a result of failure to replace each tree cut each cycle, likelihood of taking smaller trees which produce fewer seeds, and fact that sites of natural regeneration may not be optimal for growth (Gullison & Hubbell 1992).

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

Amendments to Appendices I and II of CITES

Ninth Meeting of the Conference of the Parties
Fort Lauderdale, USA, 1994

A. PROPOSAL

Include in Appendix II neotropical populations of *Swietenia macrophylla* and natural hybrids with *S. mahagoni* and *S. humilis*, and these parts and derivatives:

1. their timber and wood processed to the first stage of transformation (i.e., primary products), such as logs, wood in the rough, sawn wood, veneer sheets, and plywood;

2. exclude originating wood processed or worked to the second to final stages of transformation (i.e., secondary to final products), such as furniture and particle board; and

3. exclude the parts and derivatives specified in the standard exceptions (Resolutions Conf. 4.24 and Conf. 6.18).

B. PROPONENT:

C. SUPPORTING STATEMENT

1. Taxonomy

1.0. Division: Magnoliophyta (angiosperms; flowering plants)
1.1. Class: Magnoliopsida (dicotyledons)
1.2. Order: Sapindales
1.3. Family: Meliaceae
1.4. Genus: *Swietenia* Jacquin (3 spp.; Styles 1981, Miller 1990)

1.4.1. Species: *S. macrophylla* King 1886
[e.g. syn. = *S. candollei* Pittier]

1.4.2. Hybrids (see Whitmore & Hinojosa 1977, Styles 1981):

Natural hybrids occur between *S. macrophylla* and other species of the genus *Swietenia* with proximity in their native ranges. Artificial hybrids can occur between native and non-native (introduced or naturalized) species, either: (1) spontaneously, from crosses unaided by people; or (2) artificially, from human-aided crosses (e.g., in research for forestry or horticulture).

1.4.2.1. Natural: only *S. macrophylla* x *S. humilis*. Drier areas, NW **Costa Rica** (Whitmore 1983, Holdridge & Poveda 1975). Also potentially in **México** (Tehuantepec); and **Guatemala** (yet in the appropriate area, none was found; Styles 1981).

1.4.2.2. Artificial, sometimes spontaneous: *S. macrophylla* x *S. mahagoni* [probable syn. = *S.* x *aubrevilleana* Stehlé & Cusin]. Several Caribbean islands; also Far East (Whitmore & Hinojosa 1977, Styles 1981, Howard 1988, Schubert 1979).

1.5. Common Names (many others: e.g., Constantine 1959, Lamb 1966):

Spanish:	caoba, mara
Portuguese:	mógno
English:	American mahogany, New World mahogany bigleaf mahogany Honduras mahogany
French:	acajou amérique

Note: "Mahogany" in the trade has expanded to include other genera (Knees & Gardner 1983a). "True or genuine mahogany" is generally accepted to refer to the genus *Swietenia*, American mahoganies.

2. Biological Data

Aspects of the biology of *Swietenia* species are provided by, e.g., Snook 1993, Miller 1990, Betancourt 1987, Whitmore 1983, Styles 1981, and Record & Hess 1943. Considerable information on the ecology of *Swietenia*, as well as its history, trade, and silviculture, is in Lamb 1966; see also Betancourt 1987 and Snook 1993, the latter with a focus on Central American populations of *S. macrophylla*. Overall conservation concerns are presented by Lamb 1966, Knees & Gardner 1983a, 1983b, Read 1990, Oldfield 1988, Huxley 1984, Whitmore 1981, Bramwell 1980, Mabberley 1983, Rodan *et al.* 1992, FAO 1984, Palmberg 1987, and NRC 1991.

2.1. Distribution (Edlin *et al.* 1973; maps)

The natural distribution of *S. macrophylla* is from southern **México** southward, ordinarily on the Atlantic slope, through **Costa Rica**, through **Panamá**, NW South America and peripheral upper Amazonia to **Bolivia** and southern Amazonia into **Brazil**. Lamb (1966) maps the distribution of *S. macrophylla* (along with *S. mahagoni* and *S. humilis*) in Central and South America (Appendix A). Barros *et al.* (1992) revised the estimated distribution of *S. macrophylla* in **Brazil** using vegetation types, soils, climatological, and empirical data. Barros *et al.* (1992) indicate a smaller, but still extensive, mahogany belt in **Brazil** (Appendix B), totaling about 800,000 km^2, more equatorial in location than had been estimated by Lamb (1966). Within **Brazil**, *S. macrophylla* is most concentrated in an area of about 250,000 km^2 in southern Para state (Verissimo *et al.* 1992). Szwagrzak & Lopez (1993 draft) estimate the total range in **Bolivia** at ~243,000 km^2. *S. macrophylla* has also been introduced extensively elsewhere for forestry, also horticulture and as an ornamental tree (Styles 1981, Newman 1990, Schubert 1979, Prance & da Silva 1975); sometimes naturalized (e.g. Howard 1988).

2.2. Populations

2.2.1. Population Trends

S. macrophylla populations are undergoing exploitation nearly throughout its natural range (com. NRDC, Pennington 1990), resulting in substantial depletion of extant populations (Lamb 1966, Foster 1990, Smith 1965, Correa 1990, Betancourt 1987). Populations of *Swietenia* species have also been reduced from the general deforestation accompanying human development (Bevan 1945, Lamb 1966). Lamb (1966, p. ix) reported that:

> "the inherent characteristics of the tree in relation to the highly competitive environment of the tropical forest have resulted, after 250 years of heavy cutting, in serious depletion of mahogany growing stock. The remaining, accessible, unmanaged reserves have been reduced until they are no longer capable of supporting continuous production sufficient to supply the potential demand for the wood. Mature and over-mature stands have been liquidated without maintenance of adequate reserve growing stock. Over the years only an insignificant part of the income derived from the liquidation of this forest capital has been reinvested to maintain the source of income."

The susceptibility of mahogany to logging pressure is discussed in Martini *et al.* (1993, in press), where the authors perform a first attempt to predict Amazon tree species threatened by logging. *S. macrophylla* is considered a species susceptible to population reductions in the face of intensive logging due to its irregular fruit production; poor regeneration in natural forest; inability to sprout from cut stumps; and high insect predation on seeds. On the converse, the authors also note the good regenerative capacity of mahogany in well-lit areas and its wide geographic range (Verissimo *et al.* 1992). On a rating system of 1 to 3, with 1 representing the least desirable, 2 intermediate, and 3 most desirable characteristics, the authors assigned *S. macrophylla* the following: 1 for regeneration/number of saplings in natural forest, resprouting from stumps, and ability to withstand fire; 2 for rapidity of growth and abundance of adults; and 3 for seed dispersal and geographic range (Uhl, pers comm to F.T. Campbell, NRDC).

The conservation status of *S. macrophylla* populations in selected Latin American nations was provided in the 1992 U.S. CITES proposal, and varies from abundant to nearly extirpated depending upon the locale and information source (Rodan *et al.* 1992). Updated and additional information is provided in Hartshorn (1992), which collates reports from Central and South America presented to the Mahogany Workshop held in Washington, D.C., in February, 1992.

2.2.1.1. Central America: The historical pattern and relationship between logging and mahogany populations in the Yucatan Peninsula of **Mexico**, **Belize**, and **Guatemala** is detailed in Snook, 1993. Indigenous human populations of the Yucatan (the Maya) had in preceding centuries hollowed out enormous mahogany canoes for long-distance trading expeditions (Hammond 1982). Early European explorers also utilized mahogany for canoes and ship repairs, and had begun harvesting *S. macrophylla* in Central America as early as the year 1683 (Record 1924). Mahogany logging in this period was severely constrained logistically by the size of the tree and the paucity and inadequacy of transportation mechanisms. Logging was initially only of specimens occurring near rivers, but with the successive introduction of oxen, railroads, and then roads, these restrictions were negated. Purchaser requirements also acted in the past to protect selected *S. macrophylla* populations, and only sound, straight logs at least 14 feet long by 16 inches at the top were desired for export. More recent restrictions have limited the selective cutting of *S. macrophylla* to only those specimens of 55-60 cm diameter at breast height (dbh). Concession foresters are now proposing a reduction in the diameter limit from 60 cm to 40 cm, as communities switch from selling logs for veneer to feeding their own sawmills and as a result of overestimates of the natural growth rate of mahogany (Snook 1993, Snook 1992). Even the larger diameter falls below the size considered tentatively by Gullison & Hubbell (1992) to be necessary for providing a good seed supply. Most of the areas logged in the past have been converted to other uses, leading to an ~80% reduction in the extent of mahogany-containing forests in **Mexico** (de la Garza 1991 in Snook 1992).

In **Guatemala**, Salazar (1992) reported that:

> "The mahogany found in the biologically rich lowlands of northern Guatemala ... is naturally found only in hidden recesses protected by natural barriers such as flooded zones, steep slopes and rivers. In general, the species is undergoing extensive exploitation throughout nearly all of its natural range in northern Guatemala. Severe social and economic problems have contributed to species exploitation. Until recently (the last 8 to 10 years) there were no programs to conserve or to manage the species." ...
>
> "Unless concrete actions are taken immediately, the future for mahogany in the Peten is bleak."

In **Honduras**, mahogany and cedar are reported as the most heavily exploited species. In response to overharvesting, **Honduras** has banned the export of rough lumber of these species, along with the cutting of mahogany and cedar during fruiting (Ussach 1992).

In **Belize**, *S. macrophylla* is "characteristic" of the subtropical moist forest life zone covering the northern lowlands (The Nature Conservancy, pers comm to Jennifer Beardsley, NRDC; see also map **APPENDIX ?**). While Belize was originally settled by Europeans to exploit logwood (*Haematoxylon campechianum*) for dye, by the mid-1700s, *S. macrophylla* had become the principal export. Belize still has large mahogany reserves. The richest mahogany forests are on the private Belize Estate and Produce Co. (BEC) lands in the northwest (The Nature Conservancy, pers comm to Jennifer Beardsley, NRDC).

By the 1950s, production of both mahogany and mature pine had declined, leading to a 50% reduction in the forestry department budget which devastated the and demoralized the staff (The Nature Conservancy, pers comm to Jennifer Beardsley, NRDC). With increasing foreign assistance, the Department is considered by some to be regaining its influence. However, the entire forestry sector appears to be in disarray. Only three out of ~40 sawmills account for approximately two-thirds of production. Studies by several international organizations concur that timber production could be substantially increased on a sustained-yield basis if (emphasis added) forest reserves are protected from agricultural encroachment, effective management plants are implemented, and technology modernized (The Nature Conservancy, pers comm to Jennifer Beardsley, NRDC).

The Belize Forestry Department attempts to enforce a 63 cm dbh cutting limit for *S. macrophylla*, but some cut trees as small as 49 cm dbh. The size limits were established in order to protect some reproductive individuals as seed sources (The Nature Conservancy, pers comm to Jennifer Beardsley, NRDC); however, Gullison & Hubbell (1992) cast doubt on whether a size of 63 cm is sufficient for this purpose. Other than regulating size of logs cut, the Forestry Department "has put little effort into mahogany management for sustained yield production . . ." (The Nature Conservancy, pers comm to Jennifer Beardsley, NRDC).

2.2.1.2. Bolivia: In **Bolivia** and **Brazil**, currently the primary sources of the international trade in *S. macrophylla*, regional commercial extinctions are increasing (Collins 1990, Verissimo *et al.* 1992). In a report on Bolivian forestry commissioned by the International Tropical Timber Organization (ITTO), Synnott & Cassells (1991) state that:

"[T]he rate of harvesting of Mara is recognized by all parties as being too high to ensure that commercial logging can continue uninterrupted. There are major uncertainties about the volumes of Mara and other timbers ... There are also uncertainties about the areas of forest effectively available for logging after taking into account considerations of inaccessibility and environmental protection requirements within timber production areas. ... [T]he 1989 - 91 logging areas are now scattered widely in separate blocks, presumably selecting the richest areas first."

"The managers of logging companies told the Review Team that they did not expect to maintain their present rates of logging for more than a few years, before exhausting the best areas. Indeed, they seemed to prefer to remove the large Mara quickly and perhaps return in the future when markets for other species improve. ... However, our recommendations must aim at encouraging slower use of Mara supplies, more rapid addition of other species, and secure conditions for investment in more wood processing equipment ..."

These sentiments are echoed by Gullison & Hubbell (1992), where they conclude that:

"Mahogany logging elsewhere in Bolivia is largely unsupervised from a sustainable forestry viewpoint. ... In actual practice, logging has occurred at a much greater rate and over a larger area than originally planned (Synnott & Cassells 1991), and current commercial supplies of mahogany are likely to be exhausted much sooner than twenty years."

According to Richard Rice, director of economic policy at Conservation International:

"All the commercially usable mahogany is going to be gone in Bolivia in five years. ... What we are looking at is timber mining. They are not driving mahogany to physical extinction, but to commercial extinction." (Nash 1993).

Bascope (1992) reviews many of the biological, historical and industrial aspects of mahogany logging in Bolivia, noting that:

"Due to the overcutting of mahogany timber, these firms are diversifying to other species, and trying to interest their clients and other overseas firms in these. Meanwhile, mahogany lumber remains the number one products export business, although in the most accessible forests its supply is diminishing at an alarming rate."

2.2.1.3. Brazil: In Brazil, natural populations of *S. macrophylla* are increasingly affected by illegal as well as legal logging, and by illegal as well as planned deforestation. The Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) has included *S. macrophylla* on a list of 108 Brazilian species of flora considered to be in danger of extinction (January 15, 1992; Proclamation No. 006/92 N), and the Brazilian Botanical Society has included *S. macrophylla* in a list of species at risk of extinction (Sociedade Brasileira Botanica 1992). Greenpeace Brasil, in concert with 70 other Brazilian non-government organizations, have also expressed concern about the predatory nature of mahogany logging in Brazil and about the adverse social and biological consequences of this trade (Greenpeace Brasil 1992).

A review estimating the extent of mahogany populations in Brazil was conducted in 1992 by a consortium of forestry academics, consultants and agencies of the Brazilian government (Barros *et al.* 1992). This study utilized biological information from the RADAMBRASIL project of the

1970s, in conjunction with field surveys and professional judgements, to estimate the extent of the mahogany containing forest in **Brazil** and to predict the length of time until these resources are exhausted. In addition to revising the mahogany distribution maps of Lamb (1966), Barros *et al.* (1992) estimated that, at the current rate of exploitation of 500,000 m^3 (137,773 trees) per year, from a conservative point of view mahogany stocks would persist in legally obtainable areas for a minimum of 32 years. Given the value of this natural resource, Barros *et al.* (1992) recommended an urgent rationalization of the use of this species under a regime of sustainable management.

Verissimo et al. (1992) expressed general reservations about the accuracy of *S. macrophylla* estimates in the Amazon, noting that:

> "Mahogany trees tend to occur in small clumps in the forest. Several or even tens of kilometers may separate the mahogany clumps. Mahogany clumps tend to occur in low-lying areas. Because of this clumped distribution, it is extremely difficult to estimate the regional stock of mahogany and all such estimates should be regarded with skeptism at the present time." (Verissimo *et al.* 1992).

In regard to the conclusions of Barros et al. (1992), the RADAMBRASIL studies that form the basis for these are from the 1970s, and pre-date much of the mahogany logging and agricultural expansion that has occurred in southern Amazonia. Of the 552 one hectare sampling units of RADAMBRASIL that occur within the predicted mahogany belt, only 55 units actually revealed the presence of mahogany. Figure 4 of Barros et al. (1992) indicates that these 55 units were located in regions of Para, Rondonia and Acre where mahogany is already known to occur and has been logged (see Lamb 1966). Available sources do not make clear whether the absence of mahogany on the remaining 497 RADAM units within the purported mahogany belt was a statistical aberration caused by the scattered distribution of mahogany (see Verissimo *et al.* 1992), a result of diameter requirements in the counting of trees during the RADAMBRASIL study, or whether there was in fact no mahogany in these regions. As a result, the occurrence and density of mahogany over considerable portions of the region estimated by Barros *et al.* (1992) remains unconfirmed, leading to uncertainty regarding the extrapolated mahogany population levels estimated by the authors. Greenpeace Brasil (1992) also notes that in estimating the extent of legal mahogany containing forest, Barros *et al.* (1992) overlooked existing biological conservation reserves, and may have underestimated the extent of areas already occupied and logged by human settlers (Barros *et al.* (1992) estimated human activity has occurred in 40%, 30% and 20% of the estimated low, regular and high density mahogany regions, respectively).

With funding from the International Tropical Timber Organization (ITTO), FUNATURA, the Brazilian Foundation for Nature, also studied the occurrence and distribution of mahogany in the Brazilian Amazon (FUNATURA 1993, draft). FUNATURA highlight the large number of indigenous human reserves (140 officially recognized, ~30 autonomous territories, encompassing around 35,000,000 ha), national parks, biological reserves and ecological parks (totalling 3,492,886 ha) within the mahogany zone of **Brazil**. The extent of illegal logging of *S. macrophylla* from these areas had not been assessed or incorporated in the study by Barros et al. (1992). FUNATURA (1993, draft) also note the considerable human encroachment, agricultural conversion and deforestation that has already occurred over much of this region. FUNATURA (1993, draft) concluded that:

> "Without going into the merits of the methodology employed by Barros *et al.* (1992) in obtaining their results, and considering the acceptance of their estimate of 32 years as the minimum time of persistance of mahogany stocks, one is able to conclude that this species

is quite threatened ... This form of empirical and predatorial forest exploitation, suggests that without any urgently adopted measures to ensure the conservation of the species and a more rational utilization, mahogany will have a future similar to the parana pine (*Araucaria angustifolia*), practically exhausted, hardly remaining in some areas without becoming reserves, or similar to species of the Amazon region like pau-rosa (*Aniba duckei*) and virola (*Virola surinamensis*)."

The extent of human encroachment on the estimated mahogany containing region in Brazil is evident from satellite images taken in 1988, which were analyzed and aggregated by Skole & Tucker (1993). [See Appendix C.] Overlaying the results of this satellite analysis on the estimated mahogany region identified by Barros *et al.* (1992) indicates the presence of human activity over much of this region, leading to varying degrees of deforestation and habitat fragmentation (Appendix D). Those regions in the satellite composites where human activity is not evident generally correspond to indigenous peoples' ("Indian") reserves and biological conservation regions, as illustrated by Verissimo *et al.* (1992; Appendix D). In particular, the expanse of untouched forest in southern Para state (8°S, 53°W), overlying a region of relatively dense mahogany-containing forest, indicates the site of the Kayapo Indian reserve.

To the extent that human activity in regions of the Amazon can be correlated with mahogany extraction, these satellite composites indicate the need for caution when extrapolating mahogany resources based upon the assumption of virgin forest. The presence of un-logged forests in Indian reserves and conservation regions, with a relative abundance of mahogany and located close to existing timber industry infrastructure, also highlights the incentives present to extract mahogany from this source, rather than to expend resources on searching for the presumed mahogany reserves in more distant and isolated regions of Amazonia.

The satellite composites published by Skole & Tucker (1993) were based on satellite images taken in 1988. In the intervening 5 years, considerable further road construction has been undertaken to facilitate the extraction of mahogany, often in what were apparently areas of virgin forest in 1988. For instance, the 1988 satellite composites reveal an untouched area of presumed (Barros *et al.* 1992) high-yield mahogany forest located north of the main Kayapo Indian reserve (6°S, 53°W). Since this time, road construction by mahogany timber companies has opened this area, as illustrated in Verissimo *et al.* 1992 (Appendix E). In Para, "[t]he distance between from the extraction areas and sawmills has grown from only a few kilometers in the early 80's to 300-500 kilometers at present," and there are now more than 3,000 kms of logging roads in southern Para that have been used by colonists, ranchers, and loggers (Verissimo *et al.* 1992).

Reports from the Brazilian state of Rondonia also indicate reductions in mahogany populations, and where *S. macrophylla* and other species were once relatively close to industry they are now found only after travelling hundreds of kilometers (Matricardi & Abdala 1993, draft). Matricardi & Abdala (1993, draft) estimate that approximately 90% of Rondonia's production of mahogany in 1991 and 1992 originated from indigenous or conservation areas.

