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PROMOTION OF VALUABLE HARDWOOD PLANTATIONS IN THE TROPICS. A GLOBAL OVERVIEW

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Please Note: The figures in this paper are estimated forest plantation areas in **1995**, based on a revision to the statistics collected in the **1990** forest resources assessment. More up-to-date forest plantation statistics will be published when the **2000** forest resources assessment is published in **2001**.

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1. INTRODUCTION

The goal of this paper is to provide a broad globally oriented overview of the situation and prospects for the development of valuable hardwood plantations in the tropics and their potential to augment supplies from the natural forests. It is based on review of the literature. The specific objectives are to:

- Define valuable hardwood plantation species;
- Describe their current extent, location, species;
- Discuss economic issues surrounding their development;
- Estimate current and future woods supplies from valuable hardwood plantations and discuss their potential to supplement and substitute for supplies from natural forests.

There are various other issues related to valuable hardwood plantations that are common to forest plantations in general. These have been treated in the other papers.

2. DEFINITION OF VALUABLE HARDWOOD SPECIES

According to the Merriam Webster English Dictionary, the definitions of "valuable" are either of the following: "having monetary value; worth a good price; having desirable or esteemed characteristics or qualities; of great use or service".

Cooper (FAO 1991) has attempted a definition close to "valuable hardwoods" by defining "high value end uses" for these timbers. They are "uses ranging from those in which tropical timber (sawnwood, plywood or veneer) is virtually irreplaceable to those uses where it is strongly preferred to alternative materials (wood or non-wood) for technical, aesthetic or commercial reasons". The term "valuable" or "high value" was considered to be too imprecise and open to interpretation.

Valuable hardwoods[1] can therefore be considered as those hardwood species or group of hardwood species with special *technical properties* (e.g. strength, natural durability and good machining properties) and *appearance*[2] (i.e. grain, figure, texture and colour or aesthetic qualities) that makes them suitable for "high value end uses". These high-grade hardwoods contrast to lesser quality woods used only for woodfuel or pulpwood. The special characteristics of valuable hardwoods lend them particularly well to the speciality markets, which are usually also the highest value markets. Species such as teak (*Tectona grandis*) , mahogany and rosewood (especially the genus *Dalbergia*) obtain considerably higher prices than commodity timbers. Teak is one of the most valuable multi-purpose tropical hardwood timbers of the world. It is well known for its beauty, strength and durability, versatility of its applications, dimensional stability under a wide range array of environmental conditions, natural resistance to weathering and biological attacks, and its ability to grow well in plantations (Centeno 1996).

[1] Hardwoods can be described as the wood of non-coniferous tree species. They can be either deciduous or evergreen. The natural characteristics of most hardwood species make them differ from softwoods with respect to the finished products derived from the trees.

[2] The "Appearance" of wood used in this sense may be defined its decorative appearance due to its colour, texture and figure, either in isolation or combination. "Figure" may also be defined as the appearance of the wood due to anatomical features of wood grain, growth rings, rays and knots.

The highest value hardwood application is veneer, which normally requires larger diameter (more than 46 cm) and defect-free wood. However, veneer lathes can convert relatively small dimension material into veneer.

Even though the forests in Africa and Latin America are dominated by the family Leguminaceae, their leading commercial timbers belong to less common families, such as the Meliaceae. The Meliaceae or the 'mahogany family' are good examples of valuable tropical hardwoods. It includes the species of such genera as of *Khaya, Entandrophragma, Lovoa* in Africa and *Swietenia, Carapa, Cedrela* in Latin America. Commercially, some of the various woods resembling or substituted for Mahogany includes some species of the genera *Shorea, Tabebuia, Trichilia, Eucalyptus*, and *Aucoumea*.

The highest quality decorative veneers and sawnwood are made from Mahogany, Sapele, Teak, Kokrodua, Utile and selected logs of other species (Table 1 - see Appendix 1 for common names). Woods converted into plywood and veneers include Okoume, Obeche, Limba, and Makore from Africa; Lauan, Meranti and Seraya from Asia. Together with Abura, Iroko (African teak), Kokrodua and Niangon from Africa; Ramin and Keruing from Asia, they are also made into sawnwood for use in construction (Grainger 1993).

Ekki from Africa, Greenheart from Latin America and Keruing from Asia are heavier and very durable woods used for key structural purposes in the construction industry (e.g. for railway sleepers/ties and marine construction) – see Table 1.

