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Forest Plantations Working Papers

TEAK (Tectona grandis) IN CENTRAL AMERICA

Based on the work in 1998 of
R.V. De Camino
M.M. Alfaro
L.F.M Sage
Consultants

Edited by M. Varmola

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Forest Resources Development Service
Forest Resources Division
Forestry Department

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Comments and feedback are welcome.

For further information please contact:

Mr. Jim Carle, Senior Forestry Officer (Plantations and Protection)
Forest Resources Development Service
Forest Resources Division
Forestry Department
FAO
Viale delle Terme di Caracalla
I-00100 Rome (Italy)
e-mail: Jim.Carle@fao.org

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ABSTRACT

This report is an output of the project *Hardwood Plantations in the Tropics and Subtropics* (GCP/INT/628/UK), funded by the United Kingdom and executed by FAO. The overall aim of this project was to contribute to regional and global planning of timber (specifically hardwood timber) supplies in the medium-term. This study covered the case study of teak in Central America.

In most Central American countries the plantation process began at the end of the 1970s and was promoted by various international co-operation projects that did research during the 1980s. In Central America, total planted area was approximately 225,000 ha in 1998, whereby 40,815 ha corresponded to teak plantations (18% of the total planted area). The use of teak in planting projects increased at the beginning of the 1990s. From the total area planted with teak, 58% were planted in Costa Rica, 32% in Panama, 6% in El Salvador and 4% in Guatemala.

When growing teak several aspects have to be considered. Temperature limits are an average of 25 and 28 degree Celsius. Teak grows well when annual rainfall is between 1,250 and 2,500 mm. The best yields have been obtained under 600 meters above sea level. Teak grows well in sandy and slightly clay, fertile, deep, well drained soils, with a neutral or slightly acid pH. It is not recommended to plant teak in steep slopes; compacted or shallow soils and; heavy textures.

Important elements in teak production in Central America are the reforestation incentive systems. Teak expansion will depend from the availability of financial resources that originate mostly from: PES (Payment for Environmental Services), different incentives and foreign investments.

In Costa Rica technological packages have been developed for establishment and managing teak. In the best sites, under intensive management plans, in rotation from 20 to 25 years, the species can have a MAI of 20 to 25 m^3/ha/year. It is foreseen that well managed plantations will produce a total volume of 15 - 20 m^3/ha/year, and 10 – 15 m^3/ha/year of commercial industrial volume.

It is estimated that at least 100,000 ha more could potentially be planted with teak in Central America: 25% located in Guatemala, 25% in Nicaragua, 20% in Costa Rica, 15% in El Salvador and 15% Panama.

Recommendations are given to create a Central American Teak Growers Association; to invest in a Central American genetic improvement programme; to publish bulletins; to develop portfolios; to associate teak growers with the Teak 200 initiative; and to train people in the industrial aspects of teak production.

ACRONYMS

ANARAP	Asociación Nacional de Reforestadores de Panamá
BMI	Multisector Bank of Investments
CACH	Centro Agrícola Cantonal de Hojancha
CAF	Certificado de Abono Forestal (Certificate of Forestry Payment)
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza (Tropical Agriculture Research and Higher Education Center)
CCAD	Comisión Centroamericana de Ambiente y Desarrollo
CCF	Cámara Costarricense Forestal (Costa Rican Chamber of Forestry)
CENTA	Centro de las Nuevas Tecnologias del Agua
CIF	Cost, Insurance, Freight
CIFOR	Center for International Forestry Research
FB	Forest Bonus
FIAES	Fondo Iniciativa para Las Américas, El Salvador
FOB	Franco a Bordo
FONAES	Fondo Ambiental de El Salvador
FONAFIFO	National Forest Fund
IICA	Instituto Interamericano de Cooperación para la Agricultura (The Inter-American Institute for Cooperation on Agriculture)
INRENARE	Instituto de Recursos Naturales Renovables (The Institute of Renewable Natural Resources)
IRR	Internal Rate of Return
ITCO	Instituto de Tierras y Colonización (Institute of Lands and Colonization)
ITTO	International Tropical Timber Organization
MAG-ISTA	Ministerio de Agricultura, Instituto Salvadoreño de TransformaciónAgraria (Ministry of Agriculture, Salvadorian Institute for Agrarian Reform)
MAI	Mean Annual Increment
NPV	Net Present Value
PES	Payment for Environmental Services
PSP	Permanent Sample Plots
RNT	Recursos Naturales Tropicales
UNDP	United Nations Development Programme

CONTENTS

1 TEAK IN CENTRAL AMERICA

The first report on introduction of teak seed in Central America is from 1926, when it was planted in the Summit Botanical Garden of the former Channel Zone (Gutiérrez and Cordovéz 1978, mentioned by Morán 1998). According to the same authors, the seed came from Colombo, probably from the Paranaeniya Botanical Garden (Weidema 1966).

This place of provenience, that has been called Ceylon - Panama or Sri Lanka - Panama, gave way to teak plantations located in farms dedicated to the banana production of the Chiriquí Land Company. Furthermore, the Good Year Company, dedicated to establish rubber plantations, also planted teak.

Gutiérrez and Cordovéz (1978), mentioned by Morán (1998), report the shipment of seeds from the Summit Botanical Garden to 11 Central and South American countries and the Caribbean during the period between 1936-1948. The United Fruit Company purchased the seed in February of 1943. Records from the Botanical Garden indicate a second shipment to R.A. Nichols, at the IICA, Turrialba, in April of 1943. By 1967, the Forest Development Project in select zones directed by FAO/UNDP/ITCO used seeds from five places of origin: Honduras, Panama, Trinidad and Tobago, Quepos (Costa Rica) and Nicoya (Costa Rica).

The date of introduction of the first teak seed in El Salvador is unknown. A more detailed reference mentioned by Keogh (1997b) places the introduction of seeds in 1950, originally from Puerto Rico and Honduras. Reports do not specify if teak seeds actually came from both countries or from one of them. Other versions indicated that the first seeds came from Burma and Trinidad (Zambrana 1998). Nevertheless, it is possible that the seed from Honduras came from the trees planted with seed from Panama and any other source between 1942 and 1943.

There are no reports, in Honduras and Nicaragua, of commercial teak plantation. Guatemala reports a planted area no bigger than 2,000 hectares.

2 REFORESTED AREA IN THE REGION

In Central America, total planted area is approximately 225,000 ha, whereby 41,000 ha correspond to teak plantations (18.1% of the total planted area). The use of teak in planting projects increases at the beginning of the 1990s. As shown in Table 1, from the total area planted with teak, 57.5% has been planted in Costa Rica, 32.2% in Panama, 6.1% in El Salvador and 4.2% in Guatemala.

In most Central American countries the plantation process began at the end of the 1970s and was promoted by various international co-operation projects that did research during the 1980s. For example, the MADELEÑA project did it with multiple use species. Table 2 presents a list of the main species used in reforestation projects in Central America. Appendix 1 presents the total area planted in Guatemala, Panama and Costa Rica.

Table 1. Total reforested area in Central America and planted area with teak (Tectona grandis)

Country	Total Area (ha)	Total Reforested Area (ha)	Reforested Area with teak (ha)	Period (years)
Belize	2,143,500	2,245 [1]	Na	Na
Guatemala	10,889,000	12,444 [2]	1,717 [2]	1990-1995
El Salvador	2,097,000	6,584 [3]	2,488 [8]	Until 1996
Honduras	11,249,200	8,647 [4]	Na	Until 1995
Nicaragua	12,142,800	32,754 [5]	Na	1993-1996
Costa Rica	5,113,300	135,498 [6]	23,475 [6]	1979-1997
Panama	7,551,700	26,724 [7]	13,135 [7]	Until 1997
Total	**51,186,500**	**224,896**	**40,815**	

Source: [1] Toumasjukka (1996), [2] INAB (1998), [3] INCAE (1998), [4] SEGEPLAN *et al* (1996), [5] CAD *et al* (1997), [6] MINAE (1998), [7] INRENARE (1998), [8] Zambrana (1998), June, 1998.
Na = not available

Table 2. Main species used in reforestation projects in Central America

Country	Main Species
Guatemala	*Pinus caribaea, P. tenuifolia, P. oocarpa, P. Maximinoi, P. pseudostrobus, Cupressus lusitanica, Eucalyptus camaldulensis, Gmelina arborea, Tectona grandis, Cedrela odorata* [1]
El Salvador	*Tectona grandis, Pinus caribaea, Eucalyptus* sp., *Cupressus lusitanica*
Nicaragua	*Gmelina arborea, Eucalyptus camaldulensis, E. urophylla, Gliricidia sepiun, Lysiloma seemanii, Simarouba amara* [2]
Honduras	*Eucalyptus camaldulensis, E. grandis, E. teriticornis, Gliricidia sepium, Gmelina arborea, Leucaena leucocephala* [1]
Costa Rica	*Gmelina arborea, Tectona grandis, Cordia alliodora, Bombacopsis quinatum, Eucalyptus deglupta*, other natives.
Panama	*Tectona grandis, Pinus caribaea, Eucalyptus* spp.
Belize	Not available

Source: INCAE (1998), [1] INAB (1998), [2] Galloway (1997) , June, 1998.

3 PHYSIOLOGICAL AND TECHNICAL ISSUES

3.1 Bio-ecological requirements and growth

Most of the data of the bio-ecological requirements of teak in Central America comes from the experience of, and the studies done, in Costa Rica, and a little from Panama and El Salvador. Vásquez and Ugalde (1995) identified the following aspects in 14 sites located of the Guanacaste province, in the North Pacific region of Costa Rica,

- Best sites for teak are located in areas with medium to flat slopes, at the base of a mountain or in valleys and, in areas where the soil's depth is 90 cm or more. These sites allow more space for root growth, and have more water and nutrients available, with a calcium content higher than 10 meq/100 ml of soil in the first stratum.
- Sites classified as highly productive have rainfalls higher than 2000 mm/year. It is important to mention that the evaluated zone is the Dry Pacific of Costa Rica, with a 3 - 5 dry month period.
- Worst sites for teak are those affected by strong winds, soils area shallower than 80 cm, with high iron and low calcium contents. These areas are generally located in summits, in over-pastured soils, with rainfalls lower than 1800 mm/year.
- Plantations with a dominant height of 21.7 meters or more, at 10 years of age (base age), are classified as highly productive. Plantations with a dominant height lower than 18.1 m, at the same age, are classified as low productive.

Table 3 shows the increments in diameter, height, basal area and volume for high, middle and low productivity sites.

Table 3. Yields for Tectona grandis in Guanacaste, Costa Rica

Range	MAI-dbh (cm/year)	MAI-Height (m/year)	G (m^2/ha)	MAI-G (m^2/ha/year)	MAI-Volume (m^3/ha/year)
High	2.0 or more	2.0 or more	20 or more	2.5 or more	18 or more
Middle	1.6-1.9	1.6-1.9	15.1-19.9	1.6-2.4	12.1-17.9
Low	1.5 or less	1.5 or less	15 or less	1.5 or less	12 or less

Source: Vásquez and Ugalde (1995)

Vallejos (1996), in the same zone that Vásquez and Ugalde (1995) studied, determined that calcium content (0 - 20 cm of depth) influences significantly the yield of teak. He found that 18 cmol/l and more are adequate for good teak development. When soil present lower quantities, it is recommended to correct it with lime applications. He also determined that water deficit influences negatively the development of teak.

In this study, a Site Index prediction model was developed:

$$Ln(SI) = Ln(Hdom) + 1.8253 * ((1/Age^{\wedge 0.5162}) - (1/Base\ Age^{\wedge 0.5162}))$$

Where:

Ln = the natural logarithm
SI = site index
Hdom = dominant height (meters)
Base age = 10 years

Furthermore, a model relates the SI to the soil calcium content (Ca) and water balance (DEFHID):

$$SI = (25.432112 - 2.695521 * DEFHID + 0.268667 * Ca)/0.794$$

Where:

DEFHID = the number of months with less of 100 mm of rainfall.
Ca = the content of calcium (cmol/liter)

Vallejos (1996) developed a five class production/yield index for that area. Table 4 displays the information. Table 5 summarizes the conditions for good teak growth in Costa Rica.

Table 4. Yield and production classes for Tectona grandis in Guanacaste, Costa Rica

Variable	Unit	Marginal	Low	Middle	High	Excellent
MAI-dbh	cm/year	1.90 or less	1.91 - 2.49	2.50 – 3.01	3.02 - 3.8	3.81 or more
MAI-H	m/year	1.63 or less	1.64 - 2.32	2.33 – 3.14	3.15 - 4.05	4.06 or more
MAI-G	m^2/ha/year	0.97 or less	0.97 - 2.04	2.05 – 2.77	2.78 - 3.73	3.74 or more
MAI-Vol	m^3/ha/year	3.20 or less	3.21 - 11.83	11.84 – 18.00	18.01 - 26.57	26.58 or more

Source: Vallejos (1996)
Vol = total volume with bark in m^3

In Central America, teak has been planted in the dry forest zone as well as in the humid forest. Given the wide range of climatic, edaphic and topographic conditions in which it has been planted, there is enough experience to indicate the conditions under which it is more likely to obtain better growth and yields.

Ugalde (1997) indicates that, with the experience in Central America, the following aspects have to be considered:

- Temperature: The limits are an average of 25 and 28 degree Celsius, classified as good. Outside of those temperatures, the species does not grow well.
- Rainfall: Teak grows well between 1 250 and 2 500 mm/year. The species requires a 3 to 5 months dry period per year.
- Elevation: In Central America, the best yields have been obtained under 600 meters above sea level.
- Soils: Teak does well in sandy and slightly clay, fertile, deep, well drained soils, with a neutral or slightly acid pH.

- Limiting factors: It is not recommended to plant teak in steep slopes; compacted or shallow soils and; heavy textures.

Table 5. Bio-climatic considerations for planting teak in Costa Rica

Variable	Optimal conditions	Observations **
Temperature (°C)	25 – 28	25
Rainfall (mm)	889 – 3 689	2 500
Rainfall Distribution	At least 3 dry months	
Elevation	0 – 600	Up to 800
Soil	Deep with high fertility	
Texture	Light	Heavy/drainage
Compaction*	Absent	Can be managed
Fertility *	High	High calcium content, neutral pH, low in aluminum
Topography	Flat *(to)* undulated	
Slope *	Under 20%	
Drainage *	Good	Superficial/Internal
Holdridge's Life Zones	Tropical Humid Forest Tropical Dry Forest	Under 800 m above sea level
Winds *	Absent	Limiting

Source: Picado (1997)
*Limiting condition or variable. **Detailed values or specifications.

The MADELEÑA Project established sample plots in all countries. The results are summarized below (Ugalde 1997):

- Honduras: There are reports of a breast height diameter MAI of 2.29 cm/year in the Atlantic Coast and 1.05 cm/year in the north zone, coupled with height MAI's of 1.75 m and 1.0 m, respectively.

Range	MAI-dbh (cm/year)	MAI-Height (m/year)
High	2.5 or more	2.5 or more
Middle	1.51-2.5	1.51-2.5
Low	1.5 or less	1.5 or less

- El Salvador: Some studies indicate an MAI in breast height diameter between 1.6 and 2.5 cm/year and a MAI in height between 0.8 to 2.9 m/year.