2.2.2. Densities

S. macrophylla is a deciduous tree frequently more that 30m tall with a diameter of 1.5m at breast height (Whitmore 1992). Specimens generally are widely dispersed, although the concentration varies markedly with location and the rate and type of natural forest disturbance (Lamb 1966, Snook 1992, 1993, Rodan *et al.* 1992). In Central America, *S. macrophylla* was found to occur plentifully on sites that were disturbed hundreds of years ago, such as from Mayan agricultural practices, and such stands have a higher frequency of specimens than on undisturbed sites. Snook (1992) found up to 50 commercial-sized trees per hectare in natural mixed-species stands established after catastrophic fire. However, across the range as a whole, the average density in mahogany containing forests is approximately 1 commercial size *S. macrophylla* specimen/hectare, (Snook 1993, citing Pennington & Sarukhan 1968 and Medina *et al.* 1968).

In undisturbed forests containing mahogany in **Brazil** and **Bolivia**, harvestable specimens occur at an average density of less than 1 to 2 trees per hectare. Accurate data on stocks are difficult to collect as the mahoganies occur in scattered groups in inaccessible locations, and dispersed in a hectare to km^2 of undisturbed forest are just a few mature trees (Quevedo 1986, Verissimo *et al.* 1992, Whitmore 1983, Betancourt 1987, Edlin *et al.* 1973, Sanderson & Loth 1965). Barros *et al.* (1992) collated Brazilian data sources and calculated an average occurrence of 1.022 mahoganies (s = 0.947) per hectare of mahogany containing forest, with an average of 5.009 cubic meters of timber per tree ($s = 1.709$, $s_x = .604$, $LL = 3.61$ m^3/tree; for calculation purposes, the authors used a figure of 3.6302 m^3/tree, derived from Queiroz' 1984 volume equation). Barros *et al.* (1992) noted that, as most mahogany population studies had been performed in areas considered for logging, density estimates would constitute an upper bound having been derived from the regions of highest concentration. Taking these factors into account, Barros *et al.* (1992) estimated an average density of mahogany of 0.2 m^3/ha (1 tree/18 ha), 0.4 m^3/ha (1 tree/9 ha) and 0.6 m^3/ha (1 tree/6 ha) over the range of estimated low, normal and high density areas, respectively.

2.2.3. Regeneration

2.2.3.1. Natural Regeneration: Mature mahoganies are generally said to seed well and disperse this seed over a wide area (Lamb 1966). However, Rodriguez *et al.* (1992) (cited in Snook 1993) reported that the seeds from a mahogany 23 m tall in Quintana Roo fell on an area of approximately 3 ha. (A tree this size is rather small, which may affect both seed production and dispersal area.) The trees grow rather robustly (Lamb 1966, Snook 1992). Nevertheless, the mature, often canopy-emergent trees may be one to several centuries old (Terborgh 1990, Betancourt 1987, Mabberley 1983). Mahoganies are shade intolerant, and cannot regenerate beneath a closed, or closing, forest canopy, and thus require the combined presence of a major forest disturbance and residual seed trees in order to regenerate. As a result, *S. macrophylla* tends to occur in even-aged clumps of mature trees, lacking the age stratification necessary for continued harvest rotations (The relationship of these factors and others to mahogany silviculture are discussed under S. 3.2.1. of this proposal).

These findings were confirmed, and expanded upon, by Snook (1993), who studied the natural regeneration of *S. macrophylla* on the Yucatan Peninsula of Mexico. Snook (1993) found that:

1. *S. macrophylla* survives both fire and hurricanes as an adult.

2. *S. macrophylla* regenerates in essentially even-aged mixed-species stands, becoming established at the highest densities on areas formerly cleared or burned and less abundantly after hurricanes. Particularly favorable conditions occur after the combination of hurricane damage followed by fire.

3. The highest density of *S. macrophylla* regeneration was found on loosened, disturbed, exposed soil.

4. Where conditions are favorable (i.e. the roadside) and seed trees are available, *S. macrophylla* can become established at higher densities than any other species.

5. Light fire stimulates sprouting by several species, suppressing *S. macrophylla* seedlings.

The sensitivity of *S. macrophylla* regeneration to a variety of perturbations is evident from Snook's (1993) data. Regeneration requires the presence of seed trees. The funnel-shaped seed shadow of a mahogany 23 m tall in Quintana Roo was found to extend 200 m downwind (westward) of the tree, covering an area of approximately 3 ha (Rodriguez *et al.* 1992 in Snook 1993). The absence of seed trees, as occurs following un-regulated logging, removes the potential for natural regeneration, and isolated seed trees can only re-populate an area of 3 - 4 hectares downwind (water and animal conveyance of seed is also possible). Bees and moths have been noted as pollinators of *S. macrophylla* flowers (Styles & Khosla 1976), although it is not known what species pollinate *S. macrophylla* flowers in Quintana Roo, and what other species these creatures may require to survive (Snook 1993).

S. macrophylla regeneration was also highly sensitive to shade and to competition from already established species. For instance, while a strong fire removes competitor species and presents an ideal opportunity for *S. macrophylla* regeneration, a light fire suppresses regeneration by stimulating the sprouting of other species. The preference for loosened, disturbed, exposed soil (Snook 1993) should also be noted when assessing the regeneration potential on pasture land.

Research by Gullison & Hubbell (1992) indicated that a primary mode of natural mahogany regeneration in the Bolivian Amazon is following river meanders or course changes. The resulting expanses of light-exposed soil can be quite extensive, such as in the Peruvian Amazon where up to 12% of the forest is in early succession.

The natural growth rate of mahogany was determined by Snook (1993) using measurements of trees on a chronosequence of post-fire stands 15 - 75 years old. Mahogany growth was found to follow a sigmoid curve (Appendix F). Extrapolating from this curve, Snook (1993) calculated that *S. macrophylla* requires, on average, 120 years to attain the current 55 cm commercial diameter limit in Quintana Roo. A corollary of this is that the specimens of *S. macrophylla* currently being cut, with girths greater than 100 cm, are at least one to several centuries old, and current timber harvest rotations are based upon overestimates of the growth rate of mahogany. Simulations by Gullison & Hubbell (1992) estimate that 105 years are required to reach the current cutting diameter of 80 cm dbh.

2.2.3.2. Lack of Regeneration after Selective Logging: *S. macrophylla* has been found to regenerate poorly, if at all, following logging operations using current management practices in closed forests (Quevedo 1986, Verissimo et al. 1992, Snook 1992, Stevenson 1927, Lamb 1966, Johnson & Chaffey 1973, Finol 1971). Quevedo (1986) studied the Guarayos Forest Reserve in Bolivia, and reported that while *S. macrophylla* regeneration was found in forest harvested three years previously, in forest harvested nine years previously the mahogany seedlings had disappeared and the regrowth was dominated by other species.

Verissimo *et al.* (1992) studied mahogany logging in southern Para, Brazil, and recorded an average of 2.9 plants of all species per square meter in regeneration study plots. Ninety-five percent of these species were without wood value in current markets. *S. macrophylla* was "quite scarce" in the regeneration plots, and was found on transects in only 1 of 3 study areas, and then at extremely low densities. As a result of this finding, research was extended to visiting four sites from which mahogany had been extracted in the past, and searching a 5 x 15m plot at the base of old mahogany stumps. Vigorous regeneration had been expected around these stumps, but the authors found *S. macrophylla* seedlings/saplings in only 31% of the 70 gaps located, and at an average number of 0.59 per plot (Verissimo *et al.* 1992). The continuing presence of seed trees was noted as an important predictive variable in the finding of seedlings. At 89% of clearings without *S. macrophylla* regeneration not a single mature specimen was nearby, whereas in half of the twenty-two clearings with mahogany seedlings at least 1 older mahogany was found nearby (Verissimo *et al.* 1992).

Snook (1992) noted that selective logging impedes *S. macrophylla* regeneration in the following ways: 1) selective logging removes mahoganies but leaves other species behind to take over their space; 2) the openings created by a single tree fall do not provide conditions suitable for *S. macrophylla* regeneration, such as the provision of adequate light and disturbed mineral soil; and 3) logging removes seed sources (Snook 1992).

2.2.3.3. Minimal Prospects for a Second Cut: As a result of this mode of regeneration, *S. macrophylla* tends to occur in even-aged groups in Amazonia, lacking age stratification within individual populations (Quevedo 1986, Gullison & Hubbell 1992, Verissimo *et al.* 1992). Logging to a diameter limit has the potential to remove all mature mahoganies within a region, particularly those with good seed production and dispersal potential, resulting in a loss of seed production and curtailing regenerative options (Verissimo *et al.* 1992, Gullison & Hubbell 1992). The relative absence of intermediate sized mahoganies, and the limited potential for regeneration after selective logging, combine to provide little option for a future second cut:

> "The prospects of a second mahogany harvest in the near future are dim. The stock of mahogany trees between 10 and 45 cm dbh ... is only 0.3 trees/ha ... Considering natural mortality, it is unlikely that this stock could produce a second harvest." (Verissimo *et al.* 1992).

The small number of trees with diameters less than 80 cm presents "a potentially serious problem for sustainable management of this species." (Gullison & Hubbell 1992). Gullison & Hubbell tentatively "conclude that, with proper management, mahogany can continue to be produced in the Bosque Chimanes, although with a hiatus of 70-100 years while current seedling banks grow to merchantable size." [emphasis added]

The possibilities and constraints pertinent to human assistance of natural mahogany regeneration following logging or deforestation are covered by Snook (1993) and Verissimo *et al.* (1992). In addition to modifying the current practice of cutting to a diameter limit, these recommendations include the instituting of silvicultural policies that: encourage the early removal and use of other species; the appropriate spacing of *S. macrophylla* seed trees; the opening of regeneration areas; awaiting seed dispersal before harvesting; and the intermittent removal of seedlings and other vegetation that is competing with mahogany regrowth.

2.2.4. Genetic Concerns

2.2.4.1. Genetic Loss and Dysgenic Selection Over Range: Genetic loss within and of populations from exploitation and reduction by land-use change is of critical importance in assessing the conservation status of *S. macrophylla* populations (FAO 1984, Mabberley 1983, Oldfield 1984). One of the primary goals of CITES listing of *S. macrophylla* will be to prevent this species from suffering the same genetic erosion that afflicted *S. mahagoni*, reducing this once prized timber tree to its current state as a multi-branched or stunted species (Styles 1981). The *in situ* conservation of *S. macrophylla* was recently accorded highest priority by the FAO (1989), and the U.S. National Academy of Sciences (NRC 1991) report on plant genetic resources identified *S. macrophylla* as Vulnerable. The ITTO (1991a) cited Brazilian mahogany as a species where long term measures were becoming necessary to conserve the genetic variability of populations.

The wide variation in *S. macrophylla* leaves, flowers, fruit, and wood structure was noted by Lamb (1966), raising the possibility that this species exhibits high genetic plasticity over its large geographic range and among the many separate breeding populations. Each genetic composite may represent the subdivision of the species into adapted biotype groups which correspond to different habitats. In particular, there are indications that tree form and resistance to shoot-borer attack are heritable characteristics, emphasizing the importance of genetic conservation, as logging tends to deplete the population of individuals with these desirable genetic characteristics (Newton *et al.* 1992).

> "Selective logging acts as a source of dysgenic selection, whereby the best genotypes (in terms of growth or form) are selectively removed during the course of forestry operations. This results in a population depleted in its most favoured genotypes (genetic erosion). ... Genetic erosion of other *Swietenia* and *Cedrela* species has already occurred in Central and South America, where trees of good form are now rarely encountered except in isolated areas (Styles & Khosla, 1976)." (Newton *et al.* 1992).

Few investigations of the genetic variation in *Swietenia* species have been undertaken to date, by either forestry companies or research institutes (NRC 1991, Newton *et al.* 1992), despite the apparent amenability of *Swietenia* species to breeding techniques (Styles & Khosla, 1976). In particular,

> "... little attention has been paid to the extent of genetic variation that exists within the natural distribution of these species. Categorizing this variation is of importance for defining both *in-* and *ex-situ* conservation of particular populations, for the development of afforestation and tree improvement programmes, and for the overall process of domestication." (Newton *et al.* 1992).

2.2.4.2. <u>Genetics and Resistance to Shoot Borer Attack</u>: It has been established that some species of the genus *Swietenia* are less susceptible to attack by the mahogany shoot borer than others. In Puerto Rico, *S. mahagoni* is less attacked than *S. macrophylla*, and the hybrid *S. mahagoni* x *S. macrophylla* is intermediate (Whitmore & Hinojosa, 1977). Grijpma (1976) noted that there is a strong possibility that non-preferred mahoganies may exist, which could be exploited in a selection program to heighten shoot borer resistance. However, few studies have been made of intra-specific variation in susceptibility to attack (Newton et al. 1992).

Three forms of resistance to shoot-borer attack have been postulated in various Meliaceae species (Grijpma 1976, Newton *et al.* 1992): 1) non-preference, the insect is not attracted or is actively repelled; 2) antibiosis, the insect is killed or prevented from completing its life cycle on the tree; and 3) tolerance, the tree recovers in an acceptable fashion/level. In the early 1970s, the Institute of Terrestrial Ecology, Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) (Costa Rica) employed 100 scientists in an attempt to solve the borer problem through various planting techniques and pesticides, but with no positive results. Additional *Swietenia* trials are currently in progress at CATIE and the International Institute of Biological Control. Small-scale tree improvement programs have recently been initiated in **Trinidad**, **Costa Rica**, and **Honduras**, based on clonal selection and *ex situ* conservation (Newton 1990, Newton *et al.* 1992). The principle species are *Cedrela odorata* and *S. macrophylla*, but also *S. humilis* and *S. mahagoni* (Newton *et al.* 1992).

> "The potential loss of genotypes resistant to pest attack is perhaps one of the strongest arguments in favour of greater protection for remaining stands of mahogany. As described above, selection for pest resistance has great potential as a method of reducing the damage to commercial plantations caused by the mahogany shoot borer. The exploration and testing of *Swietenia* genotypes is therefore an urgent priority. If resistant genotypes and populations are identified, their *in situ* and *ex situ* conservation and utilization should become immediate objectives, on economic as well as biological grounds." (Newton *et al.* 1992).

2.3. Habitat

2.3.1. Preferred Ecotype

Swietenia macrophylla occurs in moist (or even wet) to dry, evergreen to deciduous tropical to subtropical forests, with typically (800-)1000-2500 mm of annual rainfall, and at altitudes from 0 to 1400 m (Lamb 1966, Whitmore 1983, Betancourt 1987, Rzedowski 1978, Toledo 1982, Pennington & Sarukhán 1968). It "reaches optimum development under tropical dry forest life zone conditions (Holdridge, 1947), namely a mean annual temperature of 24 degrees C or higher, mean annual precipitation [m.a.p] of 1000-2000 mm, and a potential evapotranspiration (pet) between 1.00 to 2.00. It also extends into the tropical moist forest life zone (24 C or above, map 2000-4000 mm, and pet 0.50-1.00), as well as into the subtropical dry and subtropical moist forest life zones (about 18-24 degrees C for both, with 1.00-2.00 pet/500-1000 mm precipitation and 0.50-1.00 pet/1000-2000mm, respectively). Ideal precipitation conditions reportedly are 1200-2000 mm (Bascope *et al.* 1957). Mahogany grows naturally on alluvial, volcanic, limestone, granitic, andesitic, and other sedimentary, igneous, and metamorphic-based soils." (Whitmore 1992).

In **Bolivia**, woodsmen recognize four distinct races of *S. macrophylla*, based upon the ecotype in which it occurs. Mara acedretada grows "very rapidly," and the wood resembles Spanish cedar. Mara acuchisada grows slowly in dry forests, producing a very dense wood. Mara peluda grows in flooded areas and poorly drained soil, producing timber with a "woolly" grain that is worthless. Mara grano de oro grows in well drained soils with a superficial water table, and is considered to produce the best wood. Unfortunately, the land and ecotype in which mara grano de oro occurs is highly suitable for slash and burn agriculture, and so is cleared for that purpose (Bascope 1992).

2.3.2. Logging, Road Construction, Habitat Loss

In regions where *S. macrophylla* occurs, there is a complex interrelationship between logging, road construction, human settlement, and deforestation/habitat loss. The adverse effects of this interrelationship directly impact mahogany populations, both in generating the impetus for logging and by altering the potential for mahogany regrowth (Rodan *et al.* 1992). Road construction, often to facilitate the extraction of commercially valuable timber such as mahogany, opens the forest to colonization and land-clearing (Nations 1987, Verissimo *et al.* 1992), especially in frontier areas that previously had limited forest disturbance (Tropical Forestry Workshop 1989). For example, in southern Para, **Brazil**:

> "the immense area bounded by Para Highway 150 on the east, the TransAmazon forest to the north, and the Cuiaba Santarem Highway to the west is rapidly being opened up by logging roads [Appendix D]. On official maps this region appears as a sea of green forest dotted with Indian reserves." (Verissimo *et al.* 1992).

The principal logging road in the Moradoa do Sol region, north of the city of Tucuma, Para, is 400 km long and was begun by mahogany loggers in 1985. Since this time, the road has grown approximately 60 km/yr over 7 years. Colonists were concentrated along the first 70 km of this road, and 42% of the area occupied had been deforested in the seven years of occupation. Seven landowners (5 of whom operate sawmills) controlled the remaining 330 kms of road, an area of perhaps 500,000 ha total, and after the mahogany is extracted from these holdings cattle pastures are being established (Verissimo *et al.* 1992).

> "In 1985 the region cut by this road was almost completely covered by forest. ... But over the past seven years, loggers, colonists and ranchers have used this logging road to gain access to the land, converting the logged forest into agricultural fields and pastures for cattle. ... The migration route of these agriculturists coincides with the movement of loggers in search of virgin mahogany forests." (Verissimo *et al.* 1992).

Human settlement may also precipitate, and be dependent upon, logging of the commercially valuable timbers present on a property. In certain instances, it is the presence of valuable commercial species on subsistence plots that makes them economically viable in the short term. In reviewing the economics of a non-mahogany forestry operation in Brazil, Uhl *et al.* (1991) noted that the security provided by timber resources allowed colonists to persist for longer periods than otherwise, while continuing to clear the forest each year for farmland on which to produce food for home consumption and sale. When the land was exhausted, settlement moved elsewhere (Uhl *et al.* 1991).

The Food & Agriculture Organization of the United Nations (FAO 1988, Lanly 1982) has estimated that "logging directly causes 10 percent of tropical deforestation -- and facilitates tropical forest losses stemming primarily from other causes. In most humid tropical forest areas, logging practices today are typically 'mining' operations that deplete or eventually eradicate tropical forests. While logging in tropical forests more generally tends to be selective, it can be very destructive if poorly planned and inadequately regulated." (Johnson & Cabarle 1993).

2.3.3. Deforestation Rates in Central and South America

Deforestation rates over Latin America provide partial information on the habitat loss of *Swietenia macrophylla*. Myers (1989) compiled estimated deforestation levels and rates based upon an extensive survey of the professional literature, including papers, reports, and other publications dealing with deforestation in the countries concerned. In **Mexico**, Myers (1989) estimated that tropical moist forests originally covered 400,000 km^2. By 1989 this area had been reduced to 166,000 km^2, of which only 110,000 km^2 was considered to be primary forest. The deforestation rate in **Mexico** was estimated to be 4.2% annually (Myers 1989).

In **Central America**, at the time of Columbus' voyage tropical moist forests covered an area of approximately 500,000 km^2. By the mid-1980s, remaining forest was estimated at 90,000 km^2, of which only 55,000 km^2 could be considered to be primary forest. Deforestation continues in **Central America** at 3.7% annually (Myers 1989). In the Peten region of **Guatemala**, the principal habitat for *S. macrophylla* in that country, tropical forests constituted 36,000 km^2 in 1960, but since that time at least one-third has been eliminated (Myers 1989). Human population in Peten province is growing at 9.5% per year, leading to agricultural encroachment, fuelwood consumption, and consequent forest loss (Salazar 1992).