Table 1: Characteristics of valuable hardwood species used in the tropics

Use Categories	Desirable Wood Properties	Main End Uses	Examples of Matching Valuable Hardwood Species	Comments
Decorative Timbers	Appearance, consistent quality, dimensional stability, durability, good machining, staining and finishing properties	Quality furniture and interior joinery	Teak, *Khaya* spp., *Swietenia* spp., *Dalbergia* spp., *Aningeria* spp., Makore, Sapele, Bete, Walnut, Iroko, Utile, Okoume, Afromosia.	Highest value. Competition from temperate hardwoods & MDF.
High to Very High-Density Timbers	Appearance, Strength, high natural durability, availability in large sizes	Principally in construction	Keruing, Greenheart, Ekki, Iroko.	Small share of total tropical timber use
Low to Medium-Density Utility Timbers	Appearance, clear grain, natural durability, good machining properties	External joinery, shop fitting, medium priced furniture.	*Shorea* spp, Limba, Niangon. Rubberwood	Largest end-uses, prone to competition from substitutes materials.

Source: Based on FAO 1991

The valuable hardwood species in the temperate climates include Oak, Ash, Cherry, Walnut, Tulipwood and Hard Maple. These are mainly used for furniture, joinery and interior decoration.

3. EXPERIENCES WITH VALUABLE TROPICAL HARDWOOD PLANTATION SPECIES

Many tropical tree species are difficult to establish in plantations because when planted in pure stands or in open environments, they usually become chlorotic and decline, or they are affected by pests and diseases (Keogh 1996). Another common explanation for this problem is a failure to recognise the important ecological characteristics of these species. The potential for pest problems may increase going from diverse communities (primary forest) through secondary and regenerating forests to enrichment plantings and monoculture plantations (Cobbinah 1997).

Operational scale native monoculture plantations of such valuable hardwoods as Iroko, the African mahoganies and Afromosia have been unsuccessful due to the activities of insects that are largely unrecognised in the natural forests. The problem with Iroko is the gall *Phytolama lata* that affects the leaves of seedlings. However, the selection of Iroko genotypes that are less susceptible to this pest and its establishment in mixed plantations, has shown considerable promise in humid regions (Cobbinah 1997).

Irrigated *Khaya* species at Aswan in upper Egypt have also grown without problems such as shoot borer attack. Experience in West Africa indicates that the principal constraint to plantations of the Meliaceae family has been their susceptibility to the shoot borer *Hypsipyla robusta*.

Most of the successful tropical hardwood plantation schemes in West Africa, for example, are employing utility or standard grade hardwoods such as *Terminalia ivorensis, T. superba* and *Triplochiton scleroxylon* (DFID 1998).

Valuable hardwood species that are amenable to vegetative propagation include: *Chlophora excelsa, Cordia alliodora, Dalbergia sissoo, Nauclea diderichii, Paraserianthes falcataria, Pterocarpus spp., and Tectona grandis* (Perlack *et al.* 1999).

4. TRENDS IN PLANTATION ESTABLISHMENT

The area of high-grade hardwood plantations grew steadily in the 1960s. The focus of planting shifted later in that decade to softwood plantations for the production of pulp and paper. Later still, non-industrial plantations became more important. Between the late 1960s and the late 1970s the annual rate of establishment of plantations in the humid tropics was about 0.7 million hectares. But the share of high-grade hardwood plantations fell from 33 to just 13 percent (Grainger 1993).

The estimated annual planting rate for all tropical countries in 1990 was 2.6 million hectares. This declined to about 1.65 million hectares during 1991-1995. Most of this fall was attributed to a reduction in the planting programme in India, probably due to reduced funding (FAO 1997).

Of the 7.7 million hectares of timber plantations in the humid tropics in 1980, only 1.4 million ha. (18 percent) were dedicated to producing high-grade hardwood similar to that extracted from the tropical rainforests (Grainger 1993). The majority of "fast-growing" hardwood plantations (i.e. yielding more than 14 m^3/yr.) are genera such as *Acacia* or

Eucalyptus grown on short rotation for such relatively low value uses as fuel, fibre or roundwood. About a third are longer rotation (typically 25 years and above) crops of either softwood or hardwood species, grown principally for sawn- or veneer-wood (Kanowski 1997).

5. LOCATION OF HARDWOOD PLANTATIONS IN THE TROPICS

The most dominant tropical and sub-tropical hardwood plantation species is the genus *Eucalyptus* (30.8 percent) followed by the genus *Acacia* (12.1 percent) and then teak, *T. grandis* (7 perecnt) – see Table 2 (FAO 1997). The "other hardwoods" make up 43 percent of the area and consists of species with unspecified area, or less extensively planted, or native species. About 90 percent of these plantations are in Asia and many species of this group are of industrial value (FAO 1997).