Range	MAI-dbh (cm/year)	MAI-Height (m/year)
Excellent	na	2.5 or more
High	na	1.6-2.5
Middle	na	1.1-1.5
Low	na	1.0 or less

na = not available

- Nicaragua: The studies reported a maximum MAI in height of 1.9 m/year and a maximum MAI in diameter of 2.2 cm/year.

Range	MAI-dbh (cm/year)	MAI-Height (m/year)
High	na	2.0 or more
Middle	na	1.0-2.1
Low	na	1.0 or less

na = not available

- Panama: diameter increments of 1.2 and 3.2 cm/year and in height between 0.18 and 3.4 m/year have been reported.

Range	MAI-dbh (cm/year)	MAI-Height (m/year)
Excellent	3.1 or more	3.1 or more
High	2.1-3.0	2.1-3.0
Middle	1.1-2.0	1.1-2.0
Low	1.0 or less	1.0 or less

Flora y Fauna S.A. reported volume MAI increments between 9.3 and 22.9 m^3/ha/year in plantations located in the North Zone of Costa Rica (Table 6). The Flora y Fauna Company has a set of production tables for the different sites of their plantations.

Table 6. Summary of four production scenarios (total and commercial volume) established for Flor y Fauna S. A. (plantation for a 20-year rotation). San Carlos, Costa Rica

Class site	Project	Trees (n/ha)	Diameter (cm)	Height (m)	MAI of Total volume) (m^3/ha	MAI of Commercial Volume (m^3/ha)
Low	Teakwood I	240	28.6	20.2	13.4	9.3
Medium	Teakwood III	240	31.8	22.5	19.8	14.2
High	Teakwood VIa	240	34.5	25.3	25.3	18.5
Maximum	Teakwood VIb	240	37.2	27.3	31.4	22.9

Source: Camacho (1998)

Annual increments in diameter, height and volume in Bosques de Puerto Carrillo were obtained from permanent sample plots. The project information is presented in Appendix 5. Some average parameters obtained from the permanent sample plots are summarized in Table 7.

Table 7. Technical information from Permanent Sample Plots (PSP) of Bosques de Puerto Carrillo's teak plantations. July, 1998

Age (years)	Total Height H_{med} (m)	Average Diameter D_g (cm)	Number Trees N (trees/ha)	Standing Volume V_{tot} (m^3/ha)	Commercial Volume V_{10} (m^3/ha)	Mean Annual Increment MAI V_{tot} (m^3/ha/year)	Mean Annual Increment MAI V_{10} (m^3/ha/year)
3	10.5	10.4	1 111	n.s.	n.s.	n.s.	n.s.
4	12.6	12.7	660	55.2	19.5	23.3	8.2
5	14.2	14.5	660	69.1	34.1	21.4	9.5
6	15.6	16.0	660	83.7	49.6	20.2	10.5
7	16.7	17.3	660	98.3	65.1	19.4	11.2
8	17.6	18.4	440	74.8	53.2	18.8	11.6
9	18.5	19.3	440	83.9	62.8	17.7	11.4
10	19.3	20.2	440	93.4	72.9	16.9	11.3
11	20.0	21.0	440	102.5	82.6	16.2	11.1
12	20.6	21.7	220	55.5	45.8	15.5	11.0

Source: Quirós (1998).
n.s. = non-significant
V_{tot} = Standing volume according to Keogh's formula (1980), $V_{tot} = 0.0359 + 0.000022\ D_g^2 * H_{med} * N$;
V_{10} = Useful volume up to a minimum diameter of 10 cm without bark.

Table 8. Expected teak growth and yield per hectare in a high quality site with minimal management in Costa Rica

Age (years)	Trees (n/ha)	Harvested trees (n/ha)	Diameter (cm)	Commercial Height [a] (m)	Commercial Volume ($m^{3/}$/ha[b])
1	1 300				
4	700	600	12.0		
8	400	200	20.8	11.0	48.59
15	200	200	31.3	14.0	140.04
20	---	200	37.3	14.0	198.87
Total gross volume					387.50

Source: Picado (1997)
[a]: Commercial height up to a diameter of 10 cm with bark;
[b]: Gross commercial volume = $(dbh/100)^2 * 0.7854 *$ Commercial Height *ff; where: ff = estimated form factor of 0.65.

Picado (1997) proposed a plantation management structure and possible yields to be obtained in Costa Rica. According to his projections, after 20 years, the MAI commercial volume will be 19.4 m^3/ha/year (Table 8). Therefore, the structure can be considered representative of the average teak production conditions in the country.

Zambrana (1998) reported preliminary data for young plantations from El Salvador, 214 m^3/ha of commercial log volume (8 cm top diameter) for 25 rotation age. Table 9 shows the proposed thinning plan and commercial volume yields.

Table 9. Preliminary yields estimates for teak in El Salvador

Parameters after thinning						Thinning			Total	
Age (years)	No. of (trees/ha)	Aver. Height (m)	Dbh (cm)	Basal Area (m^2/ha)	Vol. (m^3/ha)	No. of trees/ha	Average Dbh (cm)	Vol (m^3/ha) diameter >8 cm	Basal Area (m^2/ha)	Vol (m^3/ha) >8 cm
0	2200	-	-	-	-	-	-	-	-	-
4	1000	8	10	8	13	1200	6	9	11	22
10	500	15	17	12	50	500	14	30	23	89
17	300	18	24	13	85	200	20	35	33	159
25	190	20	30	14	100	190	27	40	40	214

Source: Zambrana (1998)

3.2 Plantation management system

To produce timber for sawmills, Picado (1997) recommends planting 1,000 – 1,600 trees/ha. In Costa Rica, in a high quality site, the first thinning must be performed between the third and fourth year. About 40 -50% of the total tree number has to be removed. Generally, this thinning does not yield any commercial timber, but it is necessary to eliminate competing, malformed, sick or damaged trees.

Until now, Costa Rica's teak plantations management has been "poor and inadequate". Poor because the owners do not wish "to lose" 400 to 500 trees, that represented an investment during first three to four years, and inadequate because they don't have enough technical knowledge. The result damages the plantation productive potential, reduces the size of the logs and limits the timber supply of better quality logs in the short term.

Martínez *et al* (1994) indicate that 62 % of the forest plantations of small and medium size farmers, with economic support from the State and technical direction from organizations of forest producers, showed management problems (lack of pruning and thinning).

Table 10 presents examples of estimated teak rotation, based on diameter increments values of 1.5 and 2 cm/year. For a 20 years rotation, average diameter at the final cut will be 30 - 40 cm. For a 25 years rotation, average diameter will vary between 37.5 and 50.0 cm. However, it is

important to clarify that it is tantamount a good site selection and timely management to reach the maximum productive potential of the site.

When the diameter increment is equal or bigger than 2 cm/year, the convenient rotation is 20 years, with trees of an average of 40 cm (dbh). Financial analysis shows that rotations of more than 25 years presented IRRs lower than 12%.

Table 10. Estimated rotation age for teak plantations in Central America

Project	Country	Rotation (years)
Bosques de Puerto Carrillo [1]	Costa Rica	25
MACORI [2]	Costa Rica	25
Flor y Fauna [3]	Costa Rica	20
General [4]	Guatemala	20
General [5]	Panama	20
General [6]	El Salvador	25

Source: [1] Quirós (1998), [2] Víquez (1998), [3] Camacho (1998), [4] Becker (1998), [5] Morán (1998) and [6] Zambrana (1998), June, 1998.

The University of Wageningen is developing yield tables for three productivity index in the Dry Pacific and Atlantic Zone of Costa Rica (de Vriend 1998, unpublished thesis).

4 POLITICAL, LEGAL AND INSTITUTIONAL ASPECTS

4.1 Legal Framework

There is a Central America Agreement for Management and Conservation of Natural Ecosystems and Development of Forest Plantations[1]. For our purposes, the convention has two relevant elements:

1. Article 2, states "*to promote national and regional mechanisms to avoid changes in the use of areas with forest coverage located in forest lands and to recover deforested areas*".
2. Article 3d indicates: "*to guide national and regional reforestation programs to recover degraded lands preferably apt for forestry and that are currently under agricultural use.....”*

On the other hand, one of the objectives of the Central American Alliance for Sustainable Development is "to promote reforestation and the productive forest activity in Central America” (CCAD 1994).

[1] Ratified by Costa Rica in 1996.

These documents show the growing political importance of timber production through forest plantations. It is obvious that, at regional level, the States are interested in promoting reforestation as an important environmental measure.

4.2 Forest plantations promotion policies

Forest plantation policies of Central American countries have very particular characteristics. An important element is a reforestation incentive system. Because most teak plantations are located in Costa Rica, Panama and El Salvador, reference is made of the legal framework of each of these countries.

4.2.1 Costa Rica

The first Forestry Law (No. 4465) of Costa Rica was promulgated on November, 1969. The present Forestry Law is No. 7575, approved in 1996. Together with its Rules and Regulations[2], constitutes the Costa Rican forest legal framework.

Costa Rica has a 29-year experience of regulating plantation and conservation activities. However, it is only in the last 10 - 12 years when private sector plantation activities attained relevance. Also, the private sector increased its participation in the decision-making process of sector.

New legislation defines the State intervention in forest plantations. Article 28 indicates that "*forest plantations, included the agroforestry systems and individually planted trees and their products, will not require harvesting, transportation, industrialization or export permit...*". Article 56 states that "*logs and rough sawnwood from forests or plantation, will not be transported, if it does not have the respective documentation*". A transportation certificate is required as a form of control in highways.

The law establishes a new incentive system for forest plantations known as Payment for Environmental Services (PES), a payment or compensation for carbon sequestering, soil, water and bio-diversity protection and scenic beauty provided to society. Some of these services benefit not only the Costa Rican population, but also the global community, as is the case of carbon sequestering.

PES is a program under the responsibility of the National Fund for Forest Financing (FONAFIFO)[3], organization created to finance forest activities by granting credits or PES. Article 69 indicates that, from the total amount collected yearly by the selective consumption tax on fuels and other hydrocarbons, a third will be allocated to the PES Program (approx. US$31 million/year).

[2] La Gaceta No. 16, January 23rd, 1997
[3] Article 69: Support to Compensation Programs. Forestry Law No. 7575

Government dispositions detailed PES conditions. The yearly amount to be paid is updated annually, for forest plantations US$600/ha for the first five years. The landowner endorses to the government the annual amount of carbon sequestered by the plantation, signing a contract for a maximum of 15-years.

Article 29 of the Forestry Law lists the incentives that the landowner can have access to:

- Exemption on real estate tax on planted areas.
- Exemption on payment of uncultivated lands tax.
- Exemption on payment of taxes of assets during the establishing, growth and thinning period, that will be considered pre-operative.
- Special protection against squatters.

Different articles permits that:

- If the landowner finance the plantation with its own resources, "the profits obtained by the marketing of products from their plantations will be tax exempted".
- An investment of US$100,000 in forest plantations will allow the investor access to the category of "Resident Investor" (Art. 70).
- Forest plantations that were established without Forest Bonus (FB) can apply for PES, and will receive an amount of US$46/ha/year during 5 years.

FONAFIFO has incorporated new elements to facilitated landowner access to these credits. Payment schedule and interest rates area designed for long-term investments. They cover not only the establishment of the plantation, but also its management. Because FONAFIFO has limited financial resources, at present the maximum area to be financed is 100 ha/year/loan. Also is possible to use the plantation (trees) as collateral to guarantees the credits. The country's commercial banking system has no similar credit plan.

Landowners and industrial managers interested in the forestry sector development have organized the Costa Rican Forestry Chamber (CCF), a union created in 1993 that represents the interests of the Costa Rican private forestry sector.

4.2.2 Panama

Panama has a detailed legal framework that regulates reforestation activities: Forestry Law No. 1 (approved in 1994). Law No. 24, approved in 1992, deals with reforestation, and was amended in June 1993, adding specific Reforestation Incentives. It establish a 30 year period during which, all forms of private reforestation will receive priority and support. This Law indicated the country's political will to increase reforestation,

The most relevant economic aspect is in article 5, which states that "*100% of the Forestry Investments made by legal or natural persons is considered deductible expenses of Income Tax,"* This incentive applies to all incomes, excepted those from forestry activities. Furthermore, machinery, equipment and inputs imported for reforestation activities are exempt of taxes and fees (Panama 1992).

The institution responsible for the implementation of the forestry policies is the National Institute of Renewable Natural Resources (INRENARE) that depends of the Planning and Economic Policy Ministry. The Finance and Treasury Ministry is responsible of registering and controlling the taxes invested in the reforestation activity.

There is a National Panamanian Association of Forest Farmers. Its members own almost 70% of the teak plantations in the country.

TEAK IN PANAMA

Up to 1997, Panama had registered a total planted area of 26,724 hectares, using mainly *Pinus caribaea, Tectona grandis, Bombacopsis quinatum, Acacia mangiun* and African mahogany. The teak area was 12,936 ha, or 48.4% of the total reforested area.

Furthermore, they have a financing policy, promoted by the National Bank, that offers credits at 7.5% interest rate for a 10-year term. In addition, the Agricultural Development Bank has a credit line for timber production projects of medium-size growers, and for sawmills.

Teak plantations were established considering a 20 years rotation. Subsequent studies of INRENARE and CATIE proposed a 25 year rotation as a minimum. ANARAP and forestry technicians, estimate average increases of 1.3 cm/year in diameter, 2 m/year in height and 12 m^3/ha/year. The total volume at 25 years is estimated as 300 m^3/ha (thinning and final cut) and the commercial volume as 250 m^3/ha

Overall, teakwood has good acceptance on the national market. Ever since woodworkers have learned how to work it, its acceptance has been on the rise and is considered comparable to mahogany and cedar. Teakwood commercialized locally comes from isolated trees or second thinning of small areas. In the last two years a teakwood market for mature trees has opened. Timber purchased from farmers is sold to Japanese and Chinese businessmen for export. As the amount of mature teak is very limited, this is a temporary business.

Teak plantation investment projects had a B/C relationship =1.38, and a NPV=US$19,380/ha, with production costs close to US$14,000/ha for a 25 years rotation, at an average price of US$600/$m^3$ for wood.

Source: Morán (1998)

4.2.3 El Salvador

El Salvador Forestry Law, approved in 1973, gives general guidelines for the reforestation process.

A Project to reform the actual Forestry Law is under consideration. Article 34, of this proposal specified that forest plantations in private properties will not require authorization for its establishment, maintenance, and thinning or final cut.

Reforestation is based on technical and financial criteria. For credits approval, banks request the technical opinion of the Forestry Service. The banks have funds for forest credits.

The institutions related with the Forestry Policy are:

- The Agriculture and Range Management Ministry through two organizations:
    - CENTA: promotes and provides technical assistance for the establishment of plantations with forest species (including teak), mainly to small farms and with agroforestry systems. The CENTA officers can not authorize harvesting of natural forest or forest plantations.
    - The Forest Service: offers technical assistance and controls the execution of the projects.
- The Banking System: finances reforestation projects with their own funds, and with funds from the Multisector Bank of Investments (BMI).
- The Environment Ministry was created in June 1997 and has little relationship with promoting forest plantations.
- Other institutions that finance forestry projects by way of different contributions are FIAES and FONAES. These organizations' policy is not to include teak in their projects, or reduce the area planted with this specie to a minimum. This decision is based on the assumption, without further technical analysis, that teak provokes erosion. Nevertheless, in good site and with adequate management, teak does not have erosion problems.