Myers (1989) estimated that the deforestation rate in **Brazil** was 2.3%. Data from the Instituto Nacional de Pesquisas Especiais in 1991 (INPE; in FUNATURA 1993) indicated the following estimated deforestation levels in Brazilian states within the "mahogany belt": Rondonia, 14.24%; Para 11.86%; Mato Grosso 19.6%; and Acre 7%. The estimated deforestation rate in **Brazil** has been reappraised by Skole & Tucker (1993) using composite satellite images taken in 1988, which could distinguish between primary and regrowth forest. Skole & Tucker (1993) calculated "that 6% of closed-canopy forest had been cleared as of 1988 and ~15% of the forested Amazon was affected by deforestation-caused habitat destruction, habitat isolation, and edge effects." As illustrated in the accompanying Appendix C, a considerable amount of this deforestation has occurred in the mahogany belt, with the primary remaining untouched regions being located in Indian and Biological Reserves (Appendix D). Road construction for timber extraction in what had been untouched areas is illustrated in Appendix E.

In **Bolivia**, Myers (1989) estimated that tropical forest originally covered 90,000 km^2, of which primary forest cover has been at least halved to 45,000 km^2. Tropical moist forest cover, including degraded forests, was estimated at 70,000 km^2 in 1989, with a continuing rate of decline 2.1% annually (Myers 1989). Szwagrzak & Lopez (1993 draft), in contrast, estimate lowland evergreen forest covers 243,322 km^2 in Bolivia; this type of forest contains mahogany at densities consistent with other regions of its range.

Whatever base number is used, deforestation is occurring rapidly. Researchers for the Inter-American Development Bank have estimated that more than 11% of Bolivian forests have been either cleared or damaged by logging and agriculture. Clearing of native forest continues at a rate of up to 600,000 acres per year (Nash 1993). Virtually no development or utilization of the Bolivian Amazon had occurred until 40 years ago, when the government built a highway to Santa Cruz (1952) that resulted in waves of immigrants, urban growth, and industrialization based on agriculture and logging. This development and forest encroachment jumped ahead of the government regional development program (Bascope 1992). Forest degradation has been increasing recently because of: the selective logging of mahogany; a weak forestry service; destruction by colonists under plans drawn up by National Colonization Institute and Agrarian National Reform Council; the building of logging roads by logging companies and rural roads by public institutions (opening the forest to settlers); increasing numbers of illegal loggers using chain saws; lack of coordination among government forest management agencies (Forest Service, National Colonization Institute, and the National Agrarian Reform Council), and agrarian development projects financed by the Inter-American Development Bank, World Bank, and USAID without any consideration for their natural resources (Bascope 1992).

3. International and National Trade Data

3.1. National Utilization and ± Legal International Trade:

National and international utilization and trade in *Swietenia* chiefly involve their timber. Properties of mahogany woods including easy workability, stability, durability, and above all beauty (grain, color and finish) have made mahogany perhaps the most valuable timber of the neotropics (e.g., see Bramwell 1976, Walker 1989, Constantine 1959, Lewington 1990, Whitmore 1981, Fosberg 1945, Lamb 1966, Styles 1981, FPRL 1956, Chudnoff 1984). Mahogany is particularly desired for high-class cabinets, chairs, joinery, panelling and pianos, and is used as solid wood or veneer (Walker 1989, Bramwell 1976, Samba Murty & Subrahmanyam 1989). Increasing costs, with supplies diminishing, have resulted in greater usage in commerce of the veneer only.

3.1.1. International Trade

International mahogany commerce began nearly 5 centuries ago in the Caribbean with the extraction of *S. mahagoni*. The severe decline in *S. mahagoni* populations from overexploitation by about the 1850s caused a commercial shift to *S. macrophylla* (Samba Murty & Subrahmanyam 1989). Although its wood is coarser grained and considered inferior (Styles 1981, Bramwell 1976), *S. macrophylla* remains the main source for the mahogany market (when it is not supplied by similar woods from Southeast Asia or Africa; Knees & Gardner 1982, 1983a). Readily accessible populations in Central America have been diminished considerably (*e.g.* Boucher *et al.* 1983, Walker 1989). Until about 1923, *S. macrophylla* was not known to occur in the Amazon (Little & Wadsworth 1964), so the intensive extraction in its last stronghold has arisen rather recently, with the opening and development of that region (*e.g.* White 1978 for **Perú**). Representative is the 1977-1987 sixfold increase in mahogany extraction with Bolivia's northeastern road construction (Depto. Beni) (Collins 1990).

Extensive data on volumes of mahogany traded internationally are available from import/export figures collated by customs agencies. Updated information from the 1992 U.S. CITES proposal is attached in Appendix H of this proposal (Jimerson 1993, Bishop 1993; see also Lamb 1966 and Knees & Gardner 1982, 1983, for additional data). It should be noted that the country listed on customs data is not necessarily the initial source (originating country) for the timber shipment. Szwagrzak & Lopez (1993 draft) estimated that clandestine exports constitute 40-50% of reported wood exports (not limited to mahogany) from **Bolivia** as a whole; and that 50% of contraband wood goes to **Brazil**, 30% to **Argentina**, 10% to **Chile**, 5% to **Peru** and 5% to **Paraguay**. Tariff-schedule listings also vary, complicating direct correlations between the export and import data, and preventing species identification in certain circumstances.

Subcontract reports to FUNATURA, **Brazil**, provide detailed data on the commerce of mahogany in the **United States** (Jimerson 1993) and **United Kingdom** (Bishop 1993). The FUNATURA study was, in turn, commissioned by the International Tropical Timber Organization as part of their project entitled: "Development work to phase out trade on unsustainably produced timber." Included in Jimerson (1993) and Bishop (1993) are current details on the volumes of trade and the prices paid for various forms of mahogany, whether sawnwood, veneer, or plywood (logs are rarely exported now due to government regulations in the originating countries). Jimerson (1993) calculated that imports of mahogany into the **United States** had, since 1980, averaged 108,000 m^3 for rough lumber, 15,000 m^3 for dressed lumber, between 2,250 and 7,500 m^3 for veneer, and 1,125 m^3 for plywood, totalling ~131,625 m^3 annually. In 1992, 86,486 m^3 of rough and 11,714 m^3 of dressed mahogany lumber were imported into the **United States** (U.S. Bureau of the Census 1993).

Current prices for rough mahogany off the dock in the **United States** vary around $700 per m^3, depending on the grade of timber. Veneer prices were noted to have doubled since 1984 to $2,200 per m^3 for A-grade imported veneer and $5,000 per m^3 for domestic veneer (Jimerson 1993). Similar information is available on the mahogany trade into the **United Kingdom** (Bishop 1993), although volumes are less than in the **United States** (~90,000 m^3 of lumber imports annually to the U.K. in the 1980s), and have declined considerably from 1990 onwards (70,000 m^3 and 55,000 m^3 of mahogany lumber in 1990 and 1991, respectively).

Rodan *et al.* (1992) calculated the value of an average mahogany tree in Para, **Brazil**, to be US$324 in log form (5.4 m^3 per tree, $60 per m^3), and US$1,500 on import to the **United States** (5.4 m^3 per tree, 50% processing loss, US$545 average declared customs value). Noting the price structures outlined by Jimerson (1993), the use of $545 per m^3 should be considered conservative in estimating the value of individual *S. macrophylla* specimens.

Domestic utilization of mahogany in **Brazil** was estimated by Barros *et al.* (1992) to account for roughly one third of the lumber extracted, the remaining two thirds being exported. The extent of this export market, and the influence and aberrations engendered by government export enhancement policies, were analyzed by Browder (1986, 1987, 1989). In **Bolivia** in 1985, approximately 73% of mahogany production was exported, representing 88% of total Bolivian timber exports. The exported mahogany generally consists of the higher grades, with domestic usage being concentrated on lower grades of timber. Logging in the Chimanes region of **Bolivia** began in 1987, and volumes of wood cut rose each year through at least 1990, as companies' capacities increased (Synnott & Cassells 1991). In the year 1990, imports of mahogany from **Bolivia** to the **United States** exceeded those from **Brazil**.

A major contemporary initiative in international trade is the use of timber certification procedures to distinguish sustainably harvested mahoganies from unsustainably logged timber originating from virgin forests. Considerable detail on a variety of these proposed certification programs is provided by Johnson & Cabarle (1993). Particular emphasis is placed upon the Smart Wood program of the Rainforest Alliance and the proposed certification program by the Forest Stewardship Council. The Smart Wood program has certified five sources of tropical timber, four of which are in Latin America. Although four of these sources harvest mahogany, only two sources had been certified for mahogany at the time of publication. These sources are New River Enterprises, Ltd., in **Belize**, and the Indonesian State Forestry Corporation, Perum Perhutani, on Java (Ussach 1992). Ussach (1992), reporting on the Smart Wood program, concluded that listing mahogany in CITES Appendix II would not be incompatible with certification:

> "on the contrary, such listing would probably lead to a much clearer elaboration of whatever forest management activities were actually being conducted, as well as act as a spur for the development of such management activities."

3.2.1. Artificial Propagation Considerations: Cultivation

Most large scale planting efforts of *S. macrophylla* for timber production have failed (Whitmore 1983, 1992). There are few, if any, examples of mahogany being managed on a sustained yield basis, either in natural forest or in plantations of various types (Lamb 1966, Whitmore 1992, 1983, Newton 1992, Rodan *et al.* 1992, Ussach 1992). In light of these past failures, all current plantings of *S. macrophylla*, particularly within its native range, must be regarded as experimental. Their success is by no means assured, as most continue to attempt to apply, in different settings, methods that have not proven effective in overcoming the many biological, technical, sociopolitical, and economic barriers that have prevented success thus far. As a result, virtually all the mahogany currently traded on international markets comes from specimens of *S. macrophylla* extracted from primary forests. In 1991, 97% of mahogany lumber imported into the **United States** came from countries with indigenous mahogany populations (U.S. Bureau of the Census 1992). Now, and for the foreseeable future, plantation grown mahoganies do not compensate for the loss of naturally occurring populations, particularly where plantation mahoganies are hybrids or are grown in non-indigenous regions.

Countries in which mahogany plantations have been reported include, e.g., **México** (also reforestation), **Belize** (founded to log dye wood and mahogany), **Honduras**, **Cuba**, **Puerto Rico**, **Martinique** (also reforestation), **Trinidad and Tobago**, **Venezuela**, **Brazil**, USA (Hawaii), **Fiji**, **Indonesia**, **Philippines** (also reforestation), **Malaysia**, **Myanmar**, **Bangladesh**, **Sri Lanka**, **India** and **Nigeria**. In the few instances where *S. macrophylla* plantations have been successful on biological grounds, concern remains regarding the quality of the timber and the economic viability of the venture (see Rodan *et al.* 1992).

3.2.1.1. <u>Shoot Borer</u>: The mahogany shoot borer is the main limitation to the artificial establishment of mahogany throughout Central and South America, accounting for the loss of thousands of hectares of plantations (see Martorell 1943, Strong 1940). For example, between 1935 - 1943 shoot borers destroyed 835,000 *Swietenia* and 1,000,000 *Cedrela* trees in **Puerto Rico** (Newton 1992). Damage is caused by larvae of shoot-boring moths (principally *Hypsipyla grandella* (Zeller), Lep. Pyralidae), which burrow inside the terminal part of the stem, destroying the shoot apex and causing branching, forking or deformation of the bole. Virtually all terminal shoots can be attacked within a year, and the resulting multiply-branched stems "seriously reduce the stand value and utility at maturity" (Liegal & Venator 1987). Although an enormous amount of effort has been put into researching mahogany plantations and shoot borers over the last 100 years, no practical control methods have been developed (Whitmore 1992, 1976a,b, Grijpma 1976, Betancourt 1987, Lamb 1966, Newton 1992). Application of insecticides has proven to be expensive and ineffective (Grijpma 1974, Liegel & Venator 1987), although slow release systemic insecticides have shown some promise (Allen *et al.* 1976). An extensive program of biological control undertaken in **Trinidad** was largely unsuccessful (Cock 1985).

Snook (1993) compiled data on the natural incidence of shoot borer attack on naturally regenerating *S. macrophylla* populations in **Mexico**. Shoot borers were found to attack between 17 and 40 % of mahoganies on stands between 8 and 15 years of age, some specimens appearing to be attacked preferentially. A similar attack rate of 11 - 58% was noted in line plantings of mahogany by the U.S. Forest Service in **Puerto Rico** (Weaver & Bauer 1986). Adult mahoganies with borer-deformed stems like those common in plantations were never seen in the forests of Quintana Roo, **Mexico**, presumably due to the death of those individuals damaged as a result of shoot borer attack and unable to compete for scarce light resources (Snook 1993).

Mahogany seedlings can also be attacked by the sugar cane stalk borer (*Diaprepes abbreviatus*), and heavy infestations can kill entire seedling beds (Liegal & Venator 1987). Mahogany planting in **Fiji** was suspended after devastation of a semi-mature plantation by an Ambrosia beetle (Whitmore 1992, Bramwell 1980).

3.2.1.2. <u>Review of Experimental Plantations</u>: Examples of relative biological successes in the silviculture of mahogany have been reported from **Puerto Rico** and **Brazil**. In the Luquillo mountains of **Puerto Rico**, about 1275 ha of *Swietenia spp.* were planted up till 1981, under the auspices of the U.S. Forest Service (Weaver 1987, Weaver & Bauer 1986). In the early plantings, seeds were spaced at 3 x 3 m intervals under the canopy of a secondary forest, which was gradually poisoned. Later plantings were established as lines, the trees being placed 2 m apart within rows and 11 m apart between rows. Heavy maintenance schedules were applied, with growth averaging 0.09 to 0.65 m/yr during the first 8 years. Although this was considered to be slow growth, "the plantation is considered to be a success in light of the innumerable failures listed in the mahogany literature" (Whitmore 1992). Shoot borer damage was found on 58, 11, and 18% of the trees planted in 1974, 1979, and 1980 respectively (Weaver & Bauer 1986).

In **Belize**, plantations covering approximately 500 ha were established, apparently in the 1960s. Shoot borer damage "has not been severe because few plantations have been established inthe past two decades." (The Nature Conservancy, pers comm to Jennifer Beardsley, NRDC).

In Brazilian trials, Yared & Carpenezzi (1981) reported that shoot borer damage was virtually absent in the line enrichment system employed. This was attributed to low initial planting densities, the presence of lateral shade, and the maintenance of some of the ecological conditions of the original forest (such as floristic diversity and microclimate). At 48 months, 87.2 % of *S. macrophylla* specimens were surviving and exhibited a medium diameter at breast height of 5.04 cm and a height of 5.45 m.

Similar efforts to enrich forests through line planting have failed in Quintana Roo (Miranda 1958, Snook 1992, 1993). In addition, it should be noted that where the U.S. Forest Service could be pleased with "slow" growth rates of 9 - 65 cm per year in heavily tended plantations not required to earn a profit, similar growth rates (63 cm annual height increase) were considered unsatisfactory when viewed as an investment intended to produce income for landholders in Rondonia, **Brazil** (Matricardi & Abdala 1993, draft). For *S. macrophylla* silviculture to be viable, both biological and economic criteria will have to be satisfied.

3.2.1.3. Time to Plantation Maturity: The U.S. Forest Service projects rotations of 40-60 years for mahogany in the Luquillo Experimental Forest in **Puerto Rico** (Whitmore 1992). Other research has estimated that a minimum of 40 years is required for mahogany plantations to reach maturity (Vega 1976, Bascope *et al.* 1957). Individual specimens may reach the designated cutting diameter more rapidly in accord with the Gaussian or bell-shaped distribution curve of tree diameters over a single age population (Snook 1993; Appendix G). Indonesian mahogany plantations require 50 years to reach maturity, in the process suffering "many plagues by pest and diseases, cattle stampedes, theft and fires" (Perum Perhutani 1991). Indonesian plantations report an average annual production of mahogany of 49,000 m^3 from clear cut and thinnings. However, only 1,618 m^3 of sawn mahogany was imported from **Indonesia** into the **United States** in 1991, and analysis of the data provided by Perum Perhutani (1991) indicates that it will take a further 25 years before even 11% of the current Perum Perhutani plantations can attain the designated level of commercial maturity (Rodan *et al.* 1992).

3.2.1.4. Current Efforts at Silviculture: Additional plantations of *S. macrophylla* have been commenced in **Brazil** and **Bolivia**, as a result of encouragement by national legislation mandating compulsory reforestation operations and in response to national and international efforts toward timber sustainability. Other *S. macrophylla* planting projects, such as the Johnny Mahoganyseed project sponsored by the (U.S.) International Hardwoods Products Association (IHPA), have also been initiated recently.

Barros *et al.* (1992; Table 25) tabulate a list of companies associated with AIMEX (Association of Timber Exporting Industries of Para and Amapa) that have forest replacement projects, and include the number of mahogany seedlings planted and the area covered in these projects. Preliminary status reports on the success and viability of these projects, both biological and economic, are currently under way. Sullivan (1991) visited several companies and government research and management stations in Para in October-November, 1991. All the mahogany seedlings were young, the oldest being estimated at 9 years (Sullivan 1991). Growth of saplings was reported as good at some sites, but Sullivan (1991) reported the occurrence of shoot borer damage, and that "at present no-one seems to have an idea about how long it will take these seedlings to mature." Verissimo *et al.* (1992) reported similar preliminary findings on the mahogany plantings by the five biggest sawmills in southern Para, noting reasonable growth but frequent problems with the shoot borer.

In Rondonia, **Brazil**, a study of mahogany silviculture and reforestation revealed that only 13 of 25 sites reviewed were planting mahogany (not all sites were registered with IBAMA/RO), and even then only to a limited extent -- about 800 ha (Matricardi & Abdala 1993, draft). Preliminary results from this study indicate varying results from different mahogany silviculture strategies. Planting in grass used as pasture resulted in excessive shoot borer attack (unless chemical pesticides were used), with additional adverse effects from soil compaction and competition for nutrients. Where *S. macrophylla* was planted with cultivated perennial crops, the site was abandoned with the demise of the cacao and coffee trees. The enrichment of logged forests with *S. macrophylla*, in combination with the elimination of competing vegetation, was noted to result in a diminished growth in diameter and height, considered to be a result of deficient levels of light. The enrichment of secondary forests, "capoeira," combined with the elimination of secondary vegetation, produced the best results, with an average annual height increment of 1.186 m and diameter of 1.2 cm (Matricardi & Abdala, draft 1993). Numerous farmers in Rondonia have also been encouraged to plant timber species on their properties, of which ~400 ha were planted with mahogany, mostly in combination with other agricultural crops. Practically all the mahogany plantings by small property owners were done with the support of IEF/Rondonia (State Institute for Forestry Studies; 1988-1991) and SEDAM (1992 and later). This support included the provision of free technical assistance, seeds, and seedlings (Matricardi & Abdala 1993, draft).

In **Bolivia**, instead of reforesting cut areas themselves, most companies pay a fee to the Camaras Forestales (Forest Industry Chamber) of each department, which is supposed to pay for reforestation. In the Chimanes Project, the fees have been "used for staff salaries, pending the arrival of full expected Government of **Bolivia** (GOB) funding" (Synnott & Cassells 1991). Some *S. macrophylla* plantations have been established in **Bolivia**, such as under the auspices of the Universidad Autonoma Gabriel Rene Moreno, Santa Cruz, which inititiated a project to develop a model sustainable management plan using the Meneses Experimental Forest in the Chore Forest Reserve (Bascope 1992). However, the Inter-American Development Bank recently withdrew its funding for this project (Synnott, pers. com.)

In Bolivia's Bosque Chimanes, Gullison & Hubbell (1992) note that "despite planting a considerable number of seedlings each year, seedling growth and survival have been poor." In the study period 1989-90, *S. macrophylla* plantings had been done on skidding trails, where they lacked sufficient light. In 1991, experimental plantings were begun along major roads and in abandoned logyards, but results are not yet available on seedling survival at these sites. Gullison & Hubbell (1992) concluded that:

> "... with proper management, mahogany can continue to be produced in the Bosque Chimanes, although with a hiatus of 70-100 years while current seedling banks grow to merchantable size."