Table 2: ***Net areas of tropical and sub-tropical hardwood plantations by species (1995)***

Species	% all tropical plantations	% tropical hardwood plantations	Net Area (10^3 ha)
Acacia auriculiformis	1.4	2.3	758
Acacia mangium	0.8	1.4	454
Acacia mearnsii	0.6	1.0	325
Other acacias	4.2	7.3	2 367
Casuarina species	1.4	2.4	787
*Dalbergia sissoo**	1.1	1.9	626
Eucalyptus species	17.7	30.8	9 950
Gmelina arborea	0.7	1.3	418
*Swetenia macrophylla**	0.3	0.5	151
Terminalia species	0.5	0.9	304
*Tectona grandis**	4	7.0	2 253
Other hardwoods	24.7	43.1	13 921
TOTAL	**57.4****	**100.0**	**3021**

Source: FAO , 1997 * valuable hardwoods **Total tropical plantations= c. 56.3million ha.
Due to rounding offs, sums may not tally

The three most widely planted high-valued hardwood species are *Dalbergia sissoo* (Rosewood), *Swietenia macrophylla* (Mahogany), and Teak (Table 2) and between them constitute about 10 percent of the global hardwood plantations. Teak is the most widely cultivated valuable hardwood. The regional distribution is given in Table 3.

More than 90 percent of Teak plantations were located in Asia; mainly in Indonesia, India, Thailand, Bangladesh, Myanmar and Sri Lanka. Other locations with significant areas of Teak are parts of tropical America (mainly Costa Rica, Trinidad and Tobago) and tropical Africa (Nigeria, Cote D'Ivoire, Sudan, Ghana, Togo and Benin) (Keogh 1996).

About 95 percent of Rosewood plantations are located in India and Pakistan while Nepal and Bangladesh make up an additional four percent. Small plantations of this species are found in tropical Africa (Nigeria and Burkina Faso).

Table 3: ***Area distribution of major valuable hardwood plantations by region (1995). Areas are in thousands of hectares.***

Species	Region				Total Area (10^3 ha)	%
	Africa	Asia	Oceania (excluding New Zealand & Australia)	C. America		
Teak	110.0	2 108.0	3.4	33.1	36.5	74
Swietenia spp.	5.5	106.4	33.9	5.5	151.3	5
Dalbergia spp.	2.8	623.3	0	0	626.1	21
Total Area (ha.)	118.3	839.7	37.3	38.6	1033.9	100
%	4	94	1	1	100	

Source: FAO, 2000. * Area in thousands of hectares and due to rounding off, sums may not tally.

The largest introduced mahogany (*Swietenia macrophylla*) plantations are located in Indonesia and Fiji, which together make up about 80 percent of the established area (FAO 2000). Other plantations are found in the Philippines (6 percent), Solomon Islands (3 percent) and Sri Lanka (2.5 percent). There are some relatively small plantations of African mahogany (*Khaya senegalensis*) in some African countries including Benin, Cameroon, Nigeria and Cote D'Ivoire (FAO 1997).

6. GLOBAL OWNERSHIP OF PLANTATIONS

In the Southern Hemisphere, there is a trend away from government development and ownership of plantations to ownership by processing companies, landowners and individual investors. The plantation ownership in South America is mostly private. Parts of Asia, on the other hand, maintain high levels of public ownership and this is likely to continue due to different political objectives (Table 4). Private ownership of plantations is, however, on the increase in all regions.

Table 4: ***Global industrial plantations at a glance by FAO statistical regions***

	Africa	North Central America	South America	Asia	Europe Former USSR	Oceania	World
Industrial Plantation Area (10^3 ha.)	3.9	24.2	7.8	30.1	47.1	2.8	115.9
Total Effective Area (10^3 ha.)	1.4	24.2	7.5	11.2	47.1	2.5	93.9
Plantation area suitable for commercial wood production (%)	36	100	96	37	100	89	81
Species planted (%softwood:%hardwood)	50:50	98:2	53:47	31:69	88:12	90:10	71:29
Ownership levels (%public:%private)	n.a.	60:40	0:100	n.a.	50:50	33:67	n.a.

Source: Commonwealth of Australia 1999 ***n.a : not available***

7. ECONOMIC FACTORS

For more details on economic issues see FAO (2000) and Keogh (1996).

For valuable hardwoods the competitive advantage results from having high growth rates without detrimental effects to wood quality, high profits and a large market share. Key factors are available land at reasonable costs, high plantation yields, well-developed plantation practices, a skilled labour force, strong research backing, the existence of a viable market, and a strong supporting infrastructure to ensure cost-effective delivery to markets.

To encourage valuable hardwood species for the niche or speciality markets they should be given separate attention from commodity species. The economic conditions necessary to develop valuable hardwood plantations, with a view of offsetting timber demand pressures on the natural forests, include:

a) *Return on Investment*. This is dependent on discount rate, capital costs (including land value), production costs, length of investment, plantation yield, future price levels, and the effect of taxes and/or incentives.

Rotation lengths need to be relatively long so that these slow growing can produce large valuable logs. Financial resources are therefore locked up without returns over long periods. It is therefore difficult for private finance, especially the local investors in tropical countries, to be wooed into such ventures without the necessary incentives that will ensure acceptable profitability. Brown (FAO 2000) states that "In many cases incentives have provided an important stimulus to planting, and may have been a more important driver than expectations of future prices and earnings".