From 1992 to 1995, an important source of capital was the social investment fund.

One of the limitations to promote reforestation in the country, is the lack of enough trained professionals. Universities do not have a degree in Forestry Engineer and there is no association of forestry professionals. Since the banks do not require that the person who implements the project has a forestry degree or background, professionals of any field can prepare and managed forestry projects,

There is a Forest Farmers Association and the Association of Seed Producers that gathers seeds and produce trees in commercial nurseries.

TEAK IN EL SALVADOR

Between 1950s and 1976, 230 hectares of teak were planted and from 1980 to 1986 about 1,200 ha were planted by the MAG-ISTA. Until 1996, the total area registered was 2,488 ha, distributed in 138 owners.

In rural area teak has great demand as round logs for housing. Farmers are using the sprouts for small diameter products. Depending on the site, landowners plant up to 2,500 trees/ha. First thinning is scheduled between 4 and 8 years, between 11 and 13 years the second, and between 16 and 18 years the third. An important aspect is that most plantations lack management. Some are being "ransacked" and are gradually degrading.

Estimated rotation age is 25 years yielding commercial volume of 214 m^3/ha of logs (up to 8 cm diameter top end) corresponding to a MAI of 8.56 m^3/ha/year.

The financing plans of the forest promotion programs are applied to all forest species, including teak. Some characteristics of these programs are: have no financing limit, the term is from 2 to 25 years, the interest rate is 6%/year, with a 10 years grace period. All cases require mortgage guarantee.

Teak markets are analyzed based on three products:

- Roundwood: used in generally for housing or rural constructions, pitchforks, beams, round plank and rods. Competition comes from eucalyptus, mangrove or other construction materials. Roundwood is also used for the construction of ranchos de plaza (recreation sites). The price is good, but the market is limited.
- Timber: the sawmill industry demands larger diameters. The main buyer is a company that manufactures export furniture. Prices depends on log diameter, they pay per cubic foot, without considering the form of the log.
- Roundwood for export: in eventual cases there is an export market. Recently, some logs were sent to Australia and India.

Wood prices vary accord to log diameter and length.

It is not sure that the expansion of planted areas will be with teak. Being one of the most criticized species, for being foreign, and for assuming it erodes steep slopes. In spite of all, teak is currently the most planted specie in El Salvador.

Sites with long drought periods produce wood with a very attractive appearance, what is a plus.

Source: Zambrana (1998)

5 ECONOMIC ASPECTS

5.1 Financing schemes for reforestation

5.1.1 International investment

Several foreign companies, dedicated to plant, manage and sale teak, began to invest in Costa Rica, either establishing operations by themselves or subscribing contracts with local forest

companies, that provide forestry services. They are not interested in State incentives, but do inscribe their farms in the Forest Regime[4] so as to have land taxes exemption, and income tax exemption from sales of plantation products.

Their funds come from selling the forest stands in parcels (and its maintenance) to the general public in Europe and North America through two main modes:

- Sale of project's shares. Its value is equivalent to a determined area, or to a fraction of the value of the project.
- Sale of planted areas that vary in size from ¼ ha to one or more hectares. Some sell not only the stand and its maintenance, but also the land, while others only sell the stand, and include the leasing of the land.

In the last years some foreign companies have purchased already established plantations from local growers who had used the incentives granted by the Costa Rican government. In these cases, the purchasing company assumes the liabilities contracted by the seller with the State.

5.1.2 State incentives

The vast majority of the plantations established in Costa Rica have been totally, or partially, financed by State incentives. The first one was to allow landowners to deduct unlimited plantation expenses/ha from income tax (theirs or from other taxpayers). Later, to prevent over-expending, it was established a fixed amount/ha, adjusted yearly. Then followed a forest bonus (CAF), still in use, to pay Government taxes, credits *etc.* (can be sold in the stock exchange at 99.9% of its face value). These two models did not require reimbursement on the part of the beneficiaries.

Presently FONAFIFO finances the planters with credits. Loans are guaranteed with mortgage, collateral or fiduciary warranties (according to the conditions of the trust that funds it). Interests are cumulative, and payments are determined according to each project's cash flow which depends on the expected production program. Credits for the management of existing plantations have similar conditions. In general, credits for timber production projects area granted at the basic passive rate (rate paid by the bank to private investors) minus 6 points (around 12 - 18%). The credit cannot exceed US$600/ha.

The same amount is also the maximum granted by the Payment for Environment Services (PES) incentive model. PES was created for the recovery and maintenance of forests, and includes all activities (protection, conservation and forest management) in natural forest and/or established forest plantations. In the later case, the US$600/ha is disbursed in the first five years, in tracks of 50, 20, 15, 10 and 5%. Since funds depends on the resources assigned by the government, and those raised by FONAFIFO by selling environmental services abroad, payments can be made with credit instruments or cash.

[4] Forest Regime, a set of legal and technical dispositions published by the government for the landowners who want to take advantage of forest incentives.

5.2 Establishment and maintenance costs

Plantation costs vary widely due to factors such as prior use of the soil, size, slope, location, access, soil and climatic conditions, existing infrastructure and the modality of financing. Planting can be done by the farmer or by a contracted company, who will be responsible for planting and the management of the farm as a whole. In the second case, costs related to farm maintenance (infrastructure and administration), and those, are charged to the plantation.

5.2.1 Plantations done by the landowner

Case 1
Cost studies of Costa Rica (GFA *et al.* 1998) (Table 11) plantations of 30 ha or more, 1,111 trees/ha, have reached US$863/ha for the first five years, and US$1,034/ha for a 20 years rotation, under the following conditions:

- An average of 100 meters of fences and 50 meters of roads per ha
- Soil is prepared with agriculture tractor
- Nursery stock produced in boxes
- A 22% of social charges paid on salaries
- Except fertilizer, no other chemical product is used;\
- Technical supervision done by professionals, who visit it 3 visits during establishment (first year), 2 in the second year and 3 times for pruning and thinning. Each visit costs an average of US$117.40, including transportation and travel expenses.

The above data refers to plantations established in parts of farms where the following cost are beared by other farm activities or, in the feasibility analysis are assumed to be negligible:

- Foreman living permanently in the farm
- Services, such as drinking water and electricity
- Accounting
- Administrative subdivision of the plantation
- Basic equipment not provided by workers, such as hand pruning saws, shovels, *etc.*
- Construction and/or improvement of infrastructure, such as houses, stockrooms, culverts, bridges
- Maintenance of infrastructure (fences and roads) after year 1
- Transportation of personnel and inputs
- Unforeseen expenses, such as materials and labour for fastening bowed trees and pests and diseases control.

Case 2
Alfaro and Villamizar (1998) estimated a cost of US$1,054/ha for the first five years (US$1,707 for a 20 years rotation). It was a plantation of 1,111 trees/ha with genetic improved material (2% higher cost over not improved material). When plantations were established, as the landowners could not afford infrastructure investments, these items were excluded from the study, together with pre-investment costs (reforestation plan). Administration and technical assistance costs added US$20/ha/year, and the daily wage was estimated at US$6.8, including social charges (Table 11).

5.2.2 Plantations done by contractors

Case 3
In these plantations, in addition to planting and managing the stand, the companies have duties and activities (below detailed) that give this system especial characteristics:

- As the main objective is to produce first quality material for international market, the management system is not limited by funds, as it happens with plantations established with local support.
- The contractor built and/or improves the necessary infrastructure and maintains it. Does the paper work for the Environmental and Energy Ministry to include the farm in the Forest Regime. As a rule, the contractor pays taxes and have the employer civil and environmental responsibilities.
- A third company, or independent professional, is subcontracted as a verifier (regency) and, sometimes, as a certifier. This company prepares the reforestation plan, visit the project bimonthly during the first year, and at least twice during other years. The verifier has to report to the contracting party if management has been done properly.
- Third company visit (RNT 1988) costs US$240, including transport and travel expenses.
- Subdivision of the planted area suitable for selling in parcels of 1 to 20 ha, done by surveyors.
- Pre-investment costs include selection of the farm, verification of its area (surveying) and legal status, and soil analysis.
- Soil preparation and fertilization according to site conditions. Where it is not possible to prepare the site with agricultural tractors, a more expensive method is used. Holes of 35 cm. depth by 30 cm diameter are dug (manually or with motor-drills). Usually a soil specialist determinates the fertilization system. Fertilizer is applied every year, except when in thinning years. After year 4 (first thinning) 500 grams are applied to each tree.
- The farm area acquired for teak planting. Farm improvements and maintenance costs are charged to the plantation. Normally, two to three permanent workers live in the farm.
- North Region of Costa Rica projects general norms are:
    - 1,300 - 1,600 trees per ha
    - 60 ha average area suitable for planting (average farm area 81 ha)
    - Average distance to paved roads; 5 km
    - 20% slope or less in 90% of the area. As they are small terraces, that rarely allow mechanization, holes are open with motor drills, and diameters are enlarged with a shovel
    - Mean annual temperature of 26 ºC and mean annual rainfall of 2,700 mm
    - A dry period of three months
    - Deep, clayey soils of average fertility, no risk of floods
    - Usually the farms have poor or non-existent infrastructure
    - Between 10% and 25% of the area is covered by bushes, or abandoned orange plantations. There are isolated –trees.

After four years of working under these conditions, a company has been able to reduce establishment and maintenance costs by 20%, and further reductions are expected (GFA *et al.* 1998). Major factors responsible for the cost reductions are: increase of the planted area reduced

fixed and administrative costs; and assuming previously subcontracted activities (marking and drilling of holes). Nowadays, under the conditions described above, cost/ha amounts to US$2,194 for the first 5 years and to US$2,250 per/ha for the following 15 years (with a 500 grams fertilization applied to each remaining tree after year 5). For a 20 years rotation period, total cost is estimated at US$4,444 (Table 11) without contractor's profits.

Table 11. Comparative reforestation cost estimates under different conditions (US$/ha)

Year	Case 1 GFA *et al.* (1998)	Case 2 Alfaro and Villamizar (1998)	Case 3 Sage (1998)
1	656	442	1 191
2	80	195	415
3	11	166	238
4	11	217	200
5	105	34	150
6	9	34	150
7	9	34	150
8	21	109	150
9	9	34	150
10	9	34	150
11	9	34	150
12	9	34	150
13	9	62	150
14	21	34	150
15	9	34	150
16	9	34	150
17	9	34	150
18	9	74	150
19	9	34	150
20	21	34	150
Total	**1 034**	**1 707**	**4 444**

Sources: GFA-RNT 1998, Alfaro and Villamizar 1998, Sage (Consultora S.A.) 1998
Dollar exchange rates: Case 1 = 255.5, Case 2 and 3 = 250.

5.3 Markets and prices

Currently in Central America, the only country that is developing an important international and local market for teak is Costa Rica but, as local information is kept confidential, their is no reliable information on domestic prices. The majority of the plantations are just producing the first commercial thinning. There is not reliable data on prices of old plantation, since these were areas planted by foreign companies in Parrita decades ago, and teak was not managed technically.

5.3.1 Plantations

Data of young plantation prices some landowners are asking is presented (Table 12). Though it is what they ask to foreign investors, they provide a first approximation of the wood value during the first stages of development.

Table 12. Prices of the forest projection requested by local farmers to foreign investors

Place	Age (years)	Price of the wood (US$/ha)
Península de Nicoya, Guanacaste	9	4 022
Península de Nicoya, Guanacaste	8	6 000
Parrita, Puntarenas	3	3 500 *
San Carlos, Alajuela	3	2 500

Source: Hernán Delgado (Parrita), Armando Campos (Guanacaste) and Mohamed Sandí (San Carlos).
*In 1998 the price increased to US$6,500/ha.

5.3.2 Standing timber for local consumption

The most reliable information source on local market standing timber teak prices is the information bulletin of the Costa Rican Forestry Chamber (CCF). It registers mostly transaction prices of the South Pacific zone, where there are the oldest plantations. Bulletin number 20 present information on local market with a price average of US$117/m^3 at December, 1996. By January - February 1998 the average price decreased to US$91 and by March - April 1998 the price was US$110/ m^3.

5.3.3 Timber (logs)

In 1998 CCF published data on sawmill yard transactions at US$260/m^3 for diameters between 15 and 24 cm, sold to European buyers. No other specification for that diameter was supplied. This price is similar to plantation logs in the international market, since their average price for the March - June 1995 period was US$240/m^3.

Sri Lanka's plantation logs reached US$243/m^{3}by the end of 1996, and Costa de Marfil's FOB price for plantation was US$286/m^{3}by the middle of 1997. In both cases were logs of 15 and 20 cm diameters. As a rule, the international market buys logs free of defects, such as twistings, knots, and rot. In 1996, this market quoted Sri Lanka plantation logs, diameters between 21 and 50 cm, at US$304 and 426/m^3; while timber from Central and South America, with diameters of 31 to 50 cm, reached FOB prices between US$190 and 200/m^3. This information is summarized in Table 13.

Table 13. Teak (Tectona grandis) log prices by diametric class, from Sri Lanka, Central and South America

Mean diameter (cm)	Sri Lanka (US$/m^3)	Central and South America (US$/m^3)
15 – 20	243	Na
21 – 30	304	Na
31 – 40	386	190
41 – 50	426	200

Source: ITTO Market report, 1995; FAO and Phillips (1997)
Na = not available

5.3.4 Sawnwood

CCF (1998b) reports a single local market transaction of rough boards for export (2"x2"x120", 50% sapwood, 50% heartwood and free of pitch) at US$500 per m^3 FOB.

The international grading includes a category "special quality scantlings", whose lengths range from 2.5 feet (short) to six feet (long), several widths and thickness. In 1995, natural forest lumber prices varied US$855 to US$1,950/m^3 for shorts, and US$1,985 to US$3,095 for long. "Special and better" category, widths of 8" and lengths between 3-4 feet and varied thickness, reached prices between US$2,580 and US$4,055/m^3. “Planks-special and better 3.5 thick" varied between US$2,460 and US$3,395/m^3 and "decks-special and better" with lengths between 11 and 15 feet, several widths and thickness ranged from US$4,785 and US$5,235/m^3 (G. Gresham, Churchill M. Group 1996). However, depending on the dimensions, plantation lumber reached prices of US$1,200 to US$1,300/m^3 in 1995 the international market (ITTO 1995).

Lumber from plantation was sold at prices of US$800 and US$1,200/m^3 FOB in Lagos in 1996, and FOB Papua New Guinea in 1995, respectively. In 1997, a mixture of several lumber categories from plantations of Trinidad, Costa Rica and Panama was sold in US$600/m^3 CIF Miami. Currently in the United Kingdom, lumber from Central America and Trinidad plantations is quoted from US$800 to US$1,200/m^3, of 1"x2.5"x2.5' and 1"x2.5"x6' (Gareth Phillips, consulting, Oxford, England).