3.3. Illegal International Trade:

Illegal logging of natural populations of *S. macrophylla* has been widely reported from National Parks, forest reserves, and Amerindian lands in many Central and South American nations.

Estimates of the extent of this illegal trade are difficult, however, as illegal timber may be admixed with legally extracted timber. The continuing high demand for this valuable wood, combined with impediments to law enforcement from fiscal constraints, corruption and/or logistical problems, have resulted in inadequate control over the logging of *S. macrophylla* in many regions (ITTO 1988, Plowden & Kusuda 1989, Lutzenberger 1992, Rodan *et al.* 1992, Szwagrzak & Lopez 1993 draft). Despite the presence of considerable domestic legislation, much of the mahogany trade from Central America and Amazonia is from illegal sources (IEWPN 1990, Juarez 1990, Monbiot 1991, Terborgh 1990, Correa 1990, Greenpeace Brasil 1992).

In **Brazil**, lands reserved for indigenous populations comprise approximately 22.5% of the mahogany containing region (Barros et al. 1992), and the logging of *S. macrophylla* is increasing in these areas (Verissimo *et al.* 1992, Greenpeace Brasil 1992). In 1987, 69% of the mahogany exported from **Brazil** came from the Kayapo reserve in the eastern Amazon (CEDI 1992). The extent of concern about the adverse effects of illegal mahogany logging have been expressed by Dr. Sydney Possuelo, president of the Brazilian Indian agency, FUNAI, and by Jose Lutzenberger, previous Brazilian Minister for the Environment. In an open letter to British mahogany consumers, Lutzenberger (1992) stated that:

> "The trade in Brazilian mahogany and other tropical timbers is out of control. In 1992, most of the timber leaving this country for Britain will come, illegally, from Indian and Biological reserves. ... The cutters are not only ransacking the forests in these protected areas to supply you with kitchens and lavatory seats: in many places they are also killing the Indians."

In the Brazilian state of Rondonia, FUNATURA (1993), in a study commissioned by the ITTO, noted the manipulation of forest inventories by timber cutters in order to obtain mahogany logging permits, a "fachada legal," which are then used to legalize timber extracted illegally. Matricardi & Abdala (1993, draft) estimate that approximately 90% of production in Rondonia in 1991 and 1992 originated from indigenous reserves or conservation areas.

In **Bolivia**, forestry officials have been unable to control the numbers of trees cut even in the intensively managed Chimanes project area. "... In other cases, the felling contractors exceeded their approved volume [for 1990] and cut unmarked trees, which could not be extracted in 1990 but are to be extracted in 1991. In other cases, logging was apparently intentionally concentrated in areas proposed for allocation to indigenous people ..., before the deadline ... " (Synnott & Cassells 1991). Nash (1993) reported that Bolivian loggers cut in areas where they do not have title, and at rates far above the levels set by the government.

Szwagrzak & Lopez (1993 draft) studied forest exploitation the Iturralde province of the Dept. of La Paz, **Bolivia**. Iturralde province was considered to be of particular importance as it is one of the last forest reserves in La Paz, and in **Bolivia** as a whole. Due to lack of infrastructure, the province had remained primarily intact until 1990. In 1990, a road was opened to Ixiamas leading to an influx of colonists, both legal and illegal, and to logging firms, whose activities primarily focussed on *S. macrophylla*. Logging concessions in Iturralde were also used to compensate loggers for the reversion of some concessions in Chimanes that resulted from the mandates of the Ecological Pause. A major portion of the subsequent logging in Iturralde was performed by "chainsaw loggers," operating illegally outside government controls and in National Parks and other protected areas. Each chainsaw logging operation usually has between two and five workers. Although large logging firms criticize the activities of the chainsaw loggers, Szwagrzak & Lopez (1993 draft) report that logging firms actually collaborate with chainsaw loggers, buying high value wood and financing equipment. Chainsaw loggers are particularly useful in the extraction of *S. macrophylla*, as this species is not found in concentrated stands.

Although Szwagrzak & Lopez (1993 draft) were unable to quantify the extent of "chainsaw logging" operations, due to their clandestine and illegal nature, it appeared that 10 such chainsaw teams were active in Ixiamas and about 300 in that region of **Bolivia.** Each team can process about 1000 trees per year. Szwagrzak & Lopez (1993 draft) calculate that clandestine wood accounts for about 40-50% of reported exports. From **Bolivia** as a whole, 50% of contraband wood goes to **Brazil**, 30% to **Argentina**, 10% to **Chile**, 5% to **Peru** and 5% to **Paraguay**.

The issue of whether logging taking place in "indigenous reserves" is legal or not is a complex and contentious issue, and subject to the legislation and constitutions of the relevant range state. Boas (1993) noted that in **Brazil**:

> "... [T]he institutionalization of logging activities by FUNAI [the Government Indian Agency] was far from being, as it first appeared, a provisional solution to the shortage of funds. ... [W]hat actually happened was that approval of logging was linked to the interests of groups of employees acting as go-betweens with the companies. As a result, the leadership of FUNAI, ... authorized, regulated and centralized the negotiation of logging indigenous areas. In 1987 countless contracts were signed between FUNAI's headquarters and the logging companies, ... even in areas where the indians did not agree with this way of exploiting their natural resources."

In **Bolivia**:

> "[t]here is some uncertainty about the long-term future ownership and management of the forest. The Decree No. 22611 of September 1991 states that the Commercial Harvesting Zones form part of the Chimanes Indigenous Area, and that these areas will ultimately revert to the indigenous people (unspecified) at the end of their long-term contracts (unspecified). It is not clear whether the proposed long term logging contracts will, in fact, be renewable or whether the whole logging area will be handed over for direct management by indigenous groups." (Synnott & Cassells 1991).

In **Peru**, considerable illegal extraction of *S. macrophylla* is reported from parks and reserves, to the extent that the only populations still sufficiently protected are those in the remote Manu National Park (Chavez 1990, Terborgh 1990).

In **Guatemala**, illegal chainsaw logging is a considerable problem, with loggers taking advantage of newly created roads to gain access to previously remote regions. UNEPET has estimated that over 1,500 illegal chainsaws are presently in use in the region (Salazar 1992). Juarez (1990) reported illicit trafficking in logs of cedar and mahogany from the Peten National Reserves of **Guatemala** to **Mexico**, using "ghost" (false) permits. Modern industrial sawmills process the wood in Quintana Roo, ten kilometers from the border. Lack of international control and law enforcement cooperation between **Guatemala, Belize**, and **Mexico** are considered to be contributing to this problem (Salazar 1992). Threatened by this illegal trade are mahogany trees over 200 years old, surrounding the Mayan ruins at Tikal.

4. Protection Status

4.1. National:

Included are general and/or specific logging regulations, and the establishment of timber reserves, nature reserves, and Amerindian lands. Many countries of origin have more or less economic regulation of the trade in *S. macrophylla*, particularly restricting the export of unprocessed logs. In some instances, regulations also ban export of the wood if not processed beyond the first stage of transformation (e.g. more than simply cut slabs or blocks).

Brazil has instituted harvest quotas for mahogany, which were set at 130,000 m^3 for year 1992 (IBAMA Ordinance No. 110/91-N). Decrees have also been enacted to enhance the "value added" from mahogany extraction, such as by banning the export of mahogany logs and by restricting the export of timber greater than 3 inches in diameter. At least 50% of all forest areas opened to new agriculture in **Brazil** are to be kept in natural forest (Forestry Code Decree Law 4771). Unfortunately, as discussed under illegal logging, continuing impediments to law enforcement from fiscal constraints, corruption and/or logistical problems, have resulted in inadequate control over the logging of *S. macrophylla* in many regions.

In **Bolivia**, the severity of declines in mahogany forests stimulated the issuance of a Presidential Decree (11 January 1990) declaring an "Historic Ecologic Pause." Under this Ecologic Pause, there is a five year freeze on approving new logging concessions, maximum cutting sizes are set, and companies are required to begin executing sustainable management plans within 1 year (Bascope 1992). Just such a plan was developed for the Bosque Chimanes, but it failed to take into consideration the indigenous people and is now under evaluation (Bascope 1992).

At the instigation of the International Tropical Timber Organization (ITTO), Synnott & Cassells (1991) reviewed the prevailing standards of forest management and protection in **Bolivia** as these pertained to the Bosque Chimanes. Their conclusions provide a contrast between regulatory intent and field implementation, the applicability of which extends beyond **Bolivia**:

> "... [I]n reality, no Bolivian forests are at present subject to professional management for sustained yield of commercial timber. In all forests, essential elements of management are either incomplete or absent. In particular, neither the legally permitted activities such as timber harvesting, nor unauthorized activities, such as forest clearance and settlement and log-stealing, are adequately controlled. ...
>
> It is widely acknowledged that government staff are unable to evaluate the accuracy of timber inventories presented to them by the timber companies or to supervise the implementation of Management Plans or the actual volumes of logs harvested. ...
>
> The principal weaknesses, which make existing operations unsustainable, are the lack of adequate controls over rates and intensities of timber harvesting (by both licensed and unlicensed loggers), and the lack of adequate controls over forest settlement and clearance by colonists, farmers, and other land-owners. ...
>
> Tree marking and log measurements [sic] activities are important elements of forest management, and, to our knowledge, are unique to Chimanes and being carried out nowhere else in Bolivia (Synnott & Cassells 1991).

Even in the Bosque Chimanes, where intensive management has been introduced with at least $400,000 of assistance from the ITTO:

> "[t]he operational control of logging is also poorly developed. ... [W]hen logging licenses were first issued by CDF, the permitted annual volumes of Mara far exceeded what was allowed in these [Management] Plans. Since then, the annual permitted volumes have been reduced steadily each year, ... in spite of protests from the logging companies. This reduction ... has occurred only on paper, and the reality in the forest is different. ...
>
> Every year, the annual permitted harvest of Mara (and the volumes actually cut in 1990) greatly exceeded the volumes prescribed in the Management Plans, and the volumes which could be sustained for a full 20 - 30 year cutting cycle. Furthermore, the report presented in Quito (Goitea, 1991a), showed a recommended permitted volume for 1991 that was even higher than the volumes actually harvested in 1990 in five of the six active areas. ...
>
> The 1988 Management Plans, the consultancy report by Dance and many other reports including Goitea (1991a) all describe the necessity of defining blocks and compartments for regulating harvesting. However, such simple management categories have not even been drawn on maps, nor decided in principle by Project staff, in spite of two years of operation and over $400,000 of funding" (Synnott & Cassells 1991).

4.1.1. Protected Reserves

The extensive distribution of *Swietenia macrophylla* has fostered its inclusion in national parks and nature and forestry reserves. Yet, they are not considered sufficient for assuring conservation of adequate biological populations of the species and its genetic variability, in part because of illegal logging (e.g. Monbiot 1991, Correa 1990). The species is (e.g.) in the Biosphere Reserves Montes Azules in Chiapas (~331,000 ha) and Calakmul in Campeche (~700,000 ha) in S **México** (Hernández 1964, Snook 1992), and Río Platano in NE **Honduras**, but illegally exploited (IUCN 1982, NYZS 1990, CI 1991). It occurs in four forestry reserves in **Venezuela**. In **Perú**, while found in a variety of parks and reserves, logging is such that the only populations still protected sufficiently are in the remote PN Manú (Chávez 1990, Terborgh 1990). Twelve new protected areas are under study for the southern Peten in **Guatemala**, and in the northern Peten *S. macrophylla* is established the 1.5 million ha Mayan Biosphere Reserve, where illegal logging is widely practiced (Salazar 1992). Numerous national parks, biological reserves and ecological parks are present within the mahogany zone of Brazil, totalling 3,492,886 ha. Again, illegal extraction of *S. macrophylla* is a major problem (FUNATURA 1993, draft).

4.2. International:

Four countries include their *Swietenia macrophylla* populations in the Annex to the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere [CNWH] (OEA 1967, USDS 1942, Coolidge 1945, 1949, Orejas-Miranda 1976):

Brazil	22/10/65:	*S. macrophylla*
Venezuela	3/02/42:	*S. macrophylla* [as *S. candollei*]
Costa Rica	22/10/65:	*S. macrophylla*
Nicaragua	23/04/41:	*S. macrophylla* [likely; "caoba *S. mahagoni*" (not native) misused in past (Standley & Steyermark 1946); with comparable spp.]

4.3. Additional Protection Needs:

The great risk of genetic deterioration in *S. macrophylla*, similar to that already experienced by *S. mahagoni*, along with its genetic distortion already in Central America, are major biological factors indicating the need to regulate the international trade. As selective logging continues to remove the best mature trees and genotypes, the long-term survival, role and value of the species will continue to be affected in adverse ways (Styles 1981, FAO 1984, NRC 1991). Furthermore, the intensifying deforestation in many areas effectively precludes the re-establishment of natural populations of *S. macrophylla* in these regions. Conservation is urgently needed for adequate representative natural populations over the range of the species. Effective conservation of base-line natural populations might assist in the development of sustainable extractive reserves and the provision of genotypes resistant to shoot borer damage and more conducive to plantation silviculture (UNESCO/UNEP/FAO 1978).

5. Information on Similar Species

Mahogany wood (from *Swietenia*) is well known and generally readily recognizable (Bramwell 1976, Edlin 1969, Bond 1950, Koehler 1922, Miller 1990). International *Swietenia* trade data may be recorded just as mahogany. Often the particular species can be surmised from the place of export, but plantation-grown wood may complicate analyses (FPRL 1956). Trade in the two other species in the genus, *S. mahagoni* and *S. humilis*, is already regulated under the Convention.

Within the Meliaceae, *Khaya* and *Entandrophragma* species sometimes are referred to as African mahoganies. They and *Swietenia* produce similar timbers, but are considered distinct in commerce (Bramwell 1976, Walker 1989, Knees & Gardner 1982, 1983a). The neotropical *Carapa guianensis* Aublet (andiroba, crabwood or royal mahogany) sometimes is mixed with *S. macrophylla* in trade; its wood is known to be inferior (Record & Hess 1943, Knees & Gardner 1982).

6. Comments from Countries of Origin

At the time the **United States** and **Costa Rica** proposed inclusion of the genus *Swietenia* in Appendix II (COP 8, Kyoto, March 1992), **México** informed the **United States** that its *S. macrophylla* population would benefit from Appendix III controls. **Costa Rica** informed the **United States** that *Swietenia* ought to be included in Appendix II. **Colombia** advised a U.S. NGO that inclusion of *Swietenia* in Appendix II seemed appropriate. Prior to its withdrawal before voting at COP8, the U.S. CITES proposal had enjoyed the support of the CITES Secretariat, the World Conservation Union (IUCN 1992), TRAFFIC, and the governments of Brazil and several other Latin American nations (Turner 1992). Further details on the previous United States and Costa Rican proposals and on tropical timber issues dealt with at the Eighth Conference of the Parties, Kyoto, are provided by Campbell (1992).

7. Additional Remarks

There is considerable variation and local adaptation in *Swietenia macrophylla*, suggesting that conserving the genetic variability of the species must include populations from throughout its range. Additional species infrequently are recognized (Styles 1981). There has been limited speculation whether to taxonomically reduce the three species usually recognized of the genus *Swietenia* to one species for the genus (Styles 1981, Whitmore & Hinojosa 1977).

Emphasis should be placed on developing sufficient long term silviculture ventures to supply the world demand for mahogany, both for the maintenance of the mahogany industry and to reduce pressures on wild *S. macrophylla* populations. However, even if the biological problems with mahogany silviculture are overcome and large scale *S. macrophylla* plantings are commenced now, it will still take another half century for the seedlings to reach the earliest levels of maturity. At this time, the timber produced will not be as good as that obtained from the wild. In the interval, pressures to extract valuable *S. macrophylla* specimens from reserves and parks will continue, indicating a disjunction between the potential of plantation mahogany and the reality of continued illegal logging in ostensibly protected areas.

Appendix II of CITES has a suitable mandate and infrastructure to facilitate international cooperation in over-seeing the mahogany trade, obliging importing nations to ensure that the timber had been obtained in accordance with the laws of the country of origin, and giving trade-monitoring organizations access to information that may reveal violations (Rodan *et al.* 1992). CITES Appendix II listing is compatible with fledgling, but rapidly evolving, timber certification schemes and with the sustainable timber objectives -- Target 2000 -- of the International Tropical Timber Organization (ITTO 1991b, 1992). As noted by John Turner (1992), Director of the U.S. Fish and Wildlife Service during the Bush Administration, Appendix II listing of the genus *Swietenia* is "an option of considerably greater merit than a blanket boycott of trade."

REFERENCES

ALLAN, C.G., CHOPRA, C.S., FRIEDHOFF, J.F., GARA, R.I., MAGGI, M.W., NEOGI, A.N., POWELL, J.C., ROBERTS, S.C., & WILKINS, R.M. 1976. The concept of controlled release insecticides and the problem of shoot borers of the Meliaceae. Pp. 110-115 in Studies on the shoot borer Hypsipyla grandella (Zeller) Lep. Pyralidae Vol. II (Ed. J.L. Whitmore). IICA Miscellaneous Publications No. 101, CATIE, Turrialba, Costa Rica: 139 pp., illustr.

BARROS, P.L.C.de, QUEIROZ, W.T., SILVA, J.N.M., OLIVEIRA, F.de A., FILHO, P.P.C., TEREZO, E.F.de M., FARIAS, M.M., BARROS, A.V. 1992. Natural and Artificial Reserves of Swietenia macrophylla, King, in the Brazilian Amazon - a Perspective for Conservation. FCAP, Belem, Para, Brazil: 56 pp. + appendices, illustr.

BASCOPE, F. 1992. Mahogany (*Swietenia macrophylla* King) in Bolivia: Its Sites, Industrial Development and Actual Situation. In Hartshorn, G., Mahogany Workshop: Review and Implication of CITES. Tropical Forest Foundation, Washington, D.C., February 3-4, 1992.

BASCOPE, F., BERNADI, A.L., & LAMPRECHT, H. 1957. Descripciones de arboles forestales No. 1: Swietenia macrophylla King. Instituto Forestal Latino-Americano, Merida, Venezuela: 18 pp.

BETANCOURT, B.A. 1987. Silvicultura Especial de Arboles Maderables Tropicales. Swietenia macrophylla & Swietenia mahagoni, pp. 309-322, 323-341. Edit. Ci.-Técn., La Habana.

BEVAN, A. 1945. Forestry in Latin America and its future. Pp. 174-176 in F. Verdoorn, ed., Plants and Plant Science in Latin America. Chron. Bot. Co., Waltham, Mass.

BISHOP, P.W. 1993. Mahogany in the UK: A study for FUNATURA. FUNATURA (fundacao pro-natureza)/International Tropical Timber Organization (ITTO).

BOAS, A.V. 1993. "Green Gold" on Indian Land: logging company activities on indigenous land in the Brazilian Amazon (2nd edition, revised, corrected, and updated). CEDI.

BOND, C.W. 1950. Colonial Timbers. Swietenia macrophylla, pp. 80, 159. Sir L Pitman & Sons, London.

BOUCHER, D.H., HANSEN, M., RISCH, S. & VANDERMEER, J.H. 1983. Agriculture: Introduction. Pp. 66-73 in D.H. Janzen, ed., Costa Rican Natural History. Univ. Chicago Press, Chicago & London.

BRAMWELL, M. 1980. Products of the jungle. Pp. 176-195 in E.S. Ayensu, ed., Jungles. Marshall Edit., London & Crown Publish., New York. (*Swietenia*, pp. 177, 181).

BRAMWELL, M. ed. 1976. The International Book of Wood. M. Beazley, London; Simon & Schuster, New York.

BROWDER, J.O. 1989. Lumber Production and Economic Development in the Brazilian Amazon: Regional Trends and a Case Study. J. World Forest Resource Management 4:1-19.