Growth rates and transport costs are often the critical factors in plantation profitability. Acceptable profitability, therefore, results from growing high-quality genetic material on fertile sites with good silviculture and having the plantation close to processing facilities as possible. Using the best methods of management is essential. The production of value-added items, instead of exporting unprocessed logs, may further enhance returns.

An assured adequate future market price for the plantation wood at harvesting is necessary to sustain investor interest in replanting, as well as encourage new growers.

Plantation management should ensure that risk of pests, diseases and fire are minimised or prevented. Similarly, it is important that these valuable plantations are insured against such intangibles as fire and windstorms.

b) *Government Policy*. The appropriate role of government in plantation forestry remains an issue of debate, regardless of the level of public ownership. The various responsibilities of government have included fostering an environment conducive to investment in tree growing; the regulation of industry and land use; environment and other community values (Kanowski 1997). The establishment of a secure and stable policy (e.g. with respect to land tenure/tree tenure) and financial environments for plantation investment, is essential for the sustenance of investor confidence.

c) *The capture and retention of niche markets.* Due to public perception of tropical deforestation tropical hardwoods have lost some of their appeal in some environmentally sensitive markets. Therefore, it is important that plantations are economically viable, environmentally appropriate, and socially desirable. Land tenure aspects – both legal and customary – often need to be considered. Environmental or 'green' certification may also assist in maintaining and developing markets.

It is essential that high-grade hardwood plantations are established on a relatively large scale and planned for a continual supply of similar quality timber. There should also be the possibility for producing some large dimension material, if the market requires this, as timber value is usually related to log size.

Decorative timbers are also subject to swings in consumer fashion. Choice of versatile species is important to counter this effect.

There are considerable barriers to expanding the market share for luxury or valuable hardwoods. Plantation grown teak may be exception to this rule (FAO 2000). Further, many supply characteristics for valuable hardwoods are not widely understood, so market research and development is required to capture and hold markets. The maintenance of high quality standards from production to marketing is essential.

Experience in Brazil and elsewhere have indicated that plantation establishment efforts should have direct links to an existing or planned end-user.

8. DEMAND FOR VALUABLE HARDWOODS

Demand for hardwood from tree plantations is predicted to intensify as worldwide commercial and political pressures continue to restrict the traditional logging of natural forests. Sawn hardwood is an important product both for structural and appearance type applications. Globally the important uses are furniture (29 percent), mouldings (20 percent), structural housing (18 percent), flooring and panelling (8 percent), and decorative (8 percent)[3]. Production and export of tropical wood products, such as plywood and veneer, have grown two to threefold in the last 30 years[4].

Japan is the third hardwood consumer after China and Indonesia, especially with respect to their wooden house market, which uses both structural and decorative timber. Substitution with softwood lumber in many construction uses has led to decline in the actual consumption of sawn hardwoods in Japan[3].

North and Central America represent the second largest hardwood market in the world. The market is however extremely competitive and has a good ongoing supply of high quality locally grown hardwoods and is currently a net exporter. The mainland USA will probably continue to be confined to an importer of specialist or niche hardwood[3].

Traditionally, Europe has been a large importer of hardwood lumber but it is expected that this region will become increasingly self sufficient as a result of maturing post-war plantings,

[3] See 'Market study for eight Hawaii-grown woods' on www. Hawaii-forest.org/execsum.html

[4] Critical consumption trends and implications : wood fibre consumption and the world's forests. World Resources Institute www.org/critcons/

coupled with regeneration following large wartime fellings[3]. A study of the markets for tropical hardwoods in Europe indicates that their demand for furniture and construction are relatively price inelastic. Future levels of consumption are likely to be affected by non-price factors, such as fashion, anti-tropical timber campaigns, and general economic conditions, rather than by the price of tropical timbers (FAO 1991).

Other effects on hardwood consumption include the use of reconstituted panels such as medium density fibreboard (MDF) in furniture manufacture, supply changes including log export bans, and the potential effect of certification[3].

There is some evidence of a shift away from veneer-based panels towards composite panels. This trend coupled with relative price changes, technology and consumer concerns over tropical deforestation may combine to reduce demand in the future. A chemical process developed in the Netherlands has proved successful in upgrading softwood into a product with all the attributes of tropical hardwood species[4]. It is not apparent as to the extent such technology can imitate the characteristics of hardwoods. Alf Leslie (1999) has argued the mass markets for specialty and decorative timber products can be met through technological developments that eliminate the technical differences between softwoods and hardwoods and reproduce the decorative figures through overlays. But beyond the mass market, only the genuine article will do.

The main alternative to solid wood for value added end uses such as mouldings, doors, flooring, furniture components and laminated products (e.g. plywood), is reconstituted panels with veneer coating. Of these MDF is the greatest competitor due to its working properties, dimensional stability, ability to accept coatings and reasonable cost. Solid wood is losing ground to MDF throughout the Asia-Pacific region. However, despite its expected lower overall market share, the reducing availability of high quality solid hardwoods is expected to provide growth opportunities for producers[3].