5.4 Income expectations

In cases 1 and 2 (Table 11), to calculate the internal return of the projects, local teak timber prices have been used. If a part of the total volume is selling to the international market, Internal Rate of Return (IRR) and Net Present Value (NPV) will be bigger.

Case 1 assumes income in years 8, 14 and 20, from the sales of 20, 40 and 180 m^3/ha, respectively. Standing timber prices are US$65, US$78 and US$91/m^3. The IRR is 23% and the NPV) (3%) is US$11,196 (GFA *et al.* 1998).

Case 2 assumes income in years 10, 15 and 20 from the sales of 25, 45 and 180 m3/ha, respectively. Standing timber prices are US$65, US$78 and US$91/$m^3$. The real internal rate of return is 22.7% and the NPV (3%) is US$11,882 (Alfaro and Villamizar 1998).

Case 3 corresponds to plantations done by contractors. Therefore higher yields in volume and quality are expected, and most of the products will be sold in the international market. Also, as the contracting companies are supposed to engage in subsequent stages of the industrialization and commercialization process, other prices must be used to estimate profitability.

A commercial accumulated volume of 327 m^3/ha is used, and is the simple average of the high class sites reported by Camacho (1998) for Flora y Fauna S. A. and Picado (1997) (section Physiological and Technical base). Logging loses are estimated at 15%, so 85% will be actually sold.

Two commercial thinnings are programmed:

- The first in year 8 produces 26 m^3/ha total volume and 22.2 m^3/ha of commercial volume will be sold at US$67/ m^3, generating a total income of US$1,467/ha. This income would make the plantation self-sustainable, as it will provide US$244.50/ha/year until the next commercial thinning.
- The second (year 15) produces 49 m^3/ha total volume and a total income of US$6,601/ha. Logs with diameters between 15 and 20 cm (50% of total commercial volume = 20.85 m^3) were priced at US$240/ m^3, minus logging costs of US$20/m3, will produce an income of US$4,587/ha. The rest of the commercial volume will be sold locally, as standing timber, at a price of US$96.60/ m^3. These prices are the lowest local price reported for standing teak trees (CCF 1998a); and will produce an income of US$2,014/ha.

The final harvest (year 20) will produce a total volume of 252 m^3/ha. All timber will be converted into rough lumber at a 55% recovery factor (117.7 m^3). Only 50% (58.85 m^3) will be sold at US$800/$m^3$ (66% of price in the international market); minus logging, milling, drying and hauling costs (US$178/$m^3$), FOB port. Net income generated is US$36,605/ha. Another 30% of the lumber can be sold at US$600/ m^3 (50% of price in the international market), FOB port, generating a net income of US$14,900/ha, after deducting logging, milling, drying and hauling costs. The remaining 20% can be sold at a price of US$400 (33% of the international market price) and generates a net income of US$5,226/ha. The final harvest income is US$56,731/ha. Logging, milling and transport costs includes the normal profits of these operations.

The expected total income of US$64,800/ha from plantations with first quality management, whose final product is rough sawn lumber (against standing timber of cases 1 and 2). The income comes from three different harvests, done in years 8 (US$1,467/ha), 15 (US$6,601/ha) and 20 (US$56,731/ha).

Plantations established by foreign companies are sold to the general public of their home countries. Information about other components of the total cost (i.e. marketing costs) were not available to the consultants. The present study is limited to calculate the Net Present Value of the income generated by the different harvests at different discount rates (Table 14).

Table 14. Present value of income at different discount rates (US$ 1998)

Discount Rate (%)	Present Value (US$/ha)
4	31,854
6	22,645
8	16,248
10	11,767
12	8,601
14	6,346
16	4,727

Source: The authors
No real price increase is assumed.

Summarizing, the major limitation of the present study are:

- Local data on teak prices comes from a small market in the South Region of Costa Rica, where most of the timber comes form plantations that were not properly managed,
- Data of plantation yields is based on projections of the growth of stands that are just undergoing their first commercial thinning.

Furthermore, in spite the availability of teak prices from other countries, there is not enough information on quality of local teak products to allow an objective price-product comparison.

To increase net income/ha, local producers and foreign investors should consider more elaborated products. Some of these foreign firms are already producing furniture and parquet flooring. Investments, costs and returns are not available.

Another particularly important factor is the future of the teak market. At a first glance, diminishing inventories of teak natural forests and restrictive policies enforced of these countries, will force future prices upwards but, given the uncertainty of prediction models, this factor is difficult to assess.

Costa Rica's Teak Marketing Experiences

In the 1990s, Costa Rica's teak area increased from around 1,000 ha (1987) to more than 25,000 ha in 1997. Before 1996, the only teak marketed came from plantations in Quepos, province of Puntarenas, established between 1943 - 1966 by the United Fruit Co.

This company began to harvest (1) in 1968 - 1969 plantations of 25 or more years. Teak use was limited to parquet, components, and accessories for yachts (Keogh *et al.* 1979). Small areas of those plantations still remain.

Nowadays, companies like Hacienda El Tecal produces parquet. However, since there are only about 1,000 ha of teak 10 years old or more, reforestation companies have focused their efforts to find markets for young teak (baby teak) products, to identify adequate designs and the necessary technology to manufacture those products.

One company with great success in marketing young teak (ages between 6-7 years) is Flor y Fauna S.A.. They participated in several international fairs in the United States with a variety of prototypes. So far, they have consolidated, with great success, the following products: 1) bed sofa, 2) tables for lamps, 3) occasional table, 4) small trunk, 5) components for computer tables and 6) floorings (boards of 3"x1 m). These products are being marketed at prices higher than US$1 000/$m^3$ and, in cases, at the following prices:

- Products 1 to 4: US$1,500 and US$1,600/m^3.
- Products 5 and 6: US$1,200/$m^3$.

Also, this company has developed, in the United States, a market for garden implements, with very good results but, as these products have to be at low prices to make them competitive, they are considered to be marginal.

Another initiative, being developed by the CCF and the CACH (Centro Agrícola Cantonal de Hojancha), is to export teak lumber at US$655/$m^3$ with the following specifications: sound knots, healthy, free of the fungi and insects attacks, free of sapwood, with up to 50% white color and 50% golden color, without cracks, sawn four sides.

Aventuras Forestales S.A. has produced ashtrays, pocket humidors and women cabinets, which are marketed in small quantities in Costa Rica and in the United States.

In spite of being a very specific experiences, they confirm the great possibility that young teak can be accepted in Costa Rica and elsewhere.

Source: Zamora (1998)

6 POTENTIAL FOR THE EXPANSION OF THE AREAS PLANTED WITH TEAK

This potential must be analyzed country by country. Statistics shows that, in some countries, teak planting is just beginning, while others have made important progress in the last decade.

First, teak availability must be analyzed. Up to 1995 there were 70.85 millions/ha of plantations of approximately 100 forest species, in 89 countries (78 of them located in the tropic and 11 in

the sub-tropics). About 57.5% of the total area hardwoods, and 42.5% softwoods. Also, 79% of the total area was planted with white woods (eucalyptus, pines and others). Teak is the only specie of fine dark wood being planted massively (2.25 million/has). As the international market will face mainly a supply of white woods, a dark wood like teak will have little competition (Pandey 1997).

All natural teak forests and 93.7% of the 2.25 million/has planted with teak are located in Asia and the Pacific, 3.1% in Africa and 3.2% in Latin America. Central America has 43,010 ha, or 1.9% of the total area planted in the world, and 86% of the area of Latin America. Furthermore, other species planted in quantities in the region are pines, eucalyptus and Melina (*Gmelina arborea*). Some dark wood native species are being planted in small scale or, in some instances, at the experimental level. In marketplace teak can be a substitute for valuable dark hardwoods from natural forests for furniture and decoration panel uses.

Wood price is another factor that determines the expansion of these plantations. Up to date, teak prices show growing trends in real terms and this motivates to continue expanding the planted areas.

Specialists predict a decrease of teak supply from Asian natural forests. Therefore consumption of teak from plantation will increase. Price of timber and lumber from plantations could rise steadily in the future (Keogh 1997b). All this could increase the interest of the farmers and investors to plant teak.

Strong international critiques for the high deforestation rates in tropical countries, and the political clout of environmentalist movements, support the belief that well managed forest plantations are the alternative to native forest wood supply.

It has been estimated that at least 100,000 ha more could potentially be planted with teak in Central America: 25% located in Guatemala, 25% in Nicaragua, 20% in Costa Rica and 15% in El Salvador and Panama. With a rotation period of 25 years, these countries could be harvesting 5,720 ha/year or, approximately 1.43 million/m^3/ of roundwood.

6.1 Costa Rica

Costa Rica has developed technological packages for establishment and managing teak. In the best sites, under intensive management plans, in rotation from 20 to 25 years, the specie has an a MAI of 20 to 25 m^3/ha/year. It is foreseen that well managed plantations will produce a total volume of 15 - 20 m3/ha/year, and 10 - 15 m3/ha/year of commercial industrial volume. These results, obtained in the last decade, have stimulated large scale planting.

Teak expansion in Costa Rica will depend from the availability of financial resources that originate from two sources:

- PES (already explained)
- Foreign investment.

The US$600/ha paid for the environmental services generated by forest plantations to society, in terms of carbon sequestering, soil protection, water cycle regulation and scenic beauty, permits the farmers to invest on this production system, where capital recovery comes in the long term.

Several facts affected foreign investments. First, the 1995 Bosques de Puerto Carrillo's bankruptcy. Although the main reasons was that the industrial investment was made before enough timber was available for the sawmill, it brought discouragement. In 1996 Flor y Fauna was the subject of a strong international critique for the data on stands growth and financial performance they reported to its investors in the Netherlands. Several authors considered it unrealistic data.

During 1997 the European stock exchange market had an attractive performance, reducing the interest in reforestation projects, that some considered of high risk. For these reasons, the yearly-planting rate between 1996 and 1998 decreased. Foreign companies that planted teak have reduced their expansion expectations to 2,000 - 3,000 ha during the next 2 - 3 years.

Also, as part of the public policies for resource conservation, the use of the natural forests for the sustainable wood harvest is being continually limited. Right or wrong, these guidelines tend to reduce the number of species, and many of the species permitted to be exploited can be classified as white woods.

In fact, the great question is if the national market will continue to appreciate teakwood. The answer is that as long as the supply of natural forests dark woods continues to be limited, local users will purchase teak. Today there are pilot experiences that show the buyers acceptance of teak products.

However, the determinant factor in present and future consumption of teak will be the price. At present, teak logs traded at local level reached prices of US$140 to US$165/m^3 at the mill yard. This price doubles the price of the woods classified as "*semi-duro"* [5]*,* and it is below the price of fine species such as cristóbal (*Platismiscium pleiostachum*) and ron-ron (*Astronium graveolens*), both "precious hardwoods". Their timber is priced at sawmill yard between US$260 to US$290/ m^3 (CCF 1998a, b).

Although teak reached the highest price of all species used in construction, it is also true that the limited quantity of natural forest wood supply leaves, as principal alternative, teak for interior decoration and furniture.

At the international market level, the big question is how Costa Rica's wood will compete with Asia and African plantations. This leads to the necessity to produce a very high quality for the export market. Producers will have to locate market niches that pay for wood quality.

6.2 Panama

Panama is second in area planted with teak. Three areas have expansion potential: the South of Veraguas Province, the East of Panama Province (currently used for cattle-raising), and the south-west of the Darién Province (in national lands, or properties currently dedicated to cattle-raising). The principal problem for teak expansion is land price (US$1,000/ha). A policy that

[5] In Costa Rica hardwoods are classified by hardness (hard, semi-hard and soft).

favored land prices increases is the reforestation incentive. As it covers 100% of the expenses, including land, it started a speculative price spiral, and nobody is interested in checking it (Morán 1998).

6.3 El Salvador

In El Salvador the plantation expansion has good possibilities; there is area available and domestic and international demand, which can motivate the farmers to plant. It is not guaranteed that the expansion will be with teak. Teak is one of the most criticized species for being exotic and its leafless appearance in the dry season. As it has been planted at 2m x 2m, no vegetation grows under the canopy, favouring erosion in steep slopes.

However, there are good reasons to use teak widely in reforestation programs (Zambrana 1998):

- It adapts very well to the climatic conditions of the country.
- There is an abundance of seeds.
- The greenhouses seedling production system is well known.
- It resists fire very well.
- It sprouts very well (mainly young plants).
- It has an acceptable performance, even in low productivity sites.
- Easy to plant.

Long drought periods cause very attractive wood streaking. In teak, this is a favourable element, as the specie to be used in those sites, which are difficult for other species that require a shorter dry season.

6.4 Guatemala

As the country still has vast areas of broadleaf and coniferous forests, reforestation moves at a very low pace. The only project that has anticipated the expansion of teak areas is ECOFOREST S.A. with its Atlantic Coast plantations, close to Puerto Barrios.

As current natural forests timber supply the national markets, planting trees have little attraction for farmers or investors. But now, the Forest Law anticipates incentives for those who plant trees.

6.5 Nicaragua

The economic crisis does not favour reforestation as an economic land use alternative. Farmers do not have capital to invest in this long term, where most of the investment is in the first years. The lack of reforestation incentives does not favor the expansion of the planted areas in the near future.

The Forest Law is being revised by the different sectors, including incentives for reforestation. However, this law will not be approved before 1999 (Tellez 1998). The Exchange of Cattle-Raising Debt for Forests, a program of the Ministry for Agriculture, could stimulate reforestation. This program is just beginning, but it is a good opportunity to plant teak.

Land prices and reforestation costs are lower than in other countries and opportunities to plant teak does exist.

6.6 Honduras

In Honduras reforestation is its infancy. The experience is with plantations of *Pinus caribaea*. Broadleaf trees have been planted at experimental level. It is estimated that, in the short and middle terms, there will not be interest to plant with teak.

6.7 Recommendations

In addition we recommend the following:

1. To create a Central American Teak Growers Association with the purpose to exchange experiences in the three main aspects of successful plantations: selecting sites, selecting vegetative material, selecting the best silvicultural program.
2. Top invest in a Central American genetic improvement programme, with the development of seed orchards, *clonal* orchards, seed production and clonal plant production.
3. To publish a bulletin of the Central American Teak Growers Association to inform themselves and the public in general.
4. To develop a portfolio of project profiles for joint ventures with foreign capital. The region would provide land, local technicians, labor and the foreign investors' capital, technology and industry funding.
5. Associate the Central American Teak Growers Association with the Teak 2000 initiative in order to open a channel for technology transfer and joint ventures.
6. Training of people in the industrial aspects of teak production: sawmilling, drying, wood processing, marketing, *etc*.
7. To begin with the promotion of the product Central American Teak as a joint venture of the Central American Association of Teak Growers.

Interest the bilateral cooperation, CIFOR, foreign and national universities to develop and execute a research plan for teak cultivation, yield modeling and financial modeling.