BROWDER, J.O. 1987. Brazil's Export Promotion Policy (1980-1984): Impacts on the Amazon's Industrial Wood Sector. J. Developing Areas 21:285-304.

BROWDER, J.O. 1986. Logging the Rainforest. Doctoral dissertation, University of Pennsylvania, Philadelphia, USA: xli + 393 pp., illustr.

CAMPBELL, F.T. 1992. Tropical Timber Issues at CITES. Species 18:28-30, June 1992.

CEDI. 1992. Povos Indigenas no Brasil 1987/88/89/90. Aconteceu Especial 18. Centro Ecumenico de Documentacao e Informacao, Sao Paulo, Brazil.

CHAVEZ, J.S. 1990. Com. to NRDC (F.T. Campbell). Centro de Datos para la Conservación [CDC]. Universidad Nacional Agraria La Molina, Lima, Perú.

CHUDNOFF, M. 1984. Tropical Timbers of the World. Swietenia macrophylla, p. 157. U.S. Dept. Agric. [USDA] Forest Serv., Agric. Handb. 607 pp. Washington, D.C.

CI. 1991. Mexico swaps debt for nature conservation. Orion Nat. Quart. 10(1):62.

COCK, M.W. 1985. A review of the biological control of pests in the Caribbean and Bermuda up to 1982. CIBC Technical Communication 9, Commonwealth Institute of Biological Control, Trinidad.

COLLINS, M., ed. 1990. The Last Rain Forests: A World Conservation Atlas. Oxford University Press, Oxford & New York: 200 pp., illustr.

CONSTANTINE, A.Jr. 1959. Know Your Woods. New World mahogany, pp. 262-266. Home Craftsman Publish. Corp., New York.

COOLIDGE. H.J.Jr. 1949. A world approach to nature protection. Pp. 714-724 in USDS, Proceedings of the Inter-American Conference on Conservation of Renewable Natural Resources, Denver, Colorado, September 7-20, 1948. U.S. Dept. State [USDS] Publ. 3382. Washington, D.C. 782 pp.

COOLIDGE, H.J.Jr. 1945. Notes on conservation in the Americas: Panamá [p. 334]. Pp. 328-335 in F. Verdoorn, ed., Plants and Plant Science in Latin America. Chron. Bot. Co., Waltham, Mass.

CORREA, G. 1990. [Most of Lacandón Forest Said Destroyed]. Proceso (México, DF) 706 (14/05): 26-29.

EDLIN, H.L., [D. Nockels & H. Barnett]. 1973. Atlas of PlantLife. W. Heinemann, London. (Mahogany pp. 84-88, 90, 94-95.)

EDLIN, H.L. 1969. What Wood is That. *Swietenia macrophylla*, pp. 129-131. Viking Press, New York.

FAO. 1989. Report of the FAO Panel of Experts on Forest Gene Resources. Food & Agriculture Organization, Rome, Italy, December 1989.

FAO. 1988. An Interim Report on the State of the Forest Resources in the Developing Countries. U.N. Food and Agriculture Organization, Rome.

FAO. 1984. A Guide to In-situ Conservation of Genetic Resources for Tropical Woody Species. FORGEN/MISC/84/2, Food & Agriculture Organization, Rome, Italy: 196 pp., illustr.

FINOL, H. 1971. Nuevos parametros a considerarse en el analisis estructural de las selvas virgenestropicales. Revista Forestal Venezolana 21:29-39.

FOSBERG, F.R. 1945. Principal economic plants of tropical America: Timbers [p. 32]. Pp. 18-35 in F. Verdoorn, ed., Plants and Plant Science in Latin America. Chron. Bot. Co., Waltham, Mass.

FOSTER, R.B. 1990. The floristic composition of the Río Manú floodplain forest. Pp. 99-111 in A.H. Gentry [& M. Guzmán-Teare], eds., Four Neotropical Rainforests. Yale Univ. Press, New Haven & London.

FPRL. 1956. A Handbook of Hardwoods, [3rd edn.]. Swietenia, pp. 141-142. DSIR Forest Prod. Res. Lab. [FPRL]; HMSO, London.

FUNATURA. 1993. Projeto Mogno. Sumario: Ocorrencia e Distribuicao do Mogno na Amazonia Brasileira. Versao Preliminar. FUNATURA (fundacao pro-naturezo)/International Tropical Timber Organization (ITTO), Brazil.

GREENPEACE BRASIL. 1992. O Corte Predatorio do Mogno: Ameaca ao Futuro da Amazonia. Versao Preliminar. Greenpeace Campanha de Florestas Tropicais, Brazil, Novembro 1992.

GRIJPMA, P. 1976. Resistance of Meliaceae against the shoot borer Hypsipyla with particular reference to Toona ciliata M. J. Roem, var. australis (F. v. Muell.) C.DC. Pp. 69-78 in Tropical trees: variation, breeding and conservation (Eds. J. Burley & B.T. Styles). Linnean Society, London, England, UK: xv + 243 pp.

GRIJPMA, P. 1974. Contributions to an integrated control programme of Hypsipyla grandella (Zeller) in Costa Rica. Doctoral thesis, Wageningen, Netherlands, Landbouwhogeschool te Wageningen: 147 pp. illustr.

GULLISON, R.E. & HUBBELL, S. 1992. Natural Regeneration of Swietenia macrophylla in the Bosque Chimanes, Bolivia. In Hartshorn, G., Mahogany Workshop: Review and Implication of CITES. Tropical Forest Foundation, Washington, D.C., February 3-4, 1992.

HAMMOND, N. 1982. Ancient Maya Civilization. Rutgers University Press, New Brunswick.

HERNANDEZ, X.E. 1964. Plantas comunes en la vegetación de la región cálida húmeda tropical del Golfo de México. Swietenia macrophylla, pp. 175, 184. In INIF, Contribuciones al Estudio Ecológico de las Zonas Cálido-Húmedas de México (eds. E. Hernández X. & J. Sarukhán K.). SAG Inst. Nac. Invest. Forest. [INIF], Publ. Espec. 3: 173-207. México, D.F.

HOLDRIDGE, L.R. 1947. Determination of world plant formations from simple climatic data. Science 105(2727):367-368.

HOLDDRIDGE, L.R. & POVEDA, L.J. 1975. Arboles de Costa Rica, Vol. 1. *Swietenia macrophylla & Swietenia mahagoni*, pp. 285, 286. Centro Ci. Trop., San José.

HOWARD, R.A. 1988. Flora of the Lesser Antilles, Vol. 4. *Swietenia*, pp. 591-593. Arnold Arbor. Harvard Univ., Jamaica Plain, Mass.

HUXLEY, A. 1984. Green Inheritance. Collins/Harvill, London.

IEWPN. 1990. Business Trends (Abroad): Brazil. Import/Export Wood Purchasing News, Aug/Sep., 1990, Memphis, Tenn., USA.

ITTO. 1992. Criteria for the Measurement of Sustainable Tropical Management. Policy Development Series, No. 3, International Tropical Timber Organization, Yokohama, Japan: 5 pp.

ITTO. 1991a. The Conservation Status of Tropical Timbers in Trade. Pre-Project Report, PPR-23/91 (M), International Tropical Timber Organization, Yokohama, Japan: 6 pp.

ITTO. 1991b. Report of Working Group on ITTO Guidelines for the Establishment and Sustainable Management of Planted Tropical Forests. ITTC (X) 9, Quito, Ecuador: iii + 50 pp.

ITTO. 1988. Conservation, Management, Utilization, Integral and Sustained Use of the Forest of the Chimanes Region Department of El Beni, Bolivia. Project PD 34/88 Rev. 1 (F, I), International Tropical Timber Organization, Yokohama, Japan: 30 pp., illustr.

IUCN. 1992. CITES and the Tropical Timber Trade. International Union for the Conservation of Nature, Position Paper, presented to the Eighth Meeting of the Parties to CITES, Kyoto, Japan: 2 pp.

IUCN. 1982. IUCN Directory of Neotropical Protected Areas. IUCN Commiss. Natl. Parks & Protected Areas [CNPPA]; Tycooly Int. Publish., Dublin. 436 pp.

JIMERSON, L.J. 1993. Mahogany in the USA: A study for FUNATURA. FUNATURA (fundacao pro-natureza)/International Tropical Timber Organization (ITTO), Brazil.

JOHNSON, M.S. & CHAFFEY, D.F. 1973. An Inventory of the Chiquibul Forest Reserve, Belize. Land Resource Study No. 14. Foreign and Commonwealth Office, Overseas Development Administration, Land Resources Division, Surrey, England: 87 pp.

JOHNSON, N. & CABARLE, B. 1993. Surviving the Cut: Natural Forest Management in the Humid Tropics. World Resources Institute, Washington, D.C.

JUAREZ, H.R. Paz. 1990. Prensa Libre, August 16, 1990, Peten, Guatemala.

KNEES, S.G. & GARDNER, M.F. 1983a. Mahoganies: candidates for the Red Data Book. Oryx, 17(2), pp. 88-92, illustr.

KNEES, S.G. & GARDNER, M.F. 1983b. Mahogany - An endangered resource. Threatened Plants Newsl. 12: 12-13.

KNEES, S.G. & GARDNER. M.F. 1982. An Assessment of World Trade in Mahoganies. Fauna and Flora Preservation Society, London, U.K. 28 pp. [unpublished]

KOEHLER, A. 1922. The Identification of True Mahogany, Certain So-called Mahoganies, and Some Common Substitutes. USDA Agric. Bull. 1050. 18 pp.

LAMB, F.B. 1966. Mahogany of Tropical America. Its Ecology and Management. The University of Michigan Press, Ann Arbor, Michigan, USA: x + 219 pp., illustr.

LANLY, J.P. 1982. Tropical Forest Resources. FAO Forestry Paper 30. Food and Agriculture Organization of the United Nations, Rome.

LEWINGTON, A. 1990. Plants for People. [British] Natural History Museum Publ., London.

LIEGEL, L.H. & VENATOR, C.R. 1987. A Technical Guide for Forest Nursery Management in the Caribbean and Latin America. General Technical Report SO-67, U.S. Department of Agriculture, Forest Service: vii + 156 pp., illustr.

LITTLE, E.L.Jr. & WADSWORTH, F.H. 1964. Common Trees of Puerto Rico and the Virgin Islands. *Swietenia macrophylla* & *Swietenia mahagoni*, pp. 248-252. USDA Forest Serv., Agric. Handb. 249. Washington, D.C.

LUTZENBERGER, J.A. 1992. Open letter to British Consumers, April 30, 1992. Porto Elegre, Brazil: 1 p.

MABBERLEY, D.J. 1983. Tropical Rain Forest Ecology. Blackie & Son, Glasgow & London; Chapman & Hall, New York.

MARTINI, A.M.Z., ROSA, N.de A., & UHL, C. 1993. A First Attempt to Predict Amazonian Tree Species Potentially Threatened by Logging Activities. In press (Environmental Conservation).

MARTORELL, L.F. 1943. Forests and Forest Entomology. Caribbean Forester, 4, pp. 132-134.

MATRICARDI, E.A.T. & ABDALA, W.S. 1993 (Draft). Mogno em Rondonia. USFWS Grant Unpublished. USFWS Grant to Natural Resources Defense Council #14-48-0009-92-1341.

MEDINA, R., CUEVAS, A., L., & de los SANTOS, M., V. 1968. Ajuste al proyecto de ordenacion forestal, UIEF, MIQRO. Chetumal, Mexico. 200 pp.

MILLER, N.G. 1990. The genera of Meliaceae in the southeastern United States. Swietenia, pp. 476-486. J. Arnold Arbor. 71:453-486.

MIRANDA, F. 1958. Estudios acerca de la vegetacion. pp. 213-272 in Beltram, E. (ed.), Los Recursos Naturales del Sureste y su Aprovechamiento. IMRNR, Mexico City. 326 pp.

MONBIOT, G. 1991. Against the grain. The Guardian, May 3, 1991, London, England, UK: 2pp., illustr.

MYERS, N. 1989. Deforestation Rates in Tropical Forests and Their Climatic Implications. Friends of the Earth, London, England, UK: 116 pp., illustr.

NASH, N.C. 1993. Bolivia's Rain Forest Falls to Relentless Exploiters. New York Times, June 21, 1993.

NATIONS, J.D. 1987. Mesoamerica's Tropical Rainforests: Conflicts and Conservation. Tulane Studies in Zoology and Botany, 26(1), pp. 59-75.

NEWMAN, A. 1990. Tropical Rainforest. Facts On File, New York.

NYZS. 1990. Mexico: Vast rainforest falling to ax, chainsaw, and match. Wildl. Conserv. 93(6): 16.

NEWTON, A.C., BAKER, P., RAMNARINE, S., HOWARD, F.W., MESEN, J.F., & LEAKEY, R.B.B. The mahogany shoot borer: prospects for control. Forest Ecology and Management. In press.

NEWTON, A.C. 1992. Prospects for growing mahogany in plantations. Presentation to: The Second Pan American Furniture Manufacturers' Symposium on Tropical Hardwoods, November 3-5, 1992. Center for Environmental Study, Grand Rapids, MI.

NEWTON, A.C., LEAKEY, R.R.B. & MESEN, J.F. 1992. Genetic variation in mahoganies: Its importance, utilization and conservation. Proceedings of Mahogany Workshop: Review and Implications of CITES. Tropical Forest Foundation, February 3-4, 1992, Washington, D.C.

NEWTON, A.C. 1990. Seleccion por resistencia al perforador de las Meliaceas. Pp. 4-7 in Noticiero (5), Mejoramiento Genetico y Semillas Forestales para America Central. CATIE, Costa Rica: 22 pp., illustr.

NRC. 1991. Managing Global Genetic Resources: Forest Trees. Board on Agriculture, National Research Council. National Academy Press, Washington, D.C., USA: x + 228 pp., illustr.

OEA. 1967. La Convención para la Protección de la Flora, de la Fauna, y de las Bellezas Escénicas Naturales de los [Países de América] [CNWH]: Listas de Especies de Fauna y Flora en Vías de Extinción en los Estados Miembros. [Conf. Especializada Interamer. Tratar Probl. Relacionados Conserv. Recursos Nat. Renovables del Continente, Mar del Plata, Argentina, 18-22 oct. 1965]. Organización de los Estados Americanos [OEA]/ Organization of American States [OAS], Washington. 48 pp.

OLDFIELD, M.L. 1984. The Value of Conserving Genetic Resources. U.S. Dept. Interior, Natl. Park Serv., Washington, D.C.

OLDFIELD, S. 1988. Rare Tropical Timbers. IUCN, Gland, Switzerland. 37 pp.

OREJAS-MIRANDA, B. 1976. The OAS and renewable natural resources. Parks 1(3):8-10.

PENNINGTON, T.D. 1990. Com. to NRDC (F.T. Campbell). Royal Botanic Gardens, Kew, Richmond, U.K.

PENNINGTON, T.D. & SARUKHÁN, J.K. 1968. Arboles Tropicales de México. Swietenia macrophylla, pp. 244-245. FAO & SAG INIF, México, D.F.

PERUM PERHUTANI. 1991. Mahagony (Swietenia spp) Plantation in Java. Perum Perhutani (State-owned Forest Enterprise), Jakarta, Indonesia: 4 pp., illustr.

PLOWDEN, C. & KUSUDA, Y. 1989. Logging in the Brazilian Rainforest. Rainforest Alliance Workshop, April 13-14, 1989, New York, USA: 25 pp., illustr.

PRANCE, G.T. & DA SILVA, M.F. 1975. Árvores de Manaus. *Swietenia macrophylla*, pp. 189-191. CNPq INPA, Manaus, Brazil.

QUEIROZ, W.T. 1984. Analise de Fatores ("Factor Analysis") pelo Metodo de Maxima Verossimilhanca: Aplicacao ao estudo da estrutura de florestas tropicais. Piracicaba - ESALQ, 112 pp. (Tese de Boutorado).

QUEVEDO, L. 1986. Evaluacion del Efecto de la Tala Selectiva Sobre la Renovacion de un Bosque Humedo Subtropical en Santa Cruz, Boliva. Masters Thesis, Universidad de Costa Rica and Centro Agronomico Tropical de Investigacion y Ensenanza, Turrialba, Costa Rica: xix + 221 pp., illustr.

READ, M. (1990). Mahogany - Forests or Furniture? Fauna and Flora Preservation Society, Brighton, England, UK: 16 pp., illustr.

RECORD, S.J. 1924. Timbers of Tropical America. Yale University Press, New Haven. *Swietenia* pp. 348-356.

RECORD, S.J. & HESS, R.W. 1943. Timbers of the New World. Yale Univ. Press, New Haven.

RODAN, B.D., NEWTON, A.C., VERISSIMO, A. 1992. Mahogany Conservation: Status and Policy Initiatives. Environmental Conservation, Vol 19, Nr. 4, Winter 1992, pp. 331-338, 342.

RODRIGUEZ, S., CHAVELAS P., B.J., ESCOTO P., J.C. 1992. Dispersion de semillas y establecimiento de caoba (Swietenia macrophylla King) despues de un tratamiento mecanico del sitio. Presented at the workshop: "Madera, Chicle, Caza y Milpa: Fundamentos para el manejo integral de las selvas de Quintana Roo. Chetumal, Quintana Roo, 9 de julio, 1992.

RZEDOWSKI, J. 1978. Vegetación de México. Edit. Limusa, México.

SALAZAR, M. 1992. A Brief Analysis of the Current Status of *Swietenia spp.* in Guatemala. In Hartshorn, G., Mahogany Workshop: Review and Implication of CITES. Tropical Forest Foundation, Washington, D.C., February 3-4, 1992.

SAMBA MURTY, A.V.S.S. & SUBRAHMANYAM, N.S. 1989. A Textbook of Economic Botany. Mahogany, pp. 321-323. Wiley Eastern Ltd., New Delhi, India.

SANDERSON, I.T. & LOTH, D. 1965. Ivan Sanderson's Book of Great Jungles. J. Messner/Pocket Books, New York. (*S. macrophylla* p. 129)

SCHUBERT, T.H. 1979. Trees for Urban Use in Puerto Rico and the Virgin Islands. *Swietenia macrophylla*, *S. mahagoni* [& their hybrid], pp. 73-74. USDA Forest Serv. Gen. Techn. Rep. SO-27.

SKOLE, D. & TUCKER, C. 1993. Tropical Deforestation and Habitat Fragmentation in the Amazon: Satellite Data from 1978 to 1988. Science 260:1905-1910, 25 June 1993.

SHANK, P.J. 1949. Forest resources of Honduras. In Proceedings of the Inter-American Conference on Conservation of Renewable Natural Resources, Denver, Colorado, Sept. 7-20, 1948. USDS Publ. 3382: 559-563. Washington, D.C.

SMITH, C.E.Jr. 1965. Meliaceae. *Swietenia*, pp. 60-62. In Flora of Panama. Ann. Missouri Bot. Gard. 52: 55-79.

SNOOK, L.K. 1993. Stand Dynamics of Mahogany (*Swietenia macrophylla* King) and Associated Species After Fire and Hurricane in the Tropical Forests of the Yucatan Peninsula, Mexico. Yale Doctoral Dissertation, May, 1993, Yale University, New Haven, CT.

SNOOK, L.K. 1992. Logging and Mahogany in the Forests of Quintana Roo, Mexico: Why Silvicultural Management is Necessary to Sustain *Swietenia Macrophylla*. In Hartshorn, G., Mahogany Workshop: Review and Implication of CITES. Tropical Forest Foundation, Washington, D.C., February 3-4, 1992.

SOCIEDADE BRASILEIRA DE BOTANICA. 1992. Centuria Plantarum Brasiliensium Exstintionis Minitata. Rio de Janeiro, Brazil: xii + 167 pp., illustr.

STANDLEY, P.C. & STEYERMARK J.A. 1946. Flora of Guatemala:Meliaceae. *Swietenia humilis* & *Swietenia macrophylla*, pp. 456-459. Fieldiana, Bot. 24(5): 444-468.

STEVENSON, N.S. 1927. Silvicultural treatment of mahogany forests in British Honduras. Empire Forestry Journal 6:219-227.