The structure of the forest products sector is expected to change given the expected changes in raw material supply. Hence, the proportion of products requiring large diameter logs as raw materials (e.g. sawnwood and plywood) will start to decline, while the proportion of products able to utilise small diameter timber and fibre, such as paper, board and non-veneer wood based panels (e.g. particleboard and MDF) will rise.

A survey of the subscribers of the ITTO Tropical Timber Market Information Service with respect to the likely trends in the tropical timber market over the next 5 to 10 years indicates that *technical properties* and *appearance* were the main factors that give tropical hardwoods a competitive advantage. The study also shows that temperate hardwoods followed by non-wood products, provide the toughest competition to tropical hardwoods in the furniture sector while the toughest competition in the joinery sector comes from softwoods followed by temperate hardwoods (Adams 2000).

Despite a forecast in the increase in the total hardwood production in the world over the next 20 years, demand is expected to increase at a faster rate, and the amount of hardwood suitable for sawing and veneer production is expected to fall. This is especially so in the Asia-Pacific region[3].

9. ESTIMATE OF CURRENT AND FUTURE SUPPLIES

Estimates for potential supplies of valuable tropical hardwoods grown in plantations were made based on FAO data for industrial plantations derived by FAO (2000). The assumptions and methodology for these conservative estimates are given in Appendix 2. The base tables are in Appendices 3 and 4. These estimates are made for the three main species, teak, mahogany and rosewood and for two assumed rotation lengths, 50 and 70 years. The trends up to year 2020 should be valid as the trees are already planted, although the estimates themselves are rough (Table 5).

Table 5: ***Yield projections – valuable hardwood plantations***

Total Area (1995 – 10^3 ha)	**Age (1995 – Years)**	**2000**	**2010**	**2020**
		10^3 m^3		
722	5			
1 053	10			
679	15			
248	20			
136	25		35 927	40 529
101	30		28 590	31 712
54	35	14 382	16 225	17 751
22	40	6 221	6 900	7 463
11	45	3 405	3 725	3 990
2.6	50	801	867	921
1	≥55	437	468	494
1308.6	-	**1646**	**2063**	**2408**

Total Yield ≥50 years.	4 643	23 125	72 241
Yield less thinnings	2 322	11 563	36 121

Yield ≥70 years	0	468	4 911
Yield less thinnings	0	234	2 456

NB: Due to rounding offs, sums may not tally

The three main species, teak, *Swietenia* and *Dalbergia* are concentrated in four main regions. These are Africa (mainly Nigeria and Sudan for teak), Asia (mainly Bangladesh, India, Indonesia, Myanmar, Pakistan and Philippines for all three species), "Other Oceania" (mainly Fiji for *Swietenia*) and Central America (mainly Costa Rica for teak).

Table 5 illustrates that any significant increase in supplies from plantations of these valuable species would be felt from the year 2020 onwards (i.e. after 20 years) and only if the rotation is reduced to below 70 years. Otherwise any impact would be realised much later as has been speculated in the literature.

The results obtained must be interpreted in the light that the derived age-class distribution, areas and growth rates may be different from reality. Better estimates may be obtained when more realistic data becomes available.

10. POTENTIAL EFFECTS ON SUPPLIES FROM NATURAL FORESTS

Valuable hardwood plantations have the potential of satisfying an appreciable proportion of the demand for forest products in addition to reducing the need to exploit the natural forest. However, when deforestation is being driven by demand to open new forest lands for farming, plantations will not help to reduce the pressure.

It has been argued that if plantations supply large amounts of quality timber efficiently, they may undermine the value of natural forest stands and lead to their more rapid destruction. Based on this, it has been suggested that a sensible balance be struck between production from natural forests and plantations where the former exist. Hence, where possible, natural forests and plantations should be managed on a complementary basis (Grainger 1993).

As the fastest growing economic region in the world, the pressures on Asia's forest resources are enormous. Land cleared for agriculture supplies timber on a one-time basis. These loses to the land base will make it very difficult for many of the countries in Asia to maintain their current supply into the next century. It is anticipated that the implementation of sustainable forest management practices will avoid a supply crisis in the region and that supplies from new plantations will start to appear before 2020 (Ministry of British Columbia 1994). However, the latter will only occur if rotations are reduced (Table 5).

It is estimated that after the year 2000 timber reserves in the natural forests in Asia could become so depleted that exports will decline and supplies would be unable even to meet domestic needs. This trend is demonstrated in Figure 1. Grainger (1993) states that "if the bulk of tropical hardwood is going to come from tropical rainforests in the foreseeable future, it is essential to reverse the bias against natural forest management and direct more resources to make this more sustainable".

High-grade hardwood plantations account for only 9 percent of the total tropical timber plantation area (FAO 2000) and less than 1 percent of all hardwood production (FAO 1997). That share is unlikely to rise above 5% in the next 30 to 40 years (Grainger 1993). Higher tropical hardwood prices will be needed to encourage a rise in the rate of planting. This is likely as supply shifts occur from low-production-cost natural forests in South East Asia to the higher-production-cost ones in Latin America and Africa.