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Appendix 1. Reforested area with teak and other species in Central American countries

Appendix 1.1. Reforested area (ha) in Guatemala during the period 1990 - 1995

SPECIES	1990	1991	1992	1993	1994	1995	TOTAL
Gmelina arborea	679.00	0.48	0.79	2,024.49	398.71	-	3,103.47
Pinus caribaea	-	826.00	133.51	-	191.00	595.79	1,746.30
Tectona grandis	-	1.41	1,715.52	-	-	-	1,716.93
Cupressus lusitánica	85.25	134.36	187.34	603.94	283.54	352.13	1,646.56
Pinus tenuifolia	92.94	293.69	78.70	103.50	0.22	359.69	928.74
Pinus sp.	-	280.00	229.76	22.25	288.52	41.85	862.38
Pinus maximinoii	1.50	-	-	64.24	57.75	599.07	722.56
Pinus oocarpa	-	357.00	-	-	20.83	23.20	401.03
Eucalyptus sp.	-	4.42	232.19	-	2.92	0.62	240.15
Cedrella odorata	-	11.86	2.81	56.39	19.20	149.38	239.64
Abies guatemalensis	0.08	-	101.50	-	10.00	0.79	112.37
Pinus pseudostrobus	0.55	67.62	-	0.67	10.85	1.75	81.44
Swiettenia sp.	10.00	11.86	-	-	10.50	-	32.36
Caesalpinea velutina	-	0.80	8.40	0.47	2.92	-	12.59
Eucalyptus camaldulensis	-	-	-	0.47	7.21	1.50	9.18
Casuarina equisetifolia	6.25	-	0.24	-	-	-	6.49
Leucaena leycocephalla	-	1.41	-	0.47	-	-	1.88
(*) Others	12.00	2.41	142.68	243.80	172.26	7.31	580.46
Total	887.57	1,993.32	2,833.44	3,120.69	1,476.43	2,133.08	12,444.53

Source: INAB (1998), June, 1998

* *Jacaranda sp. Hevea brasilensis, Alnus jorullensis, Cassia siamea, Alnus acuminata, Cordia alliodora, Psidium guajaba, Inga* sp., *Grevillea robusta, Enterollobium ciclocarpum, Quercus* sp., *Caesalpinia velutin*

Appendix 1.2. Planted area (ha) by species in Costa Rica during the period 1979 - 1996

Species	Reforested Area (ha)	Area %
Gmelina arborea (Melina)	49,274.9	35.7
Tectona grandis (Teak)	23,475.4	17.0
Cordia alliodora (Laurel)	18,373.8	13.3
Bombacopsis quinatum (Pochote)	17,020.7	12.3
Eucalyptus deglupta (Eucaliptus)	12,855.5	9.3
Pinus sp. (Pinus)	4,772.0	3,5
Cupressus lusitanica (Cypress)	5,015.1	3,6
Alnua acuminata (Jaúl)	2,667.0	1,9
Other species	4,727.9	3,4
TOTAL	**138,182.3**	**100**

Source: SINAC (1997) adjusted with updated information to 1998 from CCF (1998) and RTN S.A. records (1998), June, 1998.

Appendix 1.3. Total reforested area (ha) in Costa Rica and planted area with teak (*Tectona grandis*) during the period 1979-1997

Year	Total Reforested Area in Costa Rica (ha)	Reforested Area with teak	
		Area (ha)	% of RA Costa Rica
1979	307.9	160.0	51.96
1980	294.0	10.0	3.40
1981	707.3	5.0	.71
1982	712.8	105.0	14.73
1983	1,096.7	0.0	
1984	891.9	0.0	
1985	1,377.8	18.7	1.36
1986	3,572.3	278.1	7.78
1987	3,530.2	296.0	8.38
1988	5,049.3	322.2	6.38
1989	5,489.3	440.4	8.02
1990 *	17,542.6	1,089.1	6.21
1991 *	20,734.3	2,857.7	13.78
1992 *	19,998.3	2,341.9	11.71
1993 *	18,871.0	3,004.5	15.92
1994 **	12,991.0	4,097.8	31.54
1995 **	9,475.0	3,459.3	36.51
1996 **	8,792.8	2,717.8	30.91
1997 **	6,748.0	2,272.0	33.67
Total	**138,182.3**	**23,475.0**	16.99

Sources: Reforestation Department, DGF (1994); * DECAFOR, General Forestry Department (1994); ** SINAC (1998), June, 1998.

Note: For the period 94-97 SINAC is processing the information by species.

Appendix 1.4. Reforested area (ha) with teak, per year, in Panama until 1997 by Province

Year	Bocas del Toro	Coclé	Colón	Darién	Chiriquí	Herrera	Panama	Los Santos	Veraguas	**TOTAL**
Prior to 1992	0	26.9	108.8	8.0	57.2	9.5	171.3	412.0	428.5	**1222.2**
1992	4.0	6.4	45.5	6.0	305.8	2.5	72.1	1.0	0.5	**443.8**
1993	0	400.3	125.0	13.3	736.2	3.1	130.1	15.9	22.1	**1446.0**
1994	52.3	175.9	107.9	151.0	578.4	8.4	498.3	4.2	213.1	**1789.5**
1995	0	437.8	300.8	658.9	1498.8	77.5	779.5	62.3	44.5	**3860.1**
1996	20.0	315.8	393.0	216.2	256.9	65.7	512.1	119.1	360.1	**2258.9**
1997	2.0	251.7	686.2	50.5	73.9	59.1	534.4	26.0	232.1	**1915.9**
Total	**78.3**	**1614.8**	**1767.2**	**1103.9**	**3507.2**	**225.8**	**2697.8**	**640.5**	**1300.9**	**12936.4**

Source: Plantations Department, INRENARE (1998).

Appendix 2. Information on teak growth

Appendix 2.1. Teak growth in Costa Rica, according to age and location

Site	Trees /ha	Age (years)	Spacing (m x m)	Dbh (cm)		Height (m)		Observations
				Average	MAI	Total	Commercial	
Barra Honda	1 000	3	3x3	10.6	3.55	10.0		Deep flat soil. Plantation without management (Pwm).
Bernabela, Sta. Cruz	700	3.0	3.5x3.5	4.2	1.39	3.0		Heavy soil, comp., poor drainage, Pwm.
La Arena, Hojancha	1 000	3.0	3.0x3.0	8.1	2.69	8.5		Fertile soil, 25% Good mgt.
Nambí, Nicoya	800	4.5	3.0x3.0	13.5	3.0		12.0	Fertile flat soil Poor mgt.
Puerto Carrillo, Hojancha	750	7.0	3.0x3.0	16.2	2.45	19.6		Fertile site, 5%
Guarial, Paquera	1 840	6.0	2.5x2.0	10.8	1.8	12.0		Fertile flat soil, Pwm. (2000/ha)
	Up to 700	13.0	2.17					
Corozal, Jicaral	400	7.0	3.0x3.0	21.2	3.0	18.3	13.1	Smooth slope Two thinnings
Palo Arco,	640	6.0	3.0x3.0	18.3	3.05	14.8		
San Gerardo	600	7.5	3.0x3.0	20.1	2.7		14.0	
	Up to 400			24.1	3.2			
Cabo Blanco Jicaral	550	8.0	3.0x3.0	17.3	2.2	15.7	9.1	Good hill 10% Poor clearing at 8 years 61% live, 22% mort. and 17% thinning
	Up to 400			18.2	2.3			
Monterrey, San Carlos	244	8.0	3.0x3.0	19.6	2.45	18.1		
La Esperanza/C. Blanco, Lepanto	500	8.0	3.0x3.0	23.9	2.99	17.7	9.1	Excellent site 10% Clearing 1997, 56% live, mort. 30% & 14% thinning
San Juan, Sta, Cruz	800	8.0	3.0x3.0	18.6	2.32		11.0	Flat soil, Fertile Regular mgt, one thinning.

Appendix 2.1. Continued.

Site	Trees /ha	Age (years)	Spacing (m x m)	Dbh (cm)		Height (m)		Observations
				Average	MAI	Total	Commercial	
Pedernal, Nicoya	1 600	8.0	2.5x2.5	13.2	1.65	12.7		Regul. Soil qualit. Pltn. Without mgt
	350	17.0		18.8	1.78	17.7	11.2	Thinning in yr 15
San Juan, Queb. Honda, Nicoya	740	8.0	3.0x3.0	19.9	2.5	13.0		Stony soil, 10 % Thinning in yr 7
	Up to 400			20.0	2.5			
	400	17		24.9	1.47	20.8	11.75	Thinning in yr 16
	Up to 200			26.8	1.58			
Morote, Nicoya	2 000	9.0	3.0x3.0	16.1	1.79	16.5		Flat soil, fertile No mgt.
	Up to 400			20.5	2.28			
	500	18		19.0	1.06	18.5	10.2	
	Up to 200			22.2	1.23			
San Rafael, Hojancha	1100	9	2.5x2.5	15.1	1.67	10.5		35% hill, Regul manag., one clear.
Guarial, Paquera	625	10.0	5.0x3.0	19.1	1.91	15.0		Flat soil, fertile
	Up to 200			22.6	2.26			Manag. one clear.
Los Angeles, Hojancha	1975	10.0	2.0x2.0	14.4	1.44	12.0		Hilly soil, little depth., without management and slope above 15%
	Up to 200			17.4	1.74			
	550	19		21.0	1.11	17.7	17.7	
	Up to 200			24.0	1.26			
Nambí, Nicoya	864	10.0	3.0x3.0	19.6	1.95	15.0		Flat soil, fertile
	Up to 200			22.6	2.26			Reg. Mgt. (1480)
Hojancha, Célimo	400	11.0	3.0x3.0	24.0	2.18	21.7	13.3	40% slope Strong erosion, 3 thinnings
La Balsa, Jicaral	500	14.0	2.0x2.0	24.1	1.72	24.4	14.8	Flat, excellent condition, Thinning in 9 years and another opening 1997
	Up to 200			26.4	1.89			
Vainilla de Canjel, Jicaral	900	14.0	2.0x2.0	20.8	1.49	23.1	15.1	Exc.site, 5 % slope, thinning, heal. and at most, in 13 years.

Appendix 2.1. Continued.

Site	Trees /ha	Age (years)	Spacing (m x m)	Dbh (cm)		Height (m)		Observations
				Average	MAI	Total	Commercial	
Matambú, Hojancha	500	17.0	3.0x3.0	21.4	1.26	11.6		20% slope. Thinning at 16 years
	Up to 200			22.8	1.34			
Pilangosta, Hojancha	370	12.0	2.5x2.5	23.7	1.97	23.1	16.4	20 % slope, Good soil 3 thinnings (1600 initial density)
San Juan, Sta. Cruz	1 100	13.0	3.0x3.0	24.1	1.85	12.0		Flat fertile soil Regular mgt., 800/ha
S. Juan, Sta.Cruz	277	37	6.0x6.0	41.7	1.13	20.3	14	Flat fertile soil Poor to absent mgt.
Boca Tapada, Pital	1 111	1.0		6.97	6.97	7.0		Alluvial soil/RSC
El Cóbano, Los Chiles	1 298	2.0		8.5	4.25	10.1		Irregular relief
Santa Clara, San Carlos	1 111	2.0		7.8	3.9	8.0		Alluvial soil
Dominical, Osa	1 100	2.8		2.0	0.71	2.7		Hills
Boca Tapada, Pital, San Carlos	700	5.0		22.5	4.56	20.0	10.3	Alluvial soil, flat
Río Kooper, Pier, San Carlos	550	13.0		29.8	2.29	24.8	15.6	Alluvial soil, flat

Source: Field data from the author; Vallejos (1996); Espinoza (1997) and collaborations from José M. Valverde, Forest Engineer, MINAE/Hojancha

*: Sites with flat and fertile soils; generally correspond to flood plains or bases of mounts in areas with summers that last more than three months, effective depth above 60 cm and without obstructions for root penetration.

Appendix 2.2. MAI of dbh and average commercial and total height for teak plots in Costa Rica under situations of without management and with management

		Age (years)				
Variable	Condition	2	4	8	15	more than 15
MAI dbh	Without mgt.	1.68	3.08	2.38	1.82	1.20
	With mgt.			2.69	2.06	1.37
Total height	Without mgt.	6.05	12.0	15.5	19.5	20.0
	With mgt.			16.3	21.1	20.8
Comm. height	Without mgt.			11.4	14.3	11.0
	With mgt.			11.5	15.6	11.5

Source: Picado (1997)

Appendix 3. Flor y Fauna S.A., Costa Rica Reforestation Program

Ph.D. Pablo Camacho
Silviculturist

INTRODUCTION

Flor y Fauna S.A., a private company founded and managed by a Netherland family, is located at Altamira, San Carlos, the north region of Costa Rica. On 1997 it received the Smart Wood Program certification as a Good Managed Forest Operation. This operation consists mainly of planting and industrializing teak. As a complement to teak plantation, around 90 species have been used to establish biological corridors along drains and water ditches. It also has 470 ha of primary forest for conservation and enrichment of biodiversity.

Integration of social aspects, environmental conservation, profits and good forest growth are some of the characteristics which have contributed to the certification, especially due to the fact that reforestation was done on soils degraded by cattle farming.

More than 2.700 ha of teak have been planted, together with some 90 ha of forests planted in protection areas. The Company has an Administrative Office Centre, houses for employees and their families, school, medical community service and a sports area. The industrialization project has become very important, and steps were taken to establish a Free Zone inside the farm.

In 1997, they also received the Chain of Custody certification by Smart Wood, the Forest Stewardship Council registered it as certified plantations.

PLANTED AREA

Reforestation started on 1989 with the establishment of Teakwood 1 project. From this year on, plantation continued and the areas are shown on Table 1. Total planted area is 2,717 ha. A permanent sample plot system for monitoring plantations was developed (100 trees per plot), that covers 0.84 percent of the reforested area.

Stands Growth

The plantation measuring process started on 1994, and they have consecutive evaluations of the last five years. Table 2 shows the development of the oldest project (Teakwood 1), which presents the smallest average growth rate of the Company's projects. The Mean Annual Increment for this project is 2.0 cm, 1.91 m and 17.3 m^3 per/ha/year for diameter, height and total volume, respectively.

Table 3 presents the data from a couple of plots from Teakwood VI project. These areas have the best growth rate of the Company's projects. The Mean Annual Increment for this quality site is 3.7 cm, 3.8 m and 40.9 m^3 per/ha/year for diameter, height and total volume, respectively.

All the data has been used on growth projections for the reforestation projects. Table 4 shows the initial development of the project Teakwood VII during 4.5 years and the growth projection after this age. The total and commercial volume projections (volume u.b., minimum diameter of 8 cm) are also included. The estimated rotation age is 20 years and, for that age, the Mean Annual Increment projected is 25.3 m^3/ha/year of total volume, and a growth of 18.5 m^3/ha/year u.b. to a minimum diameter of 8 cm.

Table 1. Data of the plantation projects. Area, planting year and monitoring intensity by project. Flor y Fauna S.A. San Carlos, Costa Rica

Planting Project	Planting Year	Area (ha)	Number of Plots	Plot's Area (m^2)	Sampling Intensity
Teakwood I	1989	30	10	625	2.08%
Teakwood II	1990	10	6	625	3.75%
Teakwood III	1990	80	18	625	1.41%
Teakwood IV	1991	150	18	625	0.75%
Teakwood V	1992	300	30	625	0.63%
Teakwood VI	1993	737	120	576	0.94%
Teakwood VII	1994	710	96	576	0.78%
Teakwood VIII	1995	700	89	576	0.73%
Total		**2 717**	**387**		**0.84%**

Thinnings

Table 2 presents the thinning regime. Thinnings have been continuous, but of low intensity. The goal is to reduce to have 240 trees/per ha at final harvest (year 20). As the present density of Teakwood 1 project is 501 trees/ha, it is possible to do two more thinnings before final harvest. As Teakwood 1 to Teakwood V projects presents similar site conditions, hilly soils (Ultisols), the same thinning plan will be applied.