STRONG, L.A. 1940. Report of the Chief of the Bureau of Entomology and Plant Quarantine. U.S. Department of Agriculture, Washington, D.C., USA: 128 pp.

STYLES, B.T. 1981. Swietenioideae. Pp. 359-418, illustr., in Pennington, T.D., Styles, B.T. & Taylor, D.A.H. Flora Neotropica Monograph No. 28: Meliaceae. New York Botanical Garden, New York, USA: 470 pp., illustr.

STYLES, B.T. & KHOSLA, P.K. 1976. Cytology of and reproductive biology of Meliaceae. Pp. 61-67 in Tropical trees: variation, breeding and conservation (Eds. J. Burley & B.T. Styles). Linnean Society, London, England, UK: xv + 243 pp.

SULLIVAN, F. 1991. Visit to the State of Para, Brazil, 30th October - 7th November 1991. Draft Report to Worldwide Fund for Nature - UK: 14 pp.

SYNNOTT, T.J. personal communication to Faith Campbell, Natural Resources Defense Council.

SYNNOTT, T.J. & CASSELLS, D.S. 1991. Evaluation Report on Project PD 34/88 Rev.1 (F): Conservation, Management, Utilization and Integrated and Sustained use of the Chimanes Region, Department of Beni, Bolivia. International Tropical Timber Organization PCF(IX)1 1991.

SZWAGRZAK, A., & LOPEZ, J., S. 1993. Explotacion de las Maderas Caso: Prov. Iturralde -- Bolivia. Draft PRODENA, La Paz, Bolivia. USFWS Grant to Natural Resources Defense Council #14-48-0009-92-1341.

TERBORGH, J. 1990. An overview of research at Cocha Cashu Biological Station [Manú National Park, Perú]. Pp. 48-59 in A.H. Gentry [& M. Guzmán-Teare], eds., Four Neotropical Rainforests. Yale Univ. Press, New Haven & London.

TOLEDO, V.M. 1982. Pleistocene changes of vegetation in tropical México. Pp. 93-111 in G.T. Prance, ed., Biological Diversification in the Tropics. Columbia Univ. Press, New York.

TROPICAL FORESTRY WORKSHOP. 1989. Consensus Statement on Commercial Forestry, Sustained Yield Management and Tropical Forests. Smithsonian Institution/International Hardwood Products Association, Washington, D.C., USA, October 1989: 10 pp.

TURNER, J. 1992. Communication to the Natural Resources Defense Council (NRDC; J.H. Adams). Director, United States Department of the Interior, Fish and Wildlife Service, April 9, 1992, Washington, D.C., USA: 4 pp.

U.S. BUREAU OF THE CENSUS. 1990 - 1993. U.S. Imports for Consumption. TSUSA Commodity by Country of Origin. FT247/Annual 1989 - 1992. U.S. Department of Commerce. U.S. Government Printing Office, Washington, D.C.

U.S. BUREAU OF THE CENSUS. 1987 - 1989. U.S. Imports for Consumption and General Imports. TSUSA Commodity by Country of Origin. FT246/Annual 1986 - 1988. U.S. Department of Commerce. U.S. Government Printing Office, Washington, D.C.

U.S. CITES PROPOSAL. 1992. Proposal to list the genus Swietenia on Appendix II of the Convention on International Trade in Endangered Species (CITES). US Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA: 21 pp., illustr.

UHL, C., VERISSIMO, A., MATTOS, M.M., BRANDINO, Z., & VIEIRA, I.C.G. 1991. Social, Economic, and Ecological Consequences of Selective Logging in an Amazon Frontier: The case of Tailandia. Forest Ecology and Management, 46, pp. 243-273.

UNESCO/UNEP/FAO. 1978. Tropical Forest Ecosystems. A State of Knowledge Report. UNESCO, Paris.

USDS. 1942. [CNWH] Annex. Lists [1940-1942] of species referred to in Article VIII of the Convention [on Nature Protection and Wildlife Preservation in the Western Hemisphere [CNWH]; & Explanatory notes and translations. [U.S.] Treaty Ser. 981: 27-66, 67-77.

USSACH, I. 1992. Mahogany, Certification and CITES. In Hartshorn, G., Mahogany Workshop: Review and Implication of CITES. Tropical Forest Foundation, Washington, D.C., February 3-4, 1992.

VEGA, L. 1976. Influencia de la silvicultura en el comportamiento de Cedrela in Surinam. Pp. 26-49 in: Studies on the shoot borer Hypsipyla grandella (Zeller) Lep. Pyralidae Vol. III. (Ed. J.L. Whitmore). IICA Miscellaneous Publications No. 101, CATIE, Turrialba, Costa Rica: 116 pp., illustr.

VERISSIMO, A., BARRETO, P., UHL, C., & TARIFA, R. Impactos da exploraço de uma espécie de alto valor na Amazônia Oriental: o caso do Mogno. Revista Pará Desenvolvimento (in press).

VERISSIMO, A., BARRETO, P., TARIFA, R., & UHL, C. 1992. Mahogany Extraction in the Eastern Amazon: A Case Study. In Hartshorn, G., Mahogany Workshop: Review and Implication of CITES. Tropical Forest Foundation, Washington, D.C., February 3-4, 1992.

WALKER, A., ed. 1989. The Encyclopedia of Wood. Facts On File, Oxford & New York.

WEAVER, P.L. 1987. Enrichment plantings in tropical America. In Management of the forests of America: prospects and technologies. (Ed. J.C. Figueroa, F.H. Wadsworth & S. Branham), pp. 259-278. USDA Forest Service, Institute of Tropical Forestry, Puerto Rico.

WEAVER, P.L. 1986. Enrichment plantings in tropical America. pp. 259-277 in Management of the Forests of Tropical America: Prospects and Technologies. Proceedings of a Conference published by the Institute of Tropical Forestry, USDA Forest Service, Rio Piedras, Puerto Rico, 469 pp.

WEAVER, P.L. & BAUER, G.P. 1986. Growth, survival and shoot borer damage in mahogany plantings in the Luquillo Forest in Puerto Rico. Turrialba, 36(4):509-522.

WHITE, S. 1978. Cedar and mahogany logging in eastern Perú. Geogr. Rev. 68: 394-416.

WHITMORE, J.L. 1992. An Introduction to *Swietenia*, With Emphasis on Silvics and Silviculture. In Hartshorn, G., Mahogany Workshop: Review and Implication of CITES. Tropical Forest Foundation, Washington, D.C., February 3-4, 1992.

WHITMORE, J.L. 1983. *Swietenia macrophylla* and *S. humilis* (Caoba, Mahogany). Pp. 331-333 in: Costa Rican Natural History (Ed. D.H. Janzen). Univ. Chicago Press, Chicago, Illinois, USA: xi + 816 pp., illustr.

WHITMORE, J.L. 1976a. Studies on the shoot borer *Hypsipyla grandella* (Zeller) Lep. Pyralidae Vol. II. IICA Miscellaneous Publications No. 101, CATIE, Turrialba, Costa Rica: 139 pp., illustr.

WHITMORE, J.L. 1976b. Studies on the shoot borer *Hypsipyla grandella* (Zeller) Lep. Pyralidae. Vol. III. IICA Miscellaneous Publications No. 101, CATIE, Turrialba, Costa Rica: 116 pp., illustr.

WHITMORE, J.L. & HINOJOSA, G. 1977. Mahogany (*Swietenia*) Hybrids. U.S. Dept. Agric. Forest Serv. Res. Pap. ITF-23. 8 pp.

WHITMORE, T.C. 1981. Trees of tropical America. Pp. 267-269 in The Oxford Encyclopedia of Trees of the World (Ed. F.B. Hora). Oxford University Press, Oxford and New York: 228 pp., illustr.

YARED, J.A.G. & CARPANEZZI, A.A. 1981. Conversao de Capoeira Alta da Amazonia em Povoamento de Producao Madeireira: O Metoda "Recru" e Especies Promissoras. EMBRAPA, CPATU, Boletim de Pesquisa 25. 27pp.

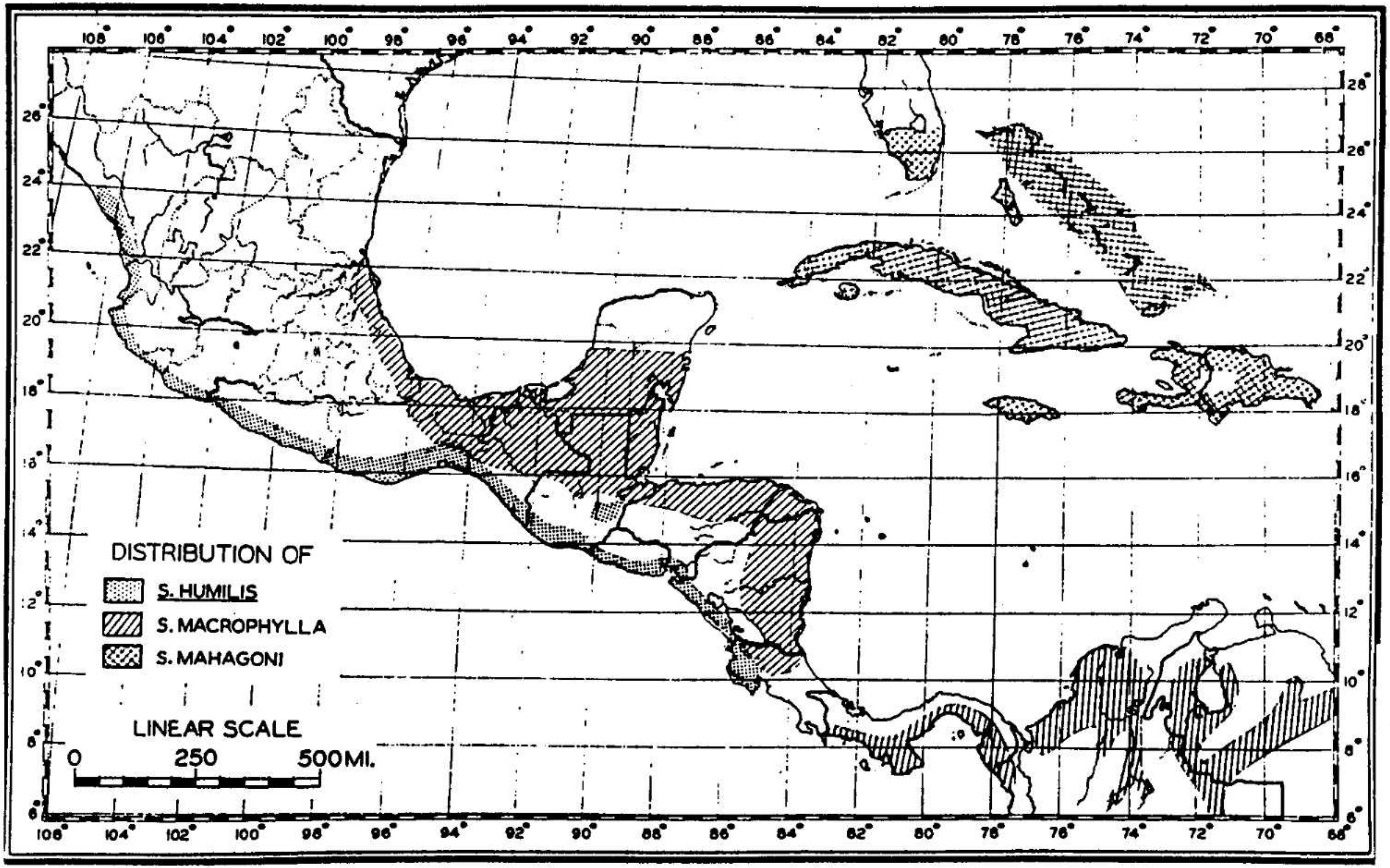


Figure 5. Distribution map of mahogany in Central America and Caribbean area.

APPENDIX B

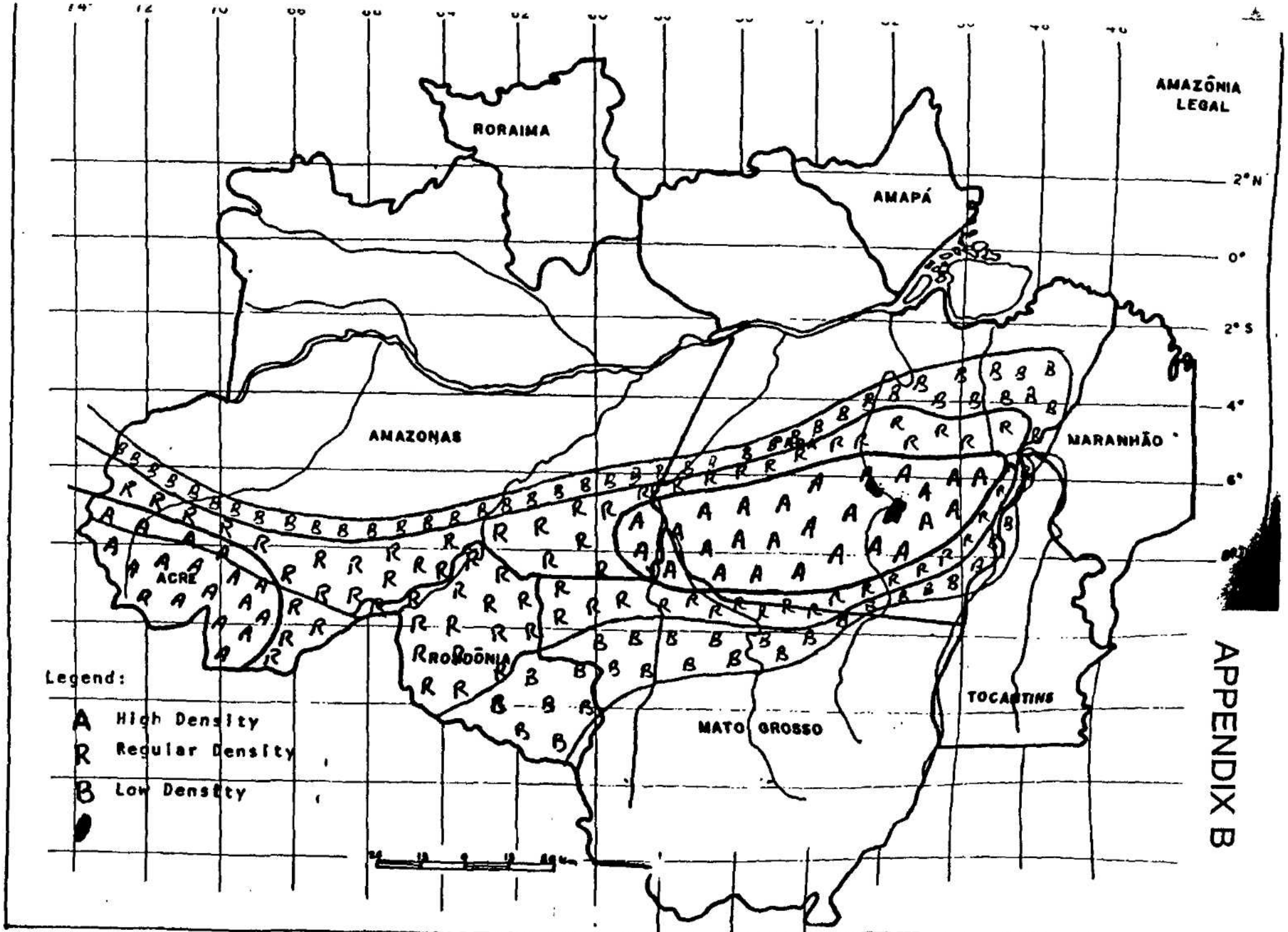
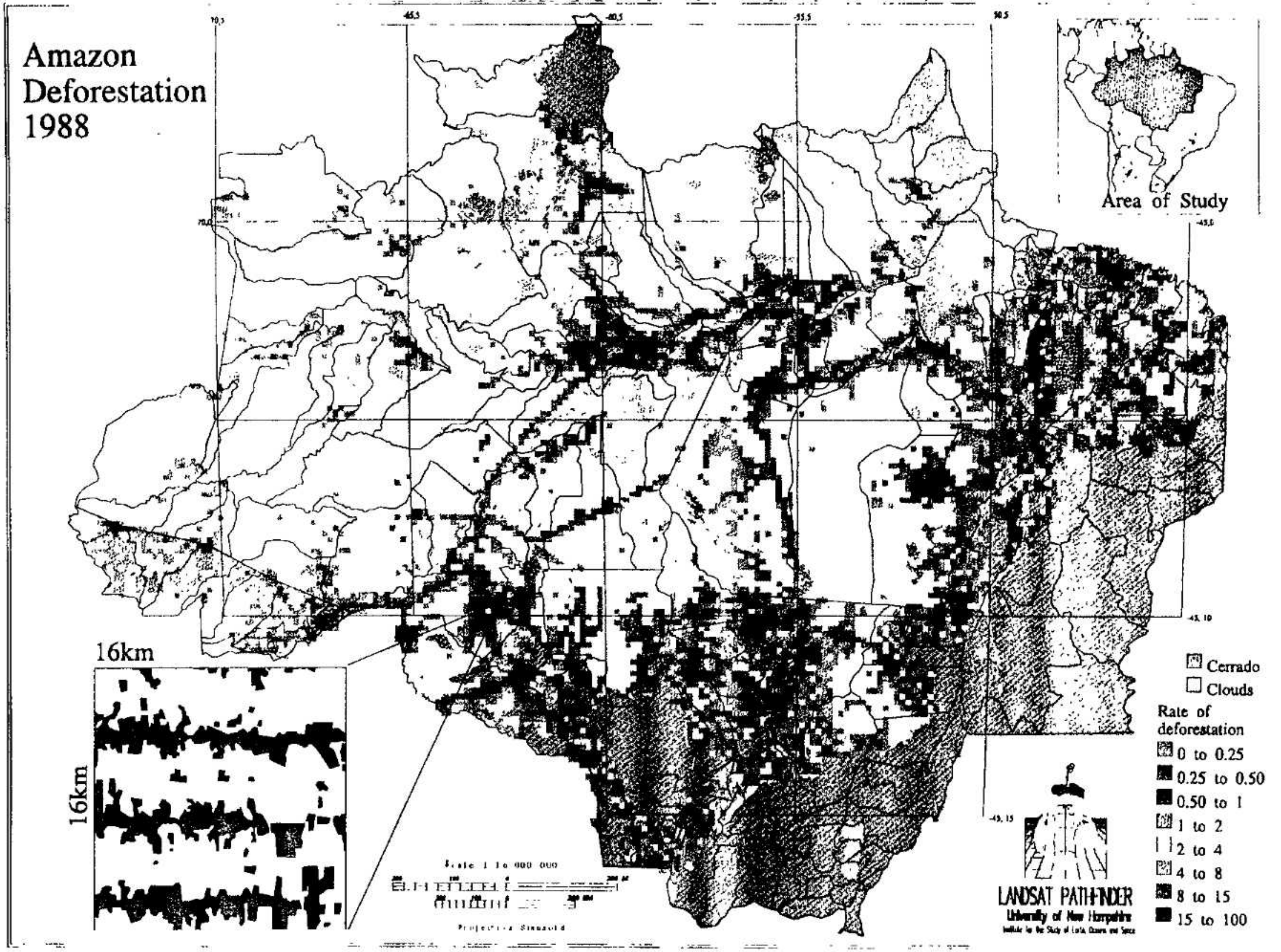
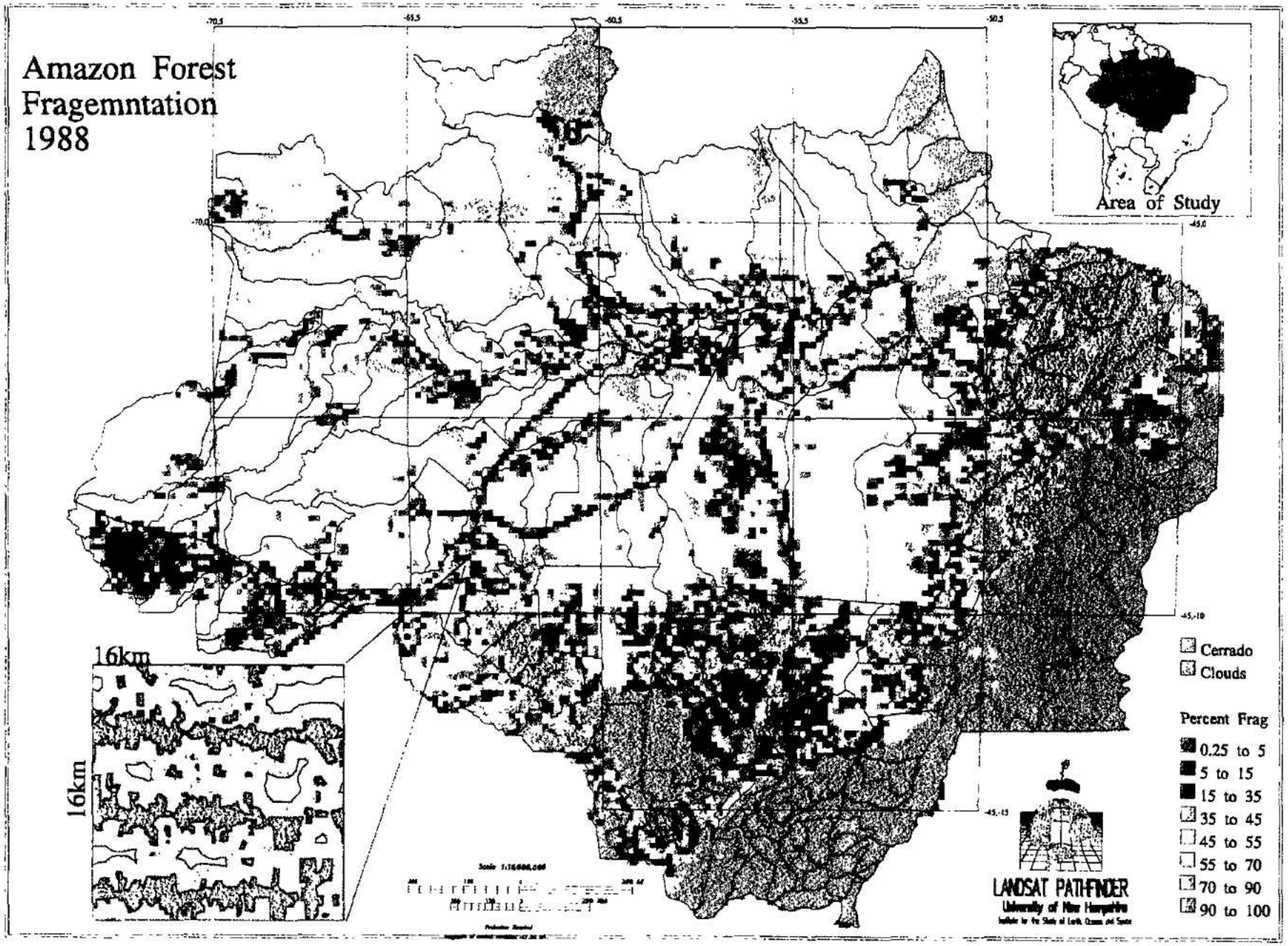