As discussed earlier, Asia has the largest area of the valuable hardwoods plantations especially with regards to teak. Due to the timing of previous tropical hardwood plantings and the delays caused by the long 70-year rotations of teak plantations established in Asia in the last few decades, overall plantation production could dip in the early part of this century. Any new high-grade hardwood plantation will take at least 40 years to mature. Hence any major initiative to expand their area significantly will not be felt in the next 30 to 40 years.

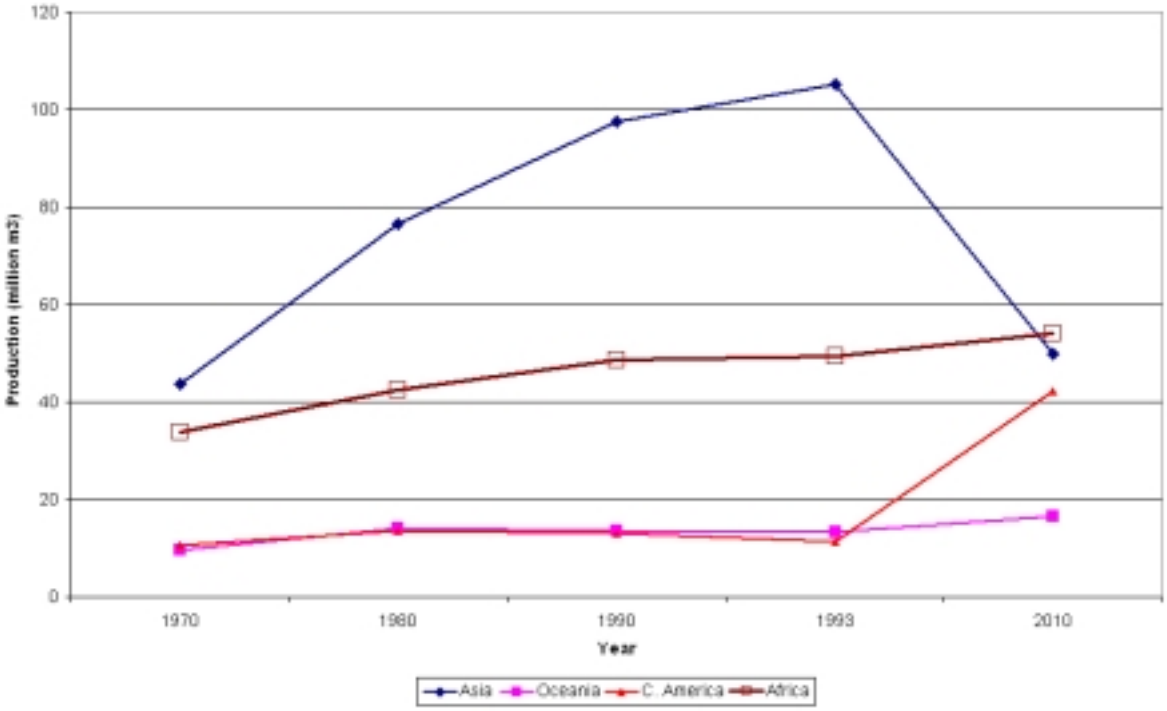

Figure 1: Global Industrial Hardwood Production from Natural and Plantation Forests from "Valuable Hardwood" Regions.

11. CONCLUSIONS

The evidence obtained from the study indicates that three valuable hardwood plantations that are in significant quantities on the ground as at 1995 are Teak, Rosewood and *Swietenia* species. They make up about 10 percent of the global hardwood plantations and over 90 percent of such plantations are in Asia. Teak forms about 74 percent of the area of the main three valuable hardwoods, followed by the *Swietenia* species with 21 percent.

Forecasts indicate that any significant production from these plantations when grown on a 70-year rotation would be felt long after year 2020. Estimated yields in year 2020 at rotations of 50 years and 70 years would be about 70 000 m^3 and 5 000 m^3, respectively.

As any newly established valuable plantation will take at least 40 years to mature, any major initiative in the formation of valuable hardwood plantations cannot be felt for a long time. The overall production of these timbers is expected to dip in the early part of this century due to the long 70-year rotations used for teak, associated with the age structure of Asian stands. Thus the amount of hardwood suitable for sawing and veneer production is expected to fall especially in the Asia-Pacific region over the next 20 years, despite a forecasted increase in the total hardwood production in the world during that period.

The success of valuable hardwood plantation programmes to take pressure off the natural forests is very much dependent on the links to an assured future. They are generally used in high-value niche or speciality markets. As such they are characterised by swings in consumer

fashion and there are considerable barriers to their expansion. Some of the supply characteristics of the valuable hardwoods are also not common knowledge. Other factors that may affect the demand for quality hardwoods include anti-tropical timber campaigns, substitution with “upgraded” softwoods, temperate hardwood supplies, and competition from composite panels such as the medium density fibreboard and non-wood products.