Table 4 presents the thinnings program of project Teakwood VI, the same that will de used in projects Teakwood VII and VIII. The technical criteria is of frequent low intensity thinnings to maximise the stands' production. Thinning intensity and frequency will adjust its according to stand dynamics.

Pruning

Early pruning has been a traditional in the Company, not only to produce superior quality stands, but also to facilitate mechanized operations in the stands. The first rule was to eliminate all the branches of the first half of the tree (50 percent intensity based on total tree height).

As constantly new branches grew on the pruned part of the steam, it was decided to keep the same pruning intensity but of only the larger diameter branches. This keeps some thin branches on the pruned segment (2 or 3), and the tree produces less branches on this area, and the top of the tree has a better development (un-pruned segment). The practices forces to come back latter to prune the small branches. However, this is more economic than total pruning, that keep re-growing.

Diameter and height growth from the pruning trials (0, 25, 33, 50 and 66 percent of total tree height) did not have statistically significant differences in the first year. It is speculated that results should be significant on inferior quality sites and/or regions with a better defined growing season, as is the Pacific Coast of Costa Rica.

Table 2. Growth development for Tectona grandis in Vasconia, San Carlos. Information for Project TEAKWOOD I, before and immediately after the application of thinning (shadow areas)

Project Name	Age (years)	Trees (n/ha)	Diameter (cm)		Height (m)	Basal Area (m^2/ha)			Total volume (m^3/ha)				
			Stand	CAI		Stand	Removed	Total	Stand	Removed	Total	MAI	CAI
TW1_JAN94	4.5	1325	7.8		7.9	6.33	-----	6.33	32.34		32.34	7.19	
TW1_JAN95	5.5	1325	10.2	2.4	11.3	10.82	-----	10.82	62.28		62.28	11.32	29.94
		1006	11.1		12.2	9.47	1.35	10.82	57.35	4.92	62.28		
TW1_JAN96	6.5	1006	13.1	2.1	13.6	14.36		15.71	85.16		90.09	13.86	27.81
		850	13.7		13.9	12.85	1.51	15.71	79.56	5.61	90.09		
TW1_JAN97	7.5	850	15.3	1.6	15.7	15.95		18.81	108.89		119.42	15.92	29.33
		658	15.5		15.8	12.84	3.11	18.81	86.98	21.91	119.42		
TW1_JAN98	8.5	658	17.3	1.8	16.3	15.69		21.66	114.72		147.16	17.31	27.74
		501	18.2		16.9	13.18	2.51	21.66	98.41	16.31	147.16		

Table 3. Growth development for Tectona grandis in Altamira, San Carlos. Information for lots 6 and 13 within Project TEAKWOOD VI, before and immediately after the application of thinning (shadow areas)

Project Name	Age (years)	Trees (n/ha)	Diameter (cm)		Height (m)	Basal Area (m2/ha)			Volume (m3/ha)				
			Stand	CAI		Stand	Removed	Total	Stand	Removed	Total	MAI	CAI
TW6_AUG95	2.0	1489	9.3		10.8	10.30	-----	10.30	58.29	-----	58.29	29.15	-----
TW6_JAN96	2.5	1474	11.1	1.8	12.1	14.10	-----	14.10	84.38	-----	84.38	33.75	-----
		1211	11.6		13.1	12.80	1.30	-----	80.03	4.35	84.38	-----	-----
TW6_JAN97	3.5	1206	14.0	2.4	15.5	18.60		19.90	129.70		134.05	38.30	49.67
		930	14.0		15.4	14.40	4.20	-----	99.42	30.28	134.05	-----	-----
TW6_JAN98	4.5	929	16.6	2.6	17.0	20.11		25.61	149.64		184.26	40.95	50.21
		716	17.6		17.8	17.43	2.68	-----	134.35	15.29	184.26	-----	-----

Stand means based on 8 permanent plots

Table 4. Initial development of Tectona grandis (Project TEAKWOOD VI). (bold section) and growth projection for a Class I site. San Carlos, Costa Rica. June, 1998. When the value in the table goes down it refers to the growth parameter immediately after the thinning (shade areas)

Age	Trees	Diameter			Basal area (m^2/ha)			Total volume (m^3/ha)				Commercial volume (m^3/ha)			
(years)	(n/ha)	(cm)	MAI	Height (m)	Stand	Thinned	Total	Stand	Removed	Total	MAI	Stand	Removed	Total	MAI
0.0	1736				0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.0	1627	5.4		6.0	4.10		4.10	23.54		23.54	11.77	0.00		0.00	0.00
3.5	1624	10.5	3.01	11.5	14.20		14.20	81.35		81.35	23.24	23.53		23.53	6.72
	1324	11.5		11.9	12.40	1.80	14.20	72.48	8.87	81.35		23.53	0.00	23.53	
4.5	1324	12.9	2.87	13.8	17.20		19.00	110.47		119.34	26.52	55.18		55.18	12.26
	977	12.9		13.8	12.90	4.30	19.00	82.85	27.62	119.34		40.72	14.46	55.18	
5.5	977	14.9	2.71	15.8	17.04		23.14	119.99		156.48	28.45	72.03		86.49	15.73
	765	14.9		15.8	13.34	3.70	23.14	93.96	26.04	156.48		56.40	15.63	86.49	
6.5	765	16.9	2.60	17.7	17.16		26.96	132.44		194.97	29.99	87.73		117.82	18.13
	650	16.9		17.7	14.58	2.58	26.96	112.53	19.91	194.97		74.54	13.19	117.82	
7.5	650	18.8	2.51	19.5	18.04		30.42	151.35		233.78	31.17	106.13		149.41	19.92
	550	18.8		19.5	15.27	2.78	30.42	128.06	23.28	233.78		89.80	16.33	149.41	
8.5	550	20.6	2.42	21.0	18.33		33.48	164.17		269.89	31.75	119.19		178.80	21.04
	468	20.6		21.0	15.60	2.73	33.48	139.70	24.48	269.89		101.42	17.77	178.80	
9.5	468	22.3	2.35	22.0	18.28		36.16	170.56		300.76	31.66	126.54		203.92	21.47
10.5	468	23.9	2.28	22.5	21.00		38.88	199.65		329.85	31.41	150.22		227.60	21.68
	398	23.9		22.5	17.86	3.14	38.88	169.79	29.86	329.85		127.75	22.47	227.60	
11.5	398	25.4	2.21	23.0	20.17		41.19	195.49		355.55	30.92	148.67		248.52	21.61
12.5	398	26.8	2.14	23.5	22.45		43.48	221.89		381.94	30.56	170.15		270.00	21.60
	338	26.8		23.5	19.07	3.38	43.48	188.44	33.45	381.94		144.50	25.65	270.00	
13.0	338	27.5	2.12	23.8	20.08		44.49	200.74		394.25	30.33	154.52		280.02	21.54
14.0	338	28.8	2.06	24.2	22.02		46.43	223.53		417.04	29.79	173.07		298.56	21.33
14.5	338	29.4	2.03	24.4	22.95		47.36	234.72		428.22	29.53	182.17		307.67	21.22
	288	29.4		24.4	19.55	3.39	47.36	200.00	34.72	428.22		155.22	26.95	307.67	
15.0	288	30.0	2.00	24.6	20.36		48.16	209.82		438.05	29.20	163.22		315.66	21.04
16.0	288	31.1	1.94	24.8	21.88		49.68	227.11		455.34	28.46	177.29		329.74	20.61
17.0	288	32.1	1.89	25.0	23.31		51.11	243.72		471.95	27.76	190.81		343.25	20.19
	240	32.1		25.0	19.42	3.88	51.11	203.10	40.62	471.95		159.01	31.80	343.25	
18.0	240	33.0	1.83	25.1	20.53		52.22	215.38		484.23	26.90	169.00		353.25	19.62
19.0	240	33.8	1.78	25.2	21.53		53.22	226.73		495.58	26.08	177.88		362.13	19.06
20.0	240	34.5	1.73	25.3	22.44		54.12	237.06		505.91	25.30	186.65		370.90	18.54

Pruning is more effective starting from the canopy, and it must be a low intensity one (no more than 33 percent). Branch re-growth on the pruned segment is greatly influenced by light that penetrates the canopy. It has been noticed that, after the leaves fell down during a strong dry season, the amount of sprouts on the pruned segment increases.

Growth Projections

Data from the last five years allowed to estimate four growth scenarios of the potential development of Flor y Fauna's plantations are given in Table 5. This data was complemented with information from older plantations, like Miller's yield tables (1969) for Trinidad. Table 5 presents a four scenarios' summary. Estimated commercial volume MAI was 9.3 and 22.9 m^3/ha/year, and 13.4 and 31.4 m^3/ha/year for total volume. Total volume Maximum Current Annual Increment was 50.2 m^3/ha/year.

The fourth scenario of maximum possible production was not take in to account for the total volume as, today there is no certitude that the areas that will reach this growth potential.

Table 5. Summary of four production scenarios (total and commercial volume) developed for Flor y Fauna's plantations, 20 years rotation. San Carlos, Costa Rica

Site Class	Project	No of trees (n/ha)	dbh (cm)	Height (m)	Total Volume (m^3/ha)			Commercial Volume (m^3/ha)		
					Stand	Acum.	MAI	Stand	Acum.	MAI
Low	Teakwood I	240	28.6	20.2	131	267	13.4	100	187	9.3
Medium	Teakwood III	240	31.8	22.5	180	396	19.8	140	284	14.2
High	Teakwood VI_a	240	34.5	25.3	237	506	25.3	187	371	18.5
Maximum	Teakwood VI_b	240	37.2	27.3	297	627	31.4	235	457	22.9

According to Table 5's production scenarios and to the growth potential shown at the beginning, each planting project was assigned to one of the three production scenarios (low, medium, and high). Afterwards, all projects were grouped according to time, to estimate total volume of all them. Table 6 shows the volume per year and per project, projected total thinning volume, and the remaining timber volume (standing) of the stands. Total production was estimated at 1.4 million of cubic meters for a 20 years rotation. Table 7 presents log estimated volume by diameter class (892,364 $m^{3)}$. A conversion from total to industrial volume will be reached by trying to increase the average diameter of logs.

Table 6. Preliminary projection for the stand and thinning volume of Flor y Fauna S.A. The final harvest was defined for year 20. Shadow values refers to the stand volume after thinning

	Stand volume by project (m^3/ha)								Total volume (m3/ha)	
Year	TW 1	TW 2	TW 3	TW 4	TW 5	TW 6	TW 7	TW 8	Stand	Thinned
1997	2 897.2	1 216.7	12 324.0	18 633.0	24 720.0	58 092.0	10 290.0	7 179.1	135 352.0	
	2 259.8	809.4	9 242.4	15 391.5	22 020.0	51 747.0	10 290.0	7 179.1	118 939.2	16 412.8
1998	2 742.7	1 114.3	10 166.5	23 107.5	32 172.5	75 605.4	57 680.0	10 407.6	212 996.5	
	2 275.2	869.1	8 762.1	17 329.5	27 533.8	64 704.5	51 380.0	10 407.6	183 261.9	29 734.5
1999	2 610.9	1 054.9	9 516.7	19 062.1	38 974.8	91 590.7	75 069.2	58 339.2	296 218.5	
	2 221.6	875.1	8 052.6	16 428.9	30 947.8	72 727.4	64 245.6	51 967.2	247 466.3	48 752.2
2000	2 516.7	1 004.2	9 190.1	17 843.8	46 451.9	109 162.1	90 941.2	75 927.1	353 037.0	
	2 140.2	854.5	7 787.5	15 098.6	39 469.0	92 752.1	72 211.6	64 979.9	295 293.3	57 743.7
2001	2 412.9	967.9	9 573.6	17 231.5	43 606.5	102 475.2	108 387.9	91 980.5	376 635.9	
	2 412.9	823.2	8 141.7	14 601.5	36 744.3	86 349.2	92 094.3	73 036.9	314 203.9	62 432.0
2002	2 708.2	928.0	9 796.7	17 950.6	43 685.3	102 660.5	101 748.4	109 626.6	389 104.3	
	2 302.0	928.0	9 796.7	15 265.6	37 172.2	87 354.8	85 736.8	93 146.8	331 703.0	57 401.3
2003	2 758.8	1 041.6	11 576.6	18 368.9	53 959.0	103 299.7	101 932.4	102 911.3	395 848.3	
	2 758.8	885.4	9 864.3	18 368.9	45 888.2	103 299.7	86 735.2	86 716.6	354 517.1	41 331.2
2004	2 833.9	1 061.1	11 747.8	21 706.2	55 327.5	126 803.7	102 567.0	103 097.4	425 144.7	
	2 414.7	1 061.1	11 747.8	18 495.5	55 327.5	107 837.4	102 567.0	87 726.5	387 177.6	37 967.1
2005	2 820.1	1 090.0	12 393.7	22 027.2	65 478.7	130 019.7	125 904.4	103 739.2	463 473.0	
	2 820.1	928.7	10 560.3	22 027.2	55 795.1	130 019.7	107 072.6	103 739.2	432 962.9	30 510.1
2006	2 977.8	1 084.7	12 449.3	23 238.2	66 537.5	153 874.9	152 783.6	127 343.3	540 289.3	
	2 481.4	1 084.7	12 449.3	19 800.6	66 537.5	131 118.4	130 188.5	108 296.2	471 956.6	68 332.6
2007	2 718.0	1 145.3	13 829.4	23 342.4	70 221.1	156 363.2	138 180.9	154 529.7	560330.0	
	2 718.0	954.4	11 524.8	23 342.4	59 648.4	156 363.2	138 180.9	131 676.4	524 408.5	35 921.5
2008	2 969.7	1 045.4	12 911.2	25 930.2	70 606.6	165 019.5	155 254.2	139 760.1	573 497.0	
	2 969.7	1 045.4	12 911.2	21 609.0	70 606.6	140 175.2	155 254.2	139 760.1	544 331.4	29 165.6
2009	3 235.7	1 142.2	14 352.8	24 208.5	78 478.1	165 925.6	163 849.2	157 028.5	608 220.6	

Table 6. Preliminary projection for the stand and thinning volume of Flor y Fauna S.A. The final harvest was defined for year 20. Shadow values refers to the stand volume after thinning