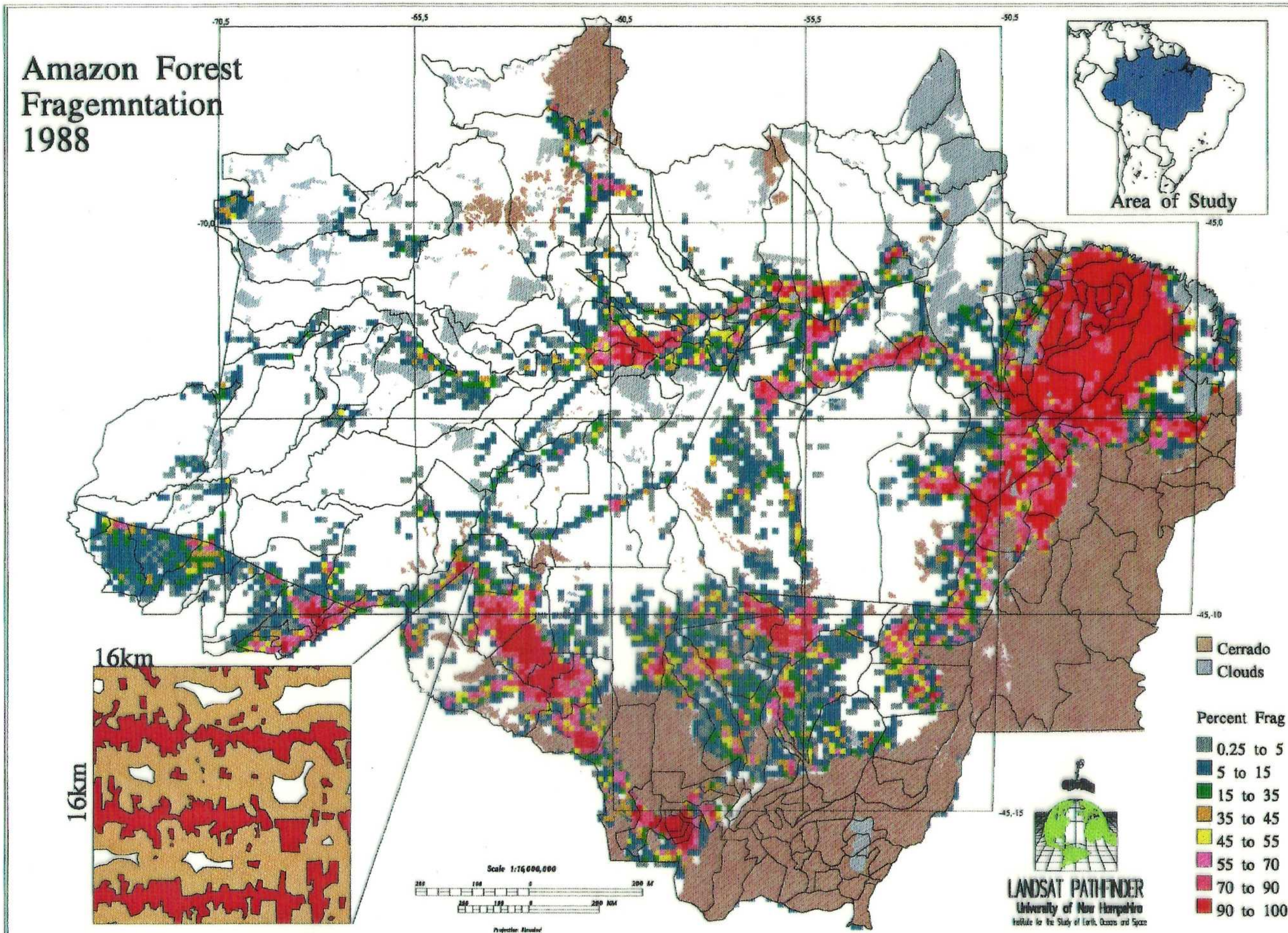
Figure 7 Zoning, according to density, of the natural area of Mahogany - <u>S.macrophylla</u>, King occurrenc in Brazilian Amazon


Amazon
Deforestation
1988
Area of Study
16km
16km
Cerrado
Clouds
Rate of deforestation
0 to 0.25
0.25 to 0.50
0.50 to 1
1 to 2
2 to 4
4 to 8
8 to 15
15 to 100
LANDSAT PATHFINDER
University of New Hampshire

APPENDIX C

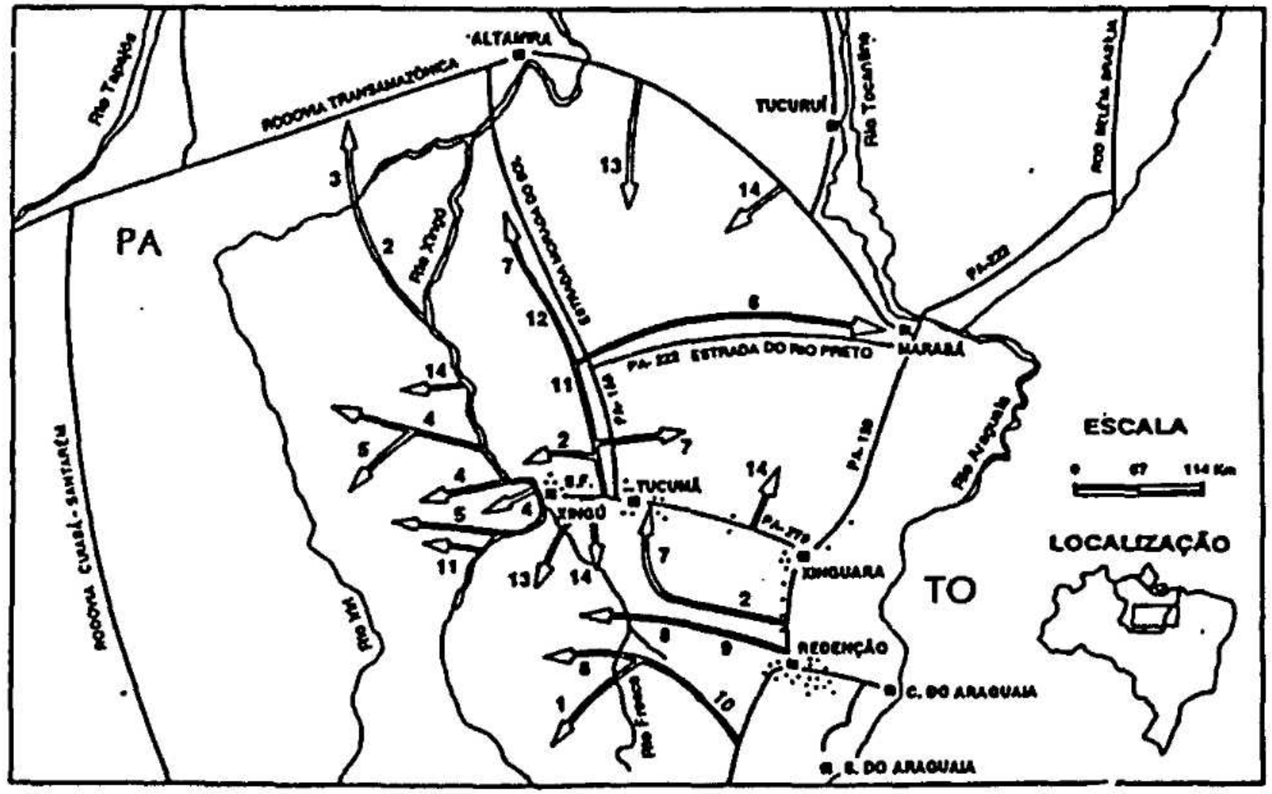
APPENDIX D


Amazon Forest
Fragemntation
1988
Area of Study
16km
16km
Cerrado
Clouds
Percent Frag
0.25 to 5
5 to 15
15 to 35
35 to 45
45 to 55
55 to 70
70 to 90
90 to 100
LANDSAT PATHFINDER
University of New Hampshire


Amazon Forest
Fragemntation
1988
Area of Study
16km
16km
Cerrado
Clouds
Percent Frag
0.25 to 5
5 to 15
15 to 35
35 to 45
45 to 55
55 to 70
70 to 90
90 to 100
LANDSAT PATHFINDER
University of New Hampshire
Institute for the Study of Earth, Oceans and Space

APPENDIX D

ESTRADAS MADEIREIRAS DO ESTADO DO PARÁ



1 Campos Altos, 2 Bannach, 3 Seba, 4 Karapanã, 5 Pau D' Arco, 6 Jacafé, 7 Perachi, 8 Juari, 9 Minuano, 10 Madeplan, 11 Maginco, 12 Impar, 13 Angelim, 14 Não Identificadas

figura 4: Sobreposição dos mapas do DER-PA (1987) e Veríssimo et al. 1992.

APPENDIX E

APPENDIX F

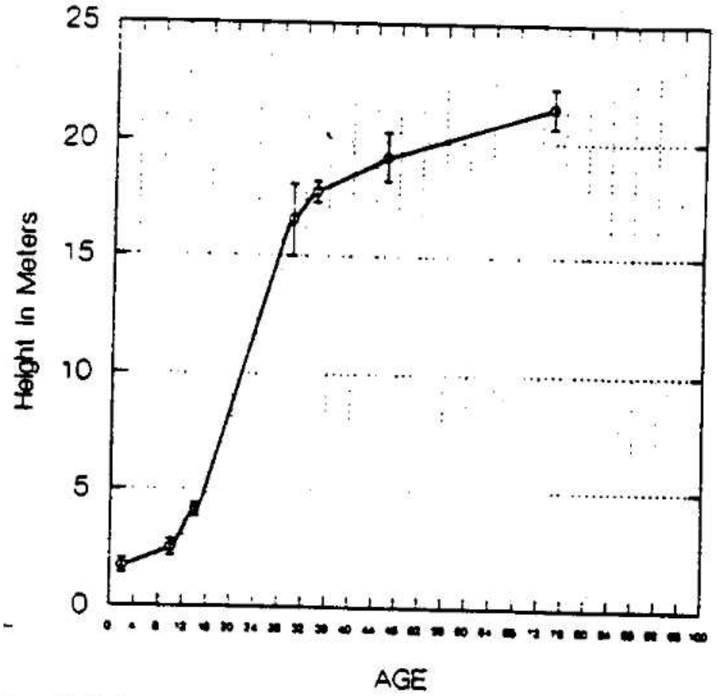


Figure 7-G. Heights of mahogany trees in mixed-species stands of known age. N = 161.

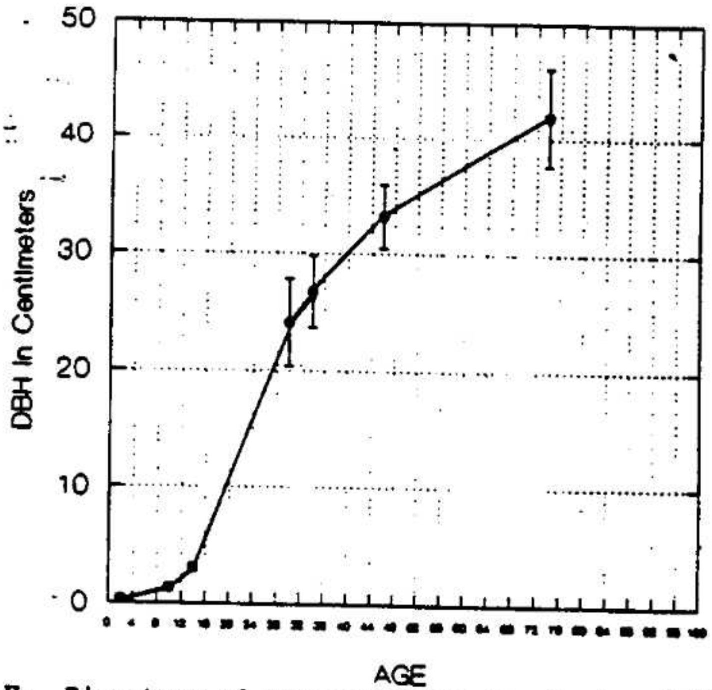
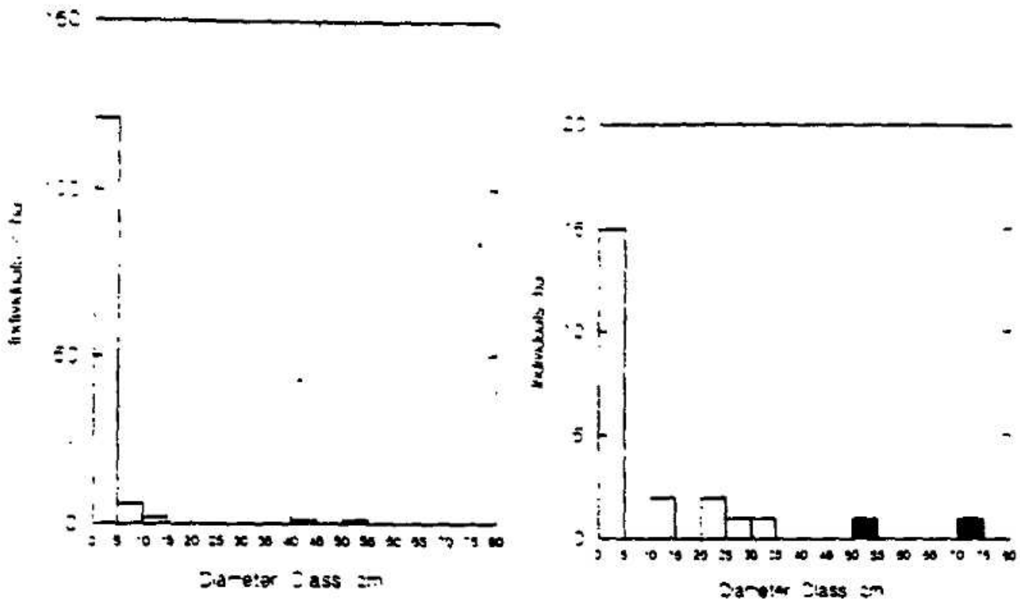
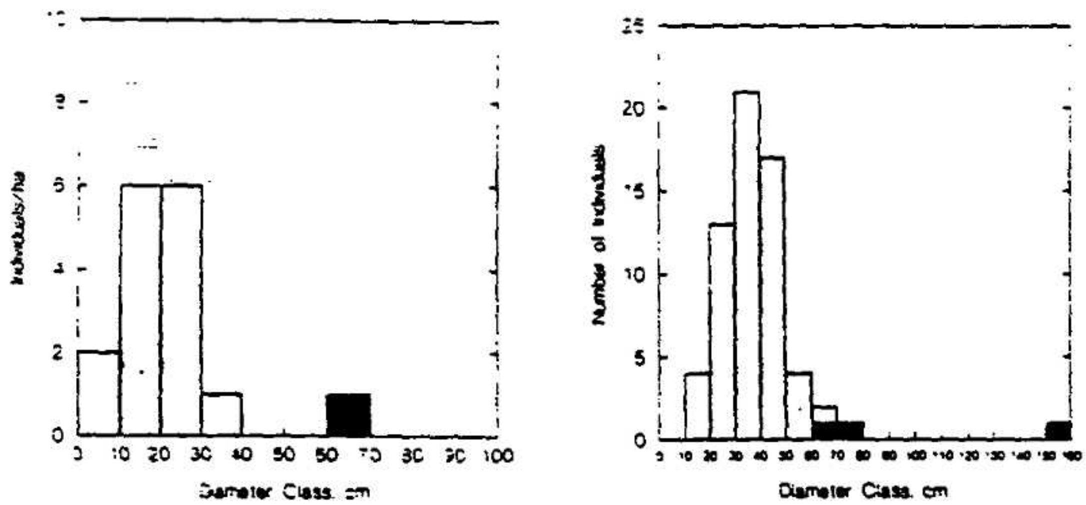


Figure 7-H. Diameters of mahogany trees in mixed-species stands of known age. N = 161



Figures 6-C (left) and 6-D (right). Diameter distributions of mahoganies on one hectare transects on a 15 year old post-fire stand (left) and a 30 year old post-fire stand (right). Residual trees that survived the fire are indicated in black. Gaps in the diameter distribution on the 30 year-old stand probably reveal past mortality due to a second fire 15 years previously.



Figures 6-E (left) and 6-F (right). Diameter distributions of mahogany on a one hectare transect in a 45 year old post-fire stand (left) and a 3 hectare transect in a 75 year old post-fire stand (right). Residual trees are indicated in black. Two of the residual trees were old stumps that would have grown to larger diameter classes if they had not been cut.