Future promotion of quality hardwood plantations needs to emphasise choosing species with versatile end-uses, market research and development to hold on to the niche markets, and maintaining high standards from production to marketing. Careful site selection, use of high quality planting materials of superior genetic origin, and good silviculture are important, and programmes should be economically viable, environmentally appropriate and socially desirable. Incentives may also be necessary to stimulate private investment because of the long rotations.

Even though valuable hardwood plantations have the potential to reduce the pressure on natural forests, they will not prevent deforestation due to agricultural encroachment. The supply of large quantities of high value timber could perhaps undermine the value of natural forest stands and so lead to more rapid destruction. Hence it is advisable, where possible, to manage plantations and natural forests on complementary basis.

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Appendix 1: Trade and botanical names of cited timbers

AFRICAN TIMBERS

TRADE NAME	BOTANICAL NAME
Abura	*Mitragyna ciliata*
Afromosia	*Pericopsis elata*
Aningre/Mukali	*Aningeria spp.*
Avodire	*Turraeanthus africana*
Azobe	*Lophira alata*
Bosse	*Guarea spp.*
Framire	*Terminalia ivorensis*
Ilomba/Calabo	*Pycnanthus angolensis*
Iroko	*Chlorophora excelsa*
Kosipo	*Entandrophragma candollei*
Koto	*Pterygota spp.*
Limba/Afara/Frake	*Terminalia superba*
Mahogany	*Khaya spp.*
Makore	*Tieghemella heckelii*
Mansonia/Bete/Mongoy/African Walnut	*Mansonia altisssima*
Niangon	*Tarrietia utilis*
Obeche/Wawa/Ayous	*Triplochiton scleroxylon*
Okoume	*Aucoumea klaineana*
Sapele	*Entandrophragma cylindricum*
Tiama	*Entandrophragma angolense*
Utile/Sipo	*Entandrophragma utile*

ASIAN TIMBERS

Kapur	*Dryobalanops aromatica*
Keruing	*Dipterocarpus spp.*
Lauan	*Shorea spp.*
Meranti/Dark Red Seraya	*Shorea spp.*
Meranti/Light Red Seraya	*Shorea spp.*
Meranti/White Seraya	*Shorea spp.*
Ramin	*Gonystylus spp.*
Teak	*Tectona grandis*

SOUTH AMERICAN TIMBERS

Brazilian Mahogany	*Swietenia macrophylla*
Greenheart	*Ocotea rodiaei*
Purpleheart	*Peltogyne spp.*
Rosewood	*Dalbergia spp.*

Appendix 2

Methodology for estimating potential harvesting volumes of valuable tropical hardwood plantations

These estimations of the current and future supplies from valuable hardwood plantations have been calculated by:

- Using the standardised age-class structures for industrial plantations derived by FAO 2000) and Pandey (1995) data on mean annual increment (MAI) data for teak in Java and India. The MAI data includes thinning yields and were the average for age 70 and 80 years. The MAI of teak has been used, as this species constitutes about 75% of the three valuable species that are under consideration (see section 5).
- Fitting trend lines to the MAI data. The MAI trend line for the poorest sites was utilised to account for poor stocking and mortality in many stands in both Indonesia and India (Pandey 1995). The equation used was MAI = -2.8918 ln(age) + 17.285 (R^2 = 0.74).
- Assuming rotations of 40 and 70 years and making projections for years 2000, 2010 and 2020. It was also assumed that the valuable hardwood plantations that have been planted since 1995 would not mature within the timeframe under consideration.
- Assuming that the age-class distribution for the three species follows the pattern in the four main regions that have them in significant quantities, as shown in Appendix 4a. The countries used with respect to the four regions and their respective age-class distributions can be found in Appendix 3.
- Using for the three valuable hardwood species in question using their respective total areas as the percentage distribution of the age-classes in Appendix 4a to construct the volumes shown in Appendix 4b.

Appendix 3:Standardised industrial plantation age-class by "valuable hardwood" regions (from FAO 2000)