	Stand volume by project (m^3/ha)								Total volume (m3/ha)	
Year	**TW 1**	**TW 2**	**TW 3**	**TW 4**	**TW 5**	**TW 6**	**TW 7**	**TW 8**	**Stand**	**Thinned**
	3 235.7	1 142.2	14 352.8	24 208.5	65 397.0	165 925.6	139 179.7	157 028.5	570 470.0	40 986.2
2010	---	1 244.5	15 032.8	26 911.5	73 308.0	184 423.4	164 748.8	165 721.7	631 390.8	
	---	1 244.5	15 032.8	26 911.5	73 308.0	153 683.0	164 748.8	140 770.3	575 698.9	71 969.2
2011	---	---	---	28 186.5	81 531.0	172 273.8	183 115.5	166 631.7	631 738.4	
	---	---	---	28 186.5	81 531.0	172 273.8	152 593.0	166 631.7	601 216.0	58 709.0
2012	---	---	---	---	85 410.0	191 597.9	171 052.0	185 208.2	633 268.1	
	---	---	---	---	85 410.0	191 597.9	171 052.0	154 336.9	602 396.8	116 281.3
2013	---	---	---	---	---	200 713.5	190 239.0	173 006.9	563959.4	
	---	---	---	---	---	200 713.5	190 239.0	173 006.9	563959.4	200 713.5
2014	---	---	---	---	---	---	199 290.0	192 413.2	391703.2	
	---	---	---	---	---	---	199 290.0	192 413.2	391703.2	199 290.0
2015	---	---	---	---	---	---	---	201 567.6	201567.6	
* Refers to the final harvest at 20 years of age									0.0	201 567.6
									Total	**1 405 221.4**

Table 7. Preliminary stem and log volume estimation by diameter class from the thinning operations and final harvest of the different reforestations projects (2679 ha). Projections for a 20 years rotation. Flor y Fauna S.A. Altamira de San Carlos

Year	Area (ha)	Diameter (cm)	Height (m)	Log volume by diameter class (m^3)				Total stand volume Thinnings and final cutting (m^3/ha)
				8 - 11 cm	11.1 - 14 cm	14.1 cm +	Total	
1998	2,679	17	17	7,434	5,947	1,487	**14,867**	29,735
1999	2,679	19	18	12,188	9,750	2,438	**24,376**	48,752
2000	2,679	20	19	14,436	11,549	2,887	**28,872**	57,744
2001	2,679	22	20	15,608	12,486	3,122	**31,216**	62,432
2002	2,679	23	21	14,350	11,480	2,870	**28,701**	57,401
2003	2,679	25	22	6,200	10,333	4,133	**20,666**	41,331
2004	2,679	25	22	5,695	9,492	3,797	**18,984**	37,967
2005	2,679	27	22	4,577	7,628	3,051	**15,255**	30,510
2006	2,679	27	22	10,250	17,083	6,833	**34,166**	68,333
2007	2,679	28	22	5,388	8,980	3,592	**17,961**	35,922
2008	2,679	29	22	4,375	8,750	5,833	**18,958**	29,166
2009	2,679	31	23	6,148	12,296	8,197	**26,641**	40,986
2010	2,653	32	23	10,795	21,591	14,394	**46,780**	71,969
2011	2,563	32	23	8,806	17,613	11,742	**38,161**	58,709
2012	2,413	33	24	17,442	34,884	23,256	**75,583**	116,281
2013	2,113	34	24	20,071	60,214	70,250	**150,535**	200,714
2014	1,408	36	24	19,929	59,787	69,752	**149,468**	199,290
2015	708	37	24	20,157	60,470	70,549	**151,176**	201,568
Total volume				**203,849**	**380,333**	**308,182**	**892,364**	**1,388,809**

Installed capacity of industry and milling

A description of the main installations and industrial processes of Flor y Fauna S.A. and other related companies (Flor y Fauna Dos S.A. and Ecomaderas S.A.) follows:

Sawmill: 5,916 m^2 in two buildings
Ovens: 1,300 m^2 on four buildings
Yards: 15,000 m^2 for round wood. A wooden building with a roof of 7,500m^2

Flor y Fauna has the following logging and transportation equipment.

Type of Machinery	Description	Units	HP	Use
Farm Tractors	Wheeled Tractor John Deere 5400	10	60	Extraction
"	Wheeled Tractor Same Solar 60	2	45	Sawmill
"	Wheeled Tractor Same Solar 50	3	30	Extraction
"	Wheeled Tractor Lamborgini 1306	3	90	Field
Dredge	Caterpillar E110 B	1	60	Plantation
BackHole	Caterpillar 428 B	2	60	Plantation
Frontal Loader	Caterpillar HIT 18	1	90	Sawmill
"	Caterpillar HIT 28	1	90	Sawmill
(Skidder)	Brimunt	3	90	Extraction
Lift car	Toyota	1	60	Ecomaderas
"	Caterpillar	2	60	Sawmill
"	Caterpillar	1	50	Ecomaderas
"	Hyster	1	50	Maintenance

Timber

Flor y Fauna has 2,717ha of teak planted between 1989 and 1995. All the industrial process has been, and will continue to be, based on this only species. Teak volume covers the Company's expectations.

Sawmilling Process

Logs top end of 8 cm are classified by diameter in three classes, according with the cutting height of the main machines. The standard log's length is 2.2 m. Sawn-wood packaged, to be classified afterwards. The sawn-wood is classified in three qualities and, once graded, is dried.

Capacity per shift

Average log received at mill is 10-cm top diameter and 2.2 m long (0.0173 m^3/log). As log's diameter increases, so does the mill production. Sawmill total capacity 18 000 m^3 yearly/8 h shift, and re-saw's capacity is 27 000 m^3/ year. With an average yield of 40% the sawn-wood production will be 7 200 m^3/shift per year (7 hours shift and 300 working days/year). There is also a machine to conform logs, as a main machine, to round the logs with less than 8 cm of diameter. These rounded logs can be used in the lathe.

Kiln Dryers

There are four Kiln Dryers with a capacity of 100 m^3/each, a total of 400 m^3. The drying period has and average of 20 days, so the drying capacity is of 600 m^3/month (7 200 m^3/year).

Dry Lumber Transportation

Dry lumber is transported to the furniture factory on wagons pulled by a wheeled carterpillar. The distance is less than 400m.

Furniture Process

To use this young lumber it has been necessary to develop new techniques and train the personnel. The factory is divided in two parts: panels and furniture.

Panels

The goal is to take out all the defects that have the sawn with a manual saw machine. Once the defects are removed, the wood is pressed with glue to build the panel.

Furniture Factory

Uses panels and sawn-wood free of defects. Panels are cut precisely to desired length, wide and thickness. After, the pieces are worked and finished (holes, channels, figures). All the equipment is precision machinery. The finished pieces go to automatic or manual sanding machines. Afterwards are stained (coloured), polished, varnished and sealed. Finished pieces are fit together, packed and sent to the market.

Installed Capacity per Shift

The factory has capacity to process 400 m^3/shift/month of dry sawn-wood to 200 m^3 of panels for furniture, and these in to 150 m^3 of furniture, 10 containers/month/shift (15 m^3/container), 120 containers per year.

Final Product

The final product is teak furniture (chairs, tables, kitchen and office cabinets, living room furniture) mouldings and doors. The production is of export quality. Main clients are United States (California) and Europe (The Netherlands). Products are packed on boxes and containers for export.

Projected Growth Plan of Capacity

The growth of the plant regarding labour, production and industrial roof is as follows:

Date	Employees	Prod./month	Containers	Roof (m^2)
Jan./98	100	one shift	3	16 000
Feb./98	125	two shifts	4	16 000
Apr./98	150	two shifts	4	16 000
Jul./98	150	two shifts	6	250 000
Jan./99	300	two shifts	10	250 000

Appendix 4. Maderas Preciosas Costa Rica S.A., Reforestation Program

M.Sc. Edgar Víquez López*
Director, Forest Research Program
Precious Woods, Costa Rica

INTRODUCTION

Since 1990, Precious Woods has been investing on planting projects through his subsidiary Maderas Preciosas Costa Rica S.A. (MACORI S.A.), the administrative and executing unit for planting, management and plantation's maintenance.

These projects have special characteristics. They are carried out in an integrated context with the environment's conservation. Considerable efforts have been done to protect and multiple-use native species. Primary forests are preserved. After studying local wildlife, trees and native shrubs to be planted are chosen according to wildlife food necessities, ornament purposes and timber production. Every year seeds are collected, and nursery seedlings are planted, along roads, borders and sites where teak does not grow well. Some native species like pochote (*Bombacopsis quinatum*) are planted for commercial purposes. Until now, 1,067 ha of native species have been planted, from which 85% was pochote, and the rest of more than 20 native regional species. In 1996 the nurseries produced 160,000 seedlings of 49 native species.

MACORI is one of the few companies which had established a Forest Research Program (PIFOMA, started in 1994) that includes nurseries and plantations tests, evaluation of native species and genetic improvement of the priority species. This lead to the development of innovating systems of seedlings production, and use of high genetic quality tree as seeds sources. Plantation's management has detailed grow data. Systems to determine the pruning and thinning year and intensity have been developed.

TECHNICAL ASPECTS

Planted Area and Species

All projects are in different five farms located in the Guanacaste Province, north-west of the country: Garza which belongs to Nicoya; Río Tabaco and Ostional in Santa Cruz; and Peñas Blancas and Santa Cecilia, in La Cruz. Total area per projects, including protected and reforested areas, are shown on the Table 1.

At present, the Garza, Ostional and Río Tabaco projects have totally planted: In Peñas Blancas 368 hectares has been planted, and 1,161 ha in Santa Cecilia, and both still have areas for planting.

* Address:
P.O. Box 118-7170, CATIE, Turrialba, Costa Rica
Phone: (506) 556 1754, Fax (506) 556 1533
Electronic addresse: eviquez@catie.ac.cr

Table 1. Total and Possible Area to Reforest by Project

Project	Protected Area (ha)	Total Area for reforestation (ha)	Planted Area until 1997 (ha)	Total Area (ha)
Garza	411	868	868	**1 279**
Ostional	110	181	181	**291**
Río Tabaco	441	325	325	**766**
Peñas Blancas	651	900	328	**1 551**
Santa Cecilia	1 377	2 500	1 161	**3 877**
Total Area	**2 990**	**4 774**	**2 863**	**7 764**

Table 2: Planted areas by Project, year and species. Maderas Preciosas Costa Rica S.A.

Project/Species	*YEAR (hectares)*							
	1990	**1991**	**1992**	**1993**	**1995**	**1996**	**1997**	**Total**
Project Garza:								
Teak	38		90	40	46		0	214
Pochote	30	233	312	46				621
Other natives		2	12	8	4	1	6	33
Total	**68**	**235**	**414**	**94**	**50**	**1**	**6**	**868**
Rio Tabaco Project:								
Teak			4				14	18
Pochote	71	138	31	29				269
Others natives	30	8						38
Total	**101**	**146**	**35**	**29**	**0**		**14**	**325**
Ostional Project:								
Teak					141	1	0	142
Pochote					17			17
Others natives					20	1	1	22
Total					**178**	**2**	**1**	**181**
Santa Cecilia Project:								
Teak					416	395	300	1111
Pochote								0
Others natives					18	3	30	51
Total					**434**	**397**	**330**	**1161**
Peñas Blancas Project:								
Teak						178	133	311
Pochote								
Others natives						0	17	17
Total						**178**	**150**	**328**
SubTotals by specie:								
Teak	38	0	94	40	603	573	448	1796
Pochote	101	371	343	75	17	0	0	907
Others natives	30	10	12	8	42	4.8	54	160
Grand Total	**169**	**381**	**449**	**123**	**662**	**578**	**501**	**2863**

Table 2 presents the data of planted areas by species. Until 1993 pochote was the most planted species. Since 1995 teak became the priority species. Up to 1997, 2, 863 ha have been planted. Of them, 63% (1,796 ha) is teak, 32% (907 ha) is pochote and 5% (160 ha) other native species (caoba (*Swietenia macrophylla*), cedro amargo (*Cedrela odorata* and *Cedrela salvadorensis*), ron ron (*Astronium graveolens*), cocobolo (*Dalbergia retusa*), cristóbal (*Platysmicium pleistotachium*), cachimbo (*P.pinnatum*), genízaro (*Pithecolobium saman*), guanacaste (*Enterolobium*

ciclocarpum), guayaquil (*Albizzia guachapele*), guapinol (*Hymenaea courbaril*), surá (*Terminalia oblonga*) and roble sabana (*Tabebuia rosea*).

Plant Production

PIFOMA collects seeds from of previously selected trees for phenotypic superiority. There is a pochote's clonal seed orchard, that produced all the 1995 sticks (plants) for Ostional, as well as for establishing four repetitions families trials, on which the genetic quality of each mother tree is evaluated.

The first clonal seed teak orchard was established in 1996 with buds grafted from plus trees. It is expected that it will start producing sticks by 1999. In 1998 it will start the planting of material from the best teak trees. This process will increase and improve as the clonal tests give better results.

Due to several trials of PIFOMA, the teak nurseries production system was changed. Plants are left in the nursery about 45 to 60 days after being transplanted, and then they are take to the field. This has increased the survival to over 90%, even when dry periods follow plantation. Nursery's maintenance costs have been reduced, and plant sizes permits to use a smaller plastic bag, diminishing the transportation costs. Another important effect from this system is that plants do not have wounds which may contribute to illnesses, especially *Agrobacterium* or fungus. Initial growth does not show significant differences with stump materials, but reduces the costs of the initial formation pruning.

Native species are also planted in plastic bags, except pochote (sticks with pruned roots).

Establishment and plantation management

General, planting is done in formerly pastures and cattle raising areas. When conditions allow it, land preparation is done with disk plough and rippers. From 1995 on, the selected spacing between trees is 3.5 x 3.5 m. (816 trees/ha). Before distances varied, with densities between 400 to 1,000 trees/ha

PIFOMA measures the plantations every year or two, to evaluate, detect growth problems and suggest corrective measures. This data is also used to define the moment and intensity for pruning and thinning.

Recently, foliar biomass studies have been performed in plantations of different ages and site qualities. Its main objectives are to develop a pruning system where it's possible to calculate the pruning height and frequency, to guarantee an optimum proportion of wood free of knots, and to diminish costs of this silvicultural intervention. The system is being implemented on commercial plantations. Different intensities of pruning for teak and pochote are tested to check its efficiency. Results will be published on technical or scientific magazines on 1999.

Due to the variability of tropical site conditions, (even inside a small track of land you could find areas with a high, medium and low site index), a decision was made to program thinnings based on the measurements of the permanent plots. Because of possible errors, it is not convenient to generalize frequency and intensity. Thinnings could be made too early or too late or, if it is done with a very low intensity, it will not have the desired effect on the stand. The general criteria is to reduce the basal area when it reaches the 20 m^2/ha level to 14 m^2/ha. This system does not work on plantations with densities of less than 600 trees/ha. To facilitate it's implementation a matrix was developed. With a simple field measure, the technician determinates the thinning intensity, based on basal area and plantation density.

Plantation Growth

The estimated rotation age is 25 years for teak and 30 for pochote, but this may vary according to site quality and market demands.

A study is being done in 1990 and 1991 on teak and pochote plantations of the Garza's project. Based on the particular site conditions, the establishment and management of this plantations, growth tables and production projections for thinnings and final harvest will be calculated, to be used in financial analysis to determine the moment of investment for industrialization.

Garza's project site index has been calculated (base age of 10 years). Results show that more than 85% of the pochote's plantations area is in medium and high Site Class. In its first years, the spacing has contributed to fast diameter growth and reduced height, so it is difficult to make thinning yields projections, in part because the growth does not correspond to values of the existing equations. However, the Company expects logs with larger diameters than the ones of Alfaro's tables (1990) and Hughell.