APPENDIX H

UNITED STATES IMPORTS - MAHOGANY ROUGH

Table 1.B Mahogany Imports to the US 1978 to 1991' Rough Lumber, Cubic Meters (Thousands)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Total	Percent
Algeria							57								57	0.00
Argentina	592	708	35					42	7			24			1,409	0.00
Australia						47	24		57	14					142	0.00
Bahamas										66					66	0.00
Belgium and Luxem								87		64					151	0.00
Belize	540	42	76	9	276	392	139	208	135	4,175	267	400	169	164	6,992	0.00
Benin											191				191	0.00
Bolivia	24,440	14,115	21,301	15,538	979	1,385	2,211	52	349	7,266	24,870	22,561	38,705	46,438	720,212	0.16
Brazil	23,376	33,068	54,660	65,157	35,256	75,397	96,099	105,806	82,204	267,364	78,923	50,788	33,476	40,116	1,041,691	0.74
Burma						5									5	0.00
Cameroon		50	59				47	26		80		56	46		364	0.00
Canada	243	2	267	92	309	54	135	132	111	864	120	119	8	5	2,461	0.00
Cayman Islands											1,473			101	1,574	0.00
Chile		99	909	363	28		260	1,525	458	319	165	12,693	370	1,646	18,834	0.01
Colombia										5					5	0.00
Costa Rica			78	144	144								19		385	0.00
Ecuador										90					90	0.00
Fiji						5	21								26	0.00
Finland								5							5	0.00
France					24	24	722	302	17	158					1,246	0.00
Gambia									38						38	0.00
Germany, West			76		5		295	19	92	111				8	605	0.00
Ghana	1,598	694					80	231	1,116	5,013	2,582	2,018	2,457	1,062	16,851	0.01
Greenland											238				238	0.00
Guatemala	1,371	411	680	1,097	557	1,326	1,067	1,784	3,330	11,177	12,845	8,630	4,106	4,814	53,195	0.04
Honduras	569	85		80	57	71	14	24	59	54	2		34		1,049	0.00
Hong Kong						90									90	0.00
Indonesia			149						106	1,055	892			19	2,221	0.00
Israel								295	101						396	0.00
Italy							19								19	0.00
Ivory Coast	1,876	368	562	87	871	281	951	923	668	4,151	333	50		162	11,283	0.01
Jamaica									2						2	0.00
Kenya		42													42	0.00
Kiribati (Gilbert Isl)								149							149	0.00
Liberia				76	94										170	0.00
Libya				19											19	0.00
Malaysia					368	194	61		694	24	26	33		19	1,418	0.00
Mali								54	57						111	0.00
Mauritius										40					40	0.00
Mexico						87		19		465	54			81	706	0.00
Netherlands			156				101	635							892	0.00
New Zealand							47								47	0.00
Nicaragua	68	354				146							12	78	659	0.00
Nigeria								35			286				321	0.00
Pakistan							26								26	0.00
Panama			24					38							61	0.00
Paraguay	142									118					260	0.00
Peru	1,149	727	1,617	290	156	533	460	1,517	186	1,555	47	356	778	1,709	11,062	0.01
Philippines	165	52	101				73			78	19				489	0.00
Pitcairn Island										80					80	0.00
Portugal								3,549			31				3,580	0.00
Republic of South A	28	394	241	45		54	47		31	78					918	0.00
Singapore								538					95	35	668	0.00
Switzerland									189	170					359	0.00
Taiwan	71	19	26		28		28	94							267	0.00
Thailand						19							30		49	0.00
Trinidad and Tobag		47													47	0.00
United Kingdom			2				132	215	432						781	0.00
Venezuela								158				265			423	0.00
Western Samoa						12									12	0.00
Yugoslavia (former)							123								123	0.00
Zaire	2,844	3,509	720	1,069	219		73	147		172	35				8,784	0.01
Zambia									625						625	0.00
World	59,073	54,787	81,736	84,068	39,372	80,122	103,314	118,604	91,063	304,806	123,400	98,745	80,399	97,187	1,416,676	1.00

54

USDA Forest Service; US Department of Commerce

UNITED STATES IMPORTS - MAHOGANY DRESSED

Table 2.A Mahogany Imports to the US 1978 to 1991: Dressed Lumber, US Dollars (Thousands)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Total	Percent
Argentina		36	13										150		199	0.00
Australia				6				16	13	40					75	0.00
Bahamas										5					5	0.00
Barbados									3						3	0.00
Belize					42	75	8	82	9	44	46		100	53	459	0.01
Bolivia	130	54	60	409	43	64	176	137		25		1,573	2,025	247	4,943	0.06
Brazil	1,503	3,961	4,895	5,844	8,621	4,921	2,330	6,872	7,958	4,358	4,518	3,462	1,307	5,556	66,106	0.77
Cameroon		1	11												12	0.00
Canada	83	91	157	100	61	125	78	186	221	39	217	37	9	4	1,408	0.02
Cayman Islands								2							2	0.00
Chile			81		32	98		51	40	8	226	253	468	884	2,141	0.02
Colombia	74	5		25	56										160	0.00
Congo										13					13	0.00
Costa Rica						13					36			16	65	0.00
Ecuador	57									16					73	0.00
France						11		43			6				60	0.00
French West Indies						4							16		20	0.00
Germany, West			10			3	3	18		85	98				217	0.00
Ghana	8	9	15					34	198	478	40		30	422	1,234	0.01
Guatemala	15		10		29		8	404	187	615	85	122	143	35	1,653	0.02
Honduras	20	8	199	9	39	85		4	43	197	187	86	15	219	1,111	0.01
Hong Kong								25							25	0.00
India			7				1		16		12				36	0.00
Indonesia								28	20	38	615	193	338	721	1,953	0.02
Israel									127						127	0.00
Italy								11		55		3			69	0.00
Ivory Coast			13			15	87	22	52	100	20				309	0.00
Jamaica			7		28										35	0.00
Kenya		1				30									31	0.00
Liberia								7							7	0.00
Malaysia		74	10	12	14	2	3	87	59	96	190	77	41	35	700	0.01
Mexico							1	16		10					27	0.00
Netherlands						23									23	0.00
New Zealand						12									12	0.00
Nicaragua	1		18											64	83	0.00
Panama							45			38					83	0.00
Paraguay		1													1	0.00
Peru		5	12	255	190	110	95	193	7	81		80		155	1,183	0.01
Philippines			11		17		55			7	34		21		145	0.00
Poland									76						76	0.00
Republic of South A					2	2	6								10	0.00
Singapore	8		3			17								244	272	0.00
Spain		13													13	0.00
Suriname	3														3	0.00
Switzerland										13			30		43	0.00
Taiwan	71					25		6	23	48	71	29			273	0.00
United Arab Emirate							40								40	0.00
United Kingdom						3			1	6	7	6			23	0.00
Uruguay			21												21	0.00
Venezuela							3	6					79	38	126	0.00
Zaire	1	11	14			39			25	24					114	0.00
World	1,975	4,270	5,568	6,660	9,175	5,678	2,938	8,251	9,077	6,439	6,409	5,973	4,787	8,959	86,159	1.00

55

USDA Forest Service; US Department of Commerce

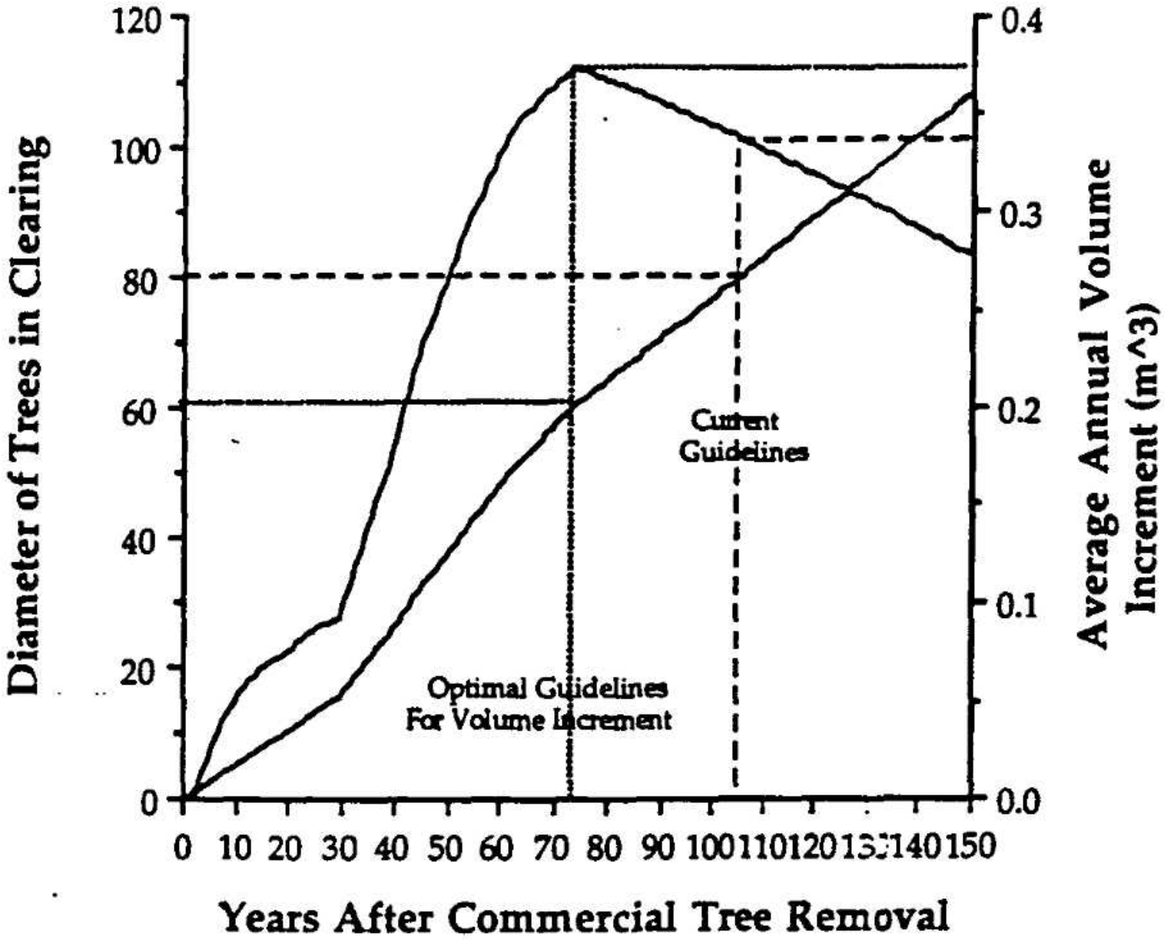


Figure 5: Predicted mean diameter of new trees surviving in a gap created by removing a single adult, and the average annual volume increment per tree of trees surviving in the gap. Growth rates are taken from growth ring data from the Bosque Chimanes, which agree closely with estimates provided by Lamb (1966). Average annual volume increment is calculated assuming a survivorship curve starting with annual values of 0.90 for seedlings (a value obtained from our plots) increasing to 0.99 (unpubl. data from Hubbell and Foster, BCI). The volume increment is calculated by assuming a commercial bole of 10 meters. Our simulation shows that 105 years are required to reach the current cutting diameter limit of 0.80 m dbh. Average annual volume increment is maximized by harvesting the trees at 73 years of age, or at a diameter of 62 cm.

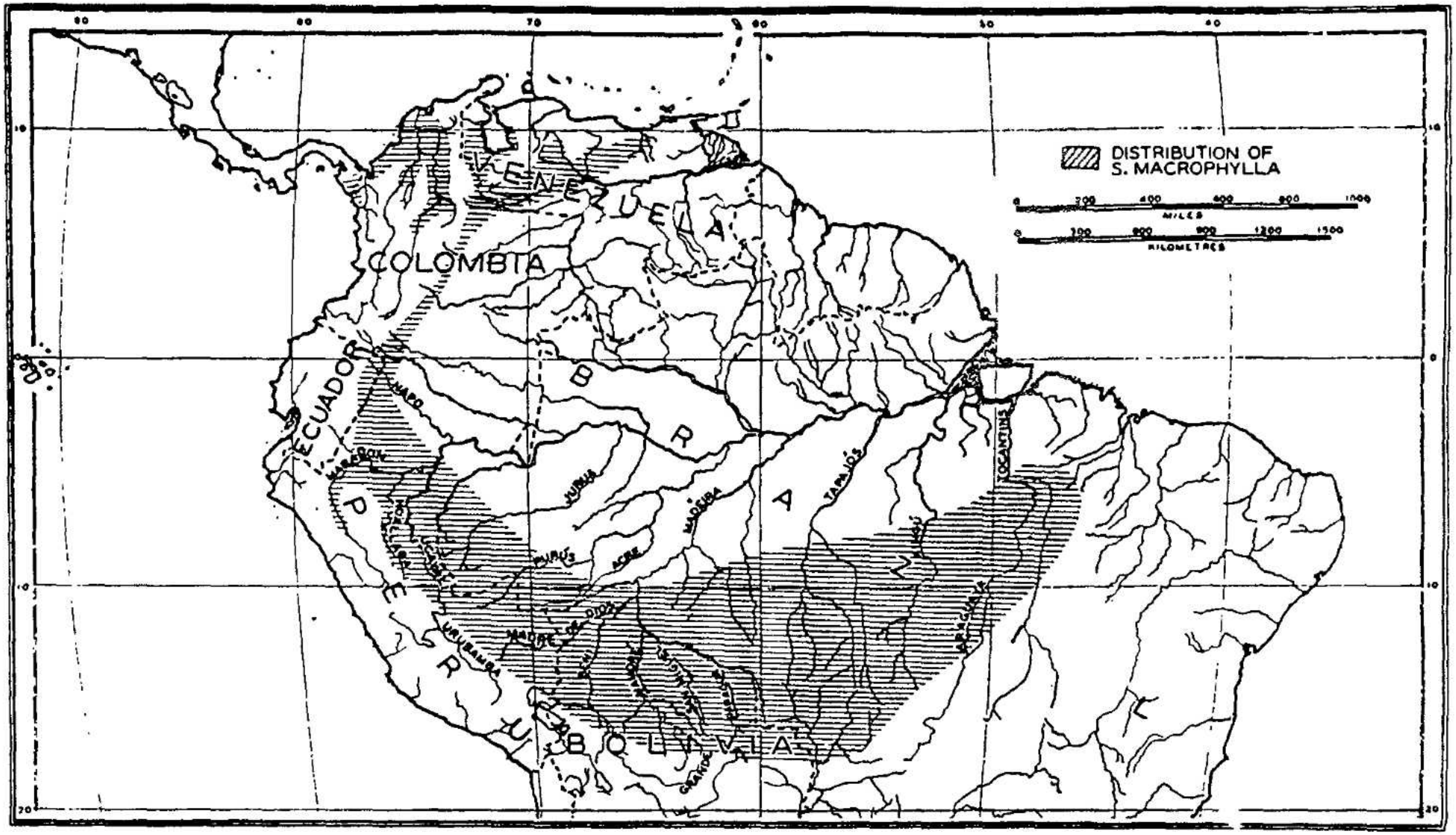


Figure 6. Distribution map of mahogany in South America.

UNITED KINGDOM IMPORTS

Figure 1. Total Latin American sawn lumber imports 1980 - 1991, m3.

	m3
1980	64300
1981	92500
1982	73300
1983	102600
1984	94000
1985	91000
1986	91800
1987	112000
1988	101500
1989	100000
1990	75400
1991	60000

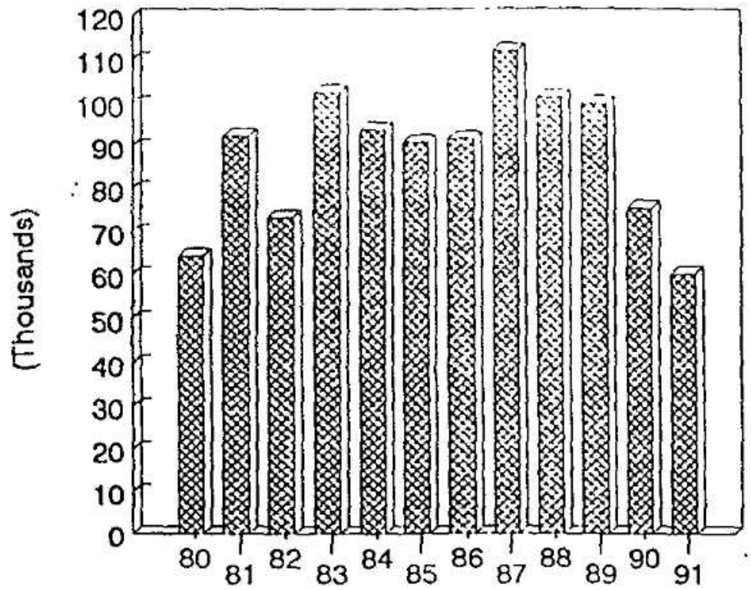
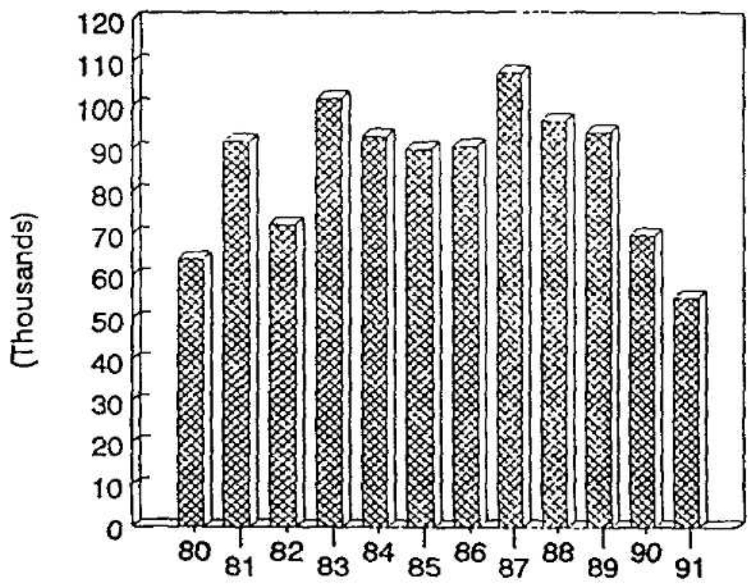


Figure 2. Total L.A. Mahogany lumber imports 1980 - 1991, m3.

	m3
1980	64000
1981	92000
1982	72500
1983	101700
1984	93100
1985	90100
1986	90800
1987	107500
1988	96500
1989	94000
1990	70000
1991	55000



3.1A.2.1. IMPORT TO EUROPEAN COMMUNITY [EC]: MAHOGANY (& other species)

m^3	+ other spp. SAWN WOOD			+ rosewood & other spp. VENEER + PLYWOOD SHEETING			PLYWOOD		
Tariff Schedule	4407.23-10, 4407.23-30, 4407.23-50 + 4407.23-90			4408.20-10, 4408.20-30, 4408.20-50, 4408.20-91 + 4408.20-99			4412.11-00		
ORIGINATING COUNTRY (selection) (EXPORTER)	1988	1989	1990	1988	1989	1990	1988	1989	1990
S. macrophylla p.p.:									
Chile	100		550		19	22	1788	327	406
Argentina		25				7			
Paraguay	40	523	2727	26			44	184	307
Bolivia	78	1305	1316	115	76			1	
Brazil	78340	70555	57989	2166	1941	1340	10705	17754	16766
Perú	104	84	30					103	11
Ecuador	760	796	1512				322	313	292
Colombia		1							
Venezuela		14	512			1			
Trinidad & Tobago								16	
Guyana	294	1322	980						
Surinam								193	
Fr Guiana			26		20				
Panamá		437							
Costa Rica			5				22		1
Nicaragua			47						
Honduras	21	53	60						
Guatemala	3	24	31						
Belize		14	6						
? *S. mahagoni*:									
Antigua & Barbuda							97		
Jamaica					4				
Bahamas				9					
Total	79740	75169	65771	2315	2060	1370	12978	18891	17783

In 1966, 79,000 m^3 of various "mahoganies" at £38/m^3 were imported by British traders; by 1979, 196,000 m^3 were imported but at £230/m^3. From the Jamaican *S. mahagoni* population in 1770, 230 m^3 of mahogany valued at £210/m^3 were imported to England (Huxley 1984; Knees & Gardner 1982, 1983a).