Country &Region	Major Val. Hdwd Species	<1946	1946-1950	1951-1955	1956-1960	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	Total Area
Nigeria	Teak	51	95	254	1,487	2,059	6,798	18,999	34,086	24,154	14,350	16,018	118,351
Sudan	Teak	640	3,803	3,902	6,841	7,029	5,209	4,624	4,831	9,107	8,809	9,074	63,869
		691	**3,898**	**4,156**	**8,328**	**9,088**	**12,007**	**23,623**	**38,917**	**33,261**	**23,159**	**25,092**	**182,220**
AFRICA		**300,880**	**103,360**	**117,199**	**139,660**	**198,950**	**287,757**	**330,424**	**436,053**	**517,180**	**567,903**	**598,947**	**3,598,313**
													0
Bangladesh	Teak, Dalbergia	0	0	510	1,659	6,029	12,472	6,699	24,211	43,636	27,432	30,622	153,270
India	Teak, Dalbergia	0	0	8,102	13,166	61,408	131,009	162,474	213,099	804,444	1,734,449	916,055	4,044,206
Indonesia	Teak, Swietenia	0	1,769	14,557	30,008	52,710	80,605	114,168	301,358	715,806	669,748	642,952	2,623,681
Myanmar	Teak	1,238	12	53	86	938	4,267	2,925	9,576	52,477	73,512	63,861	208,945
Pakistan	Dalbergia	0	0	0	208	914	1,537	7,952	3,859	4,444	4,274	4,210	27,398
Philippines	Sweitenia	0	0	0	1	32	86	252	2,608	11,084	23,400	41,745	79,208
		1,238	**1,781**	**23,222**	**45,128**	**122,031**	**229,976**	**294,470**	**554,711**	**1,631,891**	**2,532,815**	**1,699,445**	**7,136,708**
ASIA		**3,183**	**662,908**	**1,723,729**	**1,808,078**	**2,079,773**	**2,065,013**	**2,025,342**	**2,554,336**	**5,973,199**	**9,415,072**	**13,491,616**	**41,802,249**
Other Oceania	Swietenia	1,399	687	958	1,278	4,022	9,303	18,873	21,931	22,938	21,044	29,383	131,816
		1,399	**687**	**958**	**1,278**	**4,022**	**9,303**	**18,873**	**21,931**	**22,938**	**21,044**	**29,383**	**131,816**
OTHER OCEANIA		**28,839**	**14,165**	**19,741**	**26,345**	**82,882**	**191,730**	**388,964**	**451,974**	**472,735**	**433,698**	**605,573**	**2,716,646**
													0
Costa Rica	Teak	0	0	40	75	75	600	800	1,130	1,900	43,890	43,890	92,400
		0	**0**	**40**	**75**	**75**	**600**	**800**	**1,130**	**1,900**	**43,890**	**43,890**	**92,400**
USA		0	0	0	0	0	1,560,000	2,600,000	2,835,000	3,775,000	3,786,250	3,831,250	18,387,500
N&C AMERICA		**0**	**0**	**54**	**1,190**	**1,734**	**1,574,195**	**2,626,984**	**2,885,591**	**3,849,694**	**3,922,519**	**4,033,957**	**18,895,918**
N&C Am. Less USA		**0**	**0**	**54**	**1,190**	**1,734**	**14,195**	**26,984**	**50,591**	**74,694**	**136,269**	**202,707**	**508,418**

Source: FAO, 2000

Appendix 4:

4a. - General age-class distribution in "valuable hardwood" regions (areas in hectares)

Age-Class (1995)	Africa	Asia	Other Oceania	C. America	TOTAL	%
0-5	25,092	1,699,445	29,383	43,890	**1,797,810**	23.83
6-10	23,159	2,532,815	21,044	43,890	**2,620,908**	34.75
11-15	33,261	1,631,891	22,938	1,900	**1,689,990**	22.40
16-20	38,917	554,711	21,931	1,130	**616,689**	8.18
21-25	23,623	294,470	18,873	800	**337,766**	4.48
26-30	12,007	229,976	9,303	600	**251,886**	3.34
31-35	9,088	122,031	4,022	75	**135,216**	1.79
36-40	8,328	45,128	1,278	75	**54,809**	0.73
41-45	4,156	23,222	958	40	**28,376**	0.38
46-50	3,898	1,781	687	0	**6,366**	0.08
>50	691	1,238	1,399	0	**3,328**	0.04
TOTAL	**182,220**	**7,136,708**	**131,816**	**92,400**	**7,543,144**	**100.00**
%	**2.4**	**94.6**	**1.7**	**1.2**	**100**	-

Source: FAO, 2000

4b. - Derived age-class distribution for "valuable hardwood" species (areas in hectares)

Age-Class (1995)	%	Teak	Swietenia	Dalbergia	Total
0-5	23.83	537,176	36,040	149,204	**722,420**
6-10	34.75	783,114	52,540	217,514	**1,053,168**
11-15	22.40	504,960	33,878	140,256	**679,094**
16-20	8.18	184,263	12,362	51,180	**247,806**
21-25	4.48	100,923	6,771	28,032	**135,726**
26-30	3.34	75,262	5,049	20,905	**101,216**
31-35	1.79	40,402	2,711	11,222	**54,334**
36-40	0.73	16,377	1,099	4,549	**22,024**
41-45	0.38	8,479	569	2,355	**11,402**
46-50	0.08	1,902	128	528	**2,558**
>50	0.04	994	67	276	**1,337**
TOTAL	**100.00**	**2,253,852**	**151,214**	**626,020**	**3,031,086**
%		**74**	**5**	**21**	**100**

Source: FAO, 2000

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