In 1997 measurements of 7 years old teak plantations (Garza project 1990), with the exception of two plots with site index lower than 21 (medium) all the plots showed a high site index. It is possible that they might be influenced by spacing and initial management. The values were compared with Miller's growth table (1969, mentioned by CATIE, 1991). The results showed great similarity in height, diameter and basal area on this age. It was decided to use this yield table to make an appraisal of the thinnings. Miller (1969) reports a very high initial density (2,196 trees/ha), but a first thinning on the third year reduces the density to 988 trees/ha. Later on, thinnings are done in years: 7, 12, 18 and 26 and, in year 37th they have only 76 trees/ha. The company evaluates site quality after the fourth or fifth year, and interventions and yields are projected. In Precious Woods, thinnings were planned up to year twelve. Periodical evaluations are done (every 2 or 3 years) to determine need and intensity of this practice. In 1997 the first thinning was done, and results were very similar to the ones reported by Miller.

Plantations are measured every 1 - 2 years, and technical report is prepared, including average values by plot and stand. The maps of the farms are being digitalized in a GIS system, with references to areas, species, planting year and site quality. The goal is to have a clearer idea of the production. Good sites require to be thinned more often than medium or low quality ones. So thinnings of areas of different quality sites and ages will produce timber of different sizes and qualities.

The oldest pochote's (1990-91) have average diameter increments of 2.5 to 3.7 cm/year. MAI in height goes from 1.3 m to 1.8 m. For teak's older plantations, the average diameter MAI varies from 2.7 cm and 2.8 cm, and from 2.2 m to 2.4 m of height.

MARKETS

Studies started on 1998 with estimates of thinning yields and final harvest of the oldest plantations (6 to 8 years old), and were complemented with digitalized GIS maps of the farms, the planting years, species, slopes, site quality and location of permanent plots. The goal is to project, as precisely as possible, the total volume to be cut/year in each farm, by species, as well as the dimensions of the products, and their possible uses. Studies have been started to find markets for the products, and determinate prices.

EXPANSION POTENTIAL

Presently, the Company projects to expand its planted area to twelve thousand ha. Today, 63% of the available area have been planted with teak, and the trend is to maintain, at least, this proportion. The remaining available area is 1,911 ha in Santa Cecilia and Peñas Blancas (Table 1), will allows to continue planting an average of 400 to 500/ha/year up to year 2001.

RESEARCH PROGRAM

PIFOMA's first activity was to prepare a Research Plan and its budget. The three research lines were approved: 1. teak and pochote genetic improvement; 2. native species trials and; 3. research for help management (Víquez 1998).

Through systematic evaluation of materials from both selected species improvements on growth, stem form and wood quality, as well as a reduction of rotation age are expected at medium and long term periods (5 to 15 years). Selection and propagation of superior genotypes of vegetative material of both selected species (clonal tests and clonal orchards), are expected to produce vegetative material for pilot plantations after the third year.

At present, 17 species native species on pure and mixed plantations are been evaluated, in 6 test with 3 or 4 repetitions each one with annual or bi-annual measurements. On 1998 the process of selection superior trees of some of these species for vegetative propagation was started.

The commercial plantations are monitored through permanent plots to detect problems and silvicultural interventions. The following is a list of trials established on this line of PIFOMA's activities:

- Pruning intensities on teak and pochote plantations
- Lime application and teak's growth
- Teak and pochote and different types of nursery materials
- Evaluation on different containers for teak production in nursery
- Trial of *Leguminosae* cover on commercial plantations of pochote
- Evaluation of natural regeneration in plantations with a low site index.

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Appendix 5. Reforestation Project of Bosque Puerto Carillo S.A. Guanacaste, Costa Rica

M.Sc. Rodolfo Quirós Herrera.
Silviculturist

BACKGROUND

Bosque Puerto Carrillo S.A. (BPC), a private company, started commercial plantation in 1983, establishing 12 hectares of pochote (*Bombacopsis quinatum*), a native species of high commercial value in the domestic market. In 1986 the company tried teak (*Tectona grandis*), planting on almost 30 ha that first year. After comparing the initial development of this species with pochote, the BPC's technical board adopted teak as the main species of the project, and the only one for new plantations from 1987.

As land limitated the project's expansion in Puerto Carrillo, on 1991 they started operations in Jabillos de Nandayure, on "Palo Arco", a different site, with mainly flat or slightly hilly, convenient for mechanical means. Between 1986 and 1994 BPC's project grew in extension, and now has five phases. Three of them, the older ones, are teak and pochote plantations established near Puerto Carrillo and Buenos Aires of Sámara, known as Puerto Carrillo's Management Unit . The forth and fifth phases (Bosque IV and V) are homogenous teak plantations, area Palo Arco's Management Unit, with two plantations blocks; Jabillos and Moravia.

To increase the aggregated value of the forest plantations, and profit from an integration of the forest with the industry, on 1992, some BPC's partners formed Industrial Bosque Puerto Carrillo (IBPC),. This new entity was to process and market BPC's productions. Between 1993 and 1994 IBPC built an industrial plant at Palo Arco, designed to produce teak parquet. The plant has sawing section, drying ovens, parquet line and a varnishing section. Today IBPC is faced with the challenge to innovate and diversify its production line, and introduce high quality teak products in competitive markets.

PHYSIOLOGICAL AND TECHNICAL BASIS

Species requirements (region's soils, climate, topography)

The BPC plantation project is located on the Pacific North Coast of the country, in the southern part of the Nicoya's Peninsula, in areas classified as Tropical Rain Forest (bh-T) and Premontano Rain Forest (bh-P). The bh-T (warm and rainy area), seems not to coincide with the Nicoya (Dry Pacific). Nevertheless, not all the region is dry. To the south, the annual average of rainfall increases. There is a dry season of almost five months, a rainy period with a rainfall of 2,500 and 3,000 mm/year and temperatures above 30 degree centigrade.

Teak plantation's topography varies from almost flat lands (0 - 3%), to rolling areas (3 - 15%) and hilly areas with slopes between 30 to 60%. For teak requirements, flat ground is appropriate, if clay and/or severe drainage problems are not present. Areas with a rolling topography and good drainage conditions are suitable for teak. When it is not possible to provide an integrated silvicultural management with native species, teak should not be planted on very hilly areas due to the high erosion risk.

BPC teak plantations' soil conditions vary from typical Vertisols soils, where teak development is poor, to deep aluvial soils with high natural fertility, very good for teak. Some rolling areas (2-25%) are classified as Alfisols of the Haplustaf group, whose principal elements are a horizon with a minimal development (hapl), under a humidity regime ustic. They remain dry for more than 90 consecutive days/year.

On the flat regions, the most common are aluvial soils from old river overflowed shores, with isolated patches of vertisoils soils having serious limitations for teak development. As they have low infiltration rates and poor drainage, in the rainy season they have anaerobic processes with roots putrefaction. During dry months, the vertisoils crack, breaking the roots that survived the bad drainage conditions. In the rolling area, with flat parts and gentile slopes, in red-brownish tonality soils of medium deep, teak's development is satisfactory.

To determinate soil fertility, soils samples from 0 and 40 cm depth were collected. In general, soil acidity was within teak's requirements; with average pH between 5.6 and 6.9. Deficit of phosphorus and zinc were reported.

Planted area per year

The BPC planting project has 3,851 ha, of which 82% (3,174 ha) area considered as teak planted area, and a 2.1% (82 ha) as pochote stands. The remaining 15.5% (595 ha) is destined to roads, yards, buildings or natural forest for conservation. Yearly planted area by species and project's phase is shown in Table 1 and Table 2.

Table 1. Annual area planted(hectares) with Pochote (Bombacopsis quinatum) by phase of the BPC project

Year	Phase I	Phase II	Total
1983	12	0	12
1984	20	0	20
1985	20	0	20
1986	0	30	30
Total	**52**	**30**	**82**

Table 2. Annual area planted with Teak (hectares) by phase of the BPC project

Year	Phase I	Phase II	Phase III	Phase IV	Phase V	Total
1986	7	3				10
1987	59	30				89
1988	131	129				260
1989	3	208				211
1990			398			398
1991			214	758		972
1992				646	189	835
1993				30	296	326
1994					73	73
Total	**200**	**370**	**612**	**1,434**	**558**	**3,174**

Rotation Age

The cut of trees happens during the pruning and in the final cut. Because teak presents growth trends with high rates on the first eight or twelve years (according to the site quality) and later it finishes, at BPC all the pruning are programmed before the year twelve. As definitive rotation age will depend on future preferences for the teak products and their prices, a preliminary turn of 25 years has been determined, based on biologic considerations.

The plantation's density is regulated by a thinning program whose goal is larger diameters improvement and in consequence the profitable volume of the plantation. Is important concentrate the growth potential in the best trees. It means to program the pruning as soon as the more convenient features of each tree.

Teak is a forest species of rapid growth on the first years. Due to the direct relation between the size of the top of the tree and diametric increase, is necessary to apply pruning before the density level affects in a negative form on the

shaping of the tree's tops reduced and little deep. Trees with such characteristics will hardly react to late pruning. This justifies the reduction on 40% of the number of trees at the latest delay on the fourth year. At that age it is possible to determine whether a tree is promising or not.

Thinning of young stands concentrate the yield because the ones extracted are, normally, the smaller trees. With this method, the direct costs of thinning are reduced in an important way. Also investment on silvicultural activities is small. An early thinning eliminates most of the trees that will never yield a profit, and the ones of worst shape and quality. The thinning assures that the company's financial resources company will be channelled only to trees that will pay.

On the Dry Pacific teak has very clear yearly growth rings that can be used as an exact record on the annual increase of the stand. They provide enough information to determinate the moment and intensity of each thinning. Table 3 presents the normal thinning program for a stand of medium characteristics.

Table 3. Program of thinning in stand of medium characteristics

Thinning or Final Cut	Year	Trees before thinning	Trees to cut	Trees after thinning
Thinning 1	2	1,111	231	880
Select Thinning 1	4	880	220	660
Select Thinning 2	8	660	220	440
Select Thinning 3	12	440	220	220
Final Cut	25	220	220	0

Due to doubts about future market conditions and scant data on total and commercial growth, BPC has not yet decided the rotation, and has adopted, tentatively, 25 years.

Diameter, height and volume increase

A permanent plot network has been established to determine the annual increment in diameter, height and volume. The oldest records are from 1988 and today the plantations are four and twelve years old. Some average parameters from the permanent plots are summarised on the Table 4.

Table 4. Information from Permanent Sample Plots in BPC´s Project

Age (years)	Total Hight H_{med} (m)	Diameter D_g (cm)	Number of trees N (arb/ha)	Total standing volume V_{tot} (m^3/ha)	Commercial volume V_{10} (m^3/ha)	Mean Annual Increment (total volume) MAI_{tot} (m^3/ha/año)	Mean Annual Increment (commercial volume) MAI_{10} (m^3/ha/año)
3	10.5	10.4	1,111	n.s.	n.s.	n.s.	n.s.
4	12.6	12.7	660	55.2	19.5	23.3	8.2
5	14.2	14.5	660	69.1	34.1	21.4	9.5
6	15.6	16.0	660	83.7	49.6	20.2	10.5
7	16.7	17.3	660	98.3	65.1	19.4	11.2
8	17.6	18.4	440	74.8	53.2	18.8	11.6
9	18.5	19.3	440	83.9	62.8	17.7	11.4
10	19.3	20.2	440	93.4	72.9	16.9	11.3
11	20.0	21.0	440	102.5	82.6	16.2	11.1
12	20.6	21.7	220	55.5	45.8	15.5	11.0

n.s. = no significative.
V tot = Total standing volume using Keogh (1980) Vtot = 0.0359 + 0.000022 Dg2 * Hmed * N
V 10 = Commercial Volume (minimum diameter = 10 cm without bark)

Total and commercial volumes expected from thinning and final cut

Total and commercial volumes from a presumed average planted hectare, presented in Table 5, shows an average increment of 13.2 m^3/ha/year, and with a 10 cm top end under bark it is reduced to 10.3 m^3/ha/year.

Table 5. Total and commercial volume (m3/ha) from thinnings and final cut for different top log diameters for a 25 years of rotation period

Type of harvest	Age (years)	Trees harvested (trees/ha)	Commercial volume (m^3/ha) D_{min} > 20.1 cm	Commercial volume (m^3/ha) D_{min} 15.1 - 20.0 cm	Commercial volume (m^3/ha) D_{min} 10.1 - 15.0 cm	Volume (m^3/ha) D_{min} < 10 cm	Total volume (m^3/ha)
Thinning 1	2	231	0.0	0.0	0.0	10.0	10.0
Thinning 2	4	220	0.0	0.0	3.3	18.0	21.3
Thinning 3	8	220	0.0	10.7	5.8	16.0	32.5
Thinning 4	12	220	38.5	18.1	9.4	15.0	81.0
Final Cut	25	220	147.8	15.6	8.1	13.0	184.5
Total			186.3	44.4	26.6	72.0	329.3

ECONOMIC ASPECTS

Financing scheme

BPC project has financed its activities with resources from investors. On each phase a certain amount of ha/shares were issue, and its value covered the establishment and the development of the plantation until the final harvest. The income from the share's sell financed each phase and the start up of the following. The system provided an

homogeneous silvicultural management by selling shares, instead of specific planted plots. At first investors could take advantage of the legislation which gave the costarrican residence to foreign retirees who invested a certain amount on national projects.

Cash flow from reforestation teak projects

BPC is developing one of the first medium size commercial teak plantations. The Company's experience might be useful for other companies who want to plant teak. Some aspects regarding the cash flow are:

- Planting teak demands long production periods. Planning must be done for at least 25 years.
- Economic-financing considerations must be applied to each activity of the process.
- When calculate teak budgets, all the productive cycle must be included. The lack of resources to implement silvicultural treatments might destroy any planned management, and its profits.
- When the cash flow does not have enough resources for a top technical management, it might be reasonable to incorporate the environmental services incentive to cover the gap.

Teak regional market

A huge variety of intermediate goods and final products can be expected from varied forest production, when teak is used as the wood species of a project, due the different applications and uses that can be done to the wood. As it is done with the traditional plantations, it is possible to classify the production, guiding the high quality and value goods to special place on the foreign market, and the ones of lesser quality and price directed to markets of few exigency or to the internal market.

Solid wood of high quality, veneer, yacht decoration, moulding, parquet and refined furniture constitutes the production lines with possibilities of exportation. In the internal market, teak wood can be used for handcraft, house and buildings construction, or designing economic furniture. In any case, all efforts go to the direct production of teak plantations, as an option to keep the sustainability of the plantation.

Log and sawn wood prices

Due to the teak's log production in Costa Rica has been reduced to a few stands of small size, especially located in Santa Cruz, Nicoya and Paquera at the Dry Pacific; also in Quepos, Parrita and Paso Canoas on the South Pacific, local teak prices do not show its planting costs. Logs with more than 25 cm of diameter on the slimmer part, placed on yards to be sawn prices are among US$100 and US$189/m^3. However, those are speculative amounts. It will be convenient to examine price trends of this wood, as plantations will consolidate their production, when the market forces to let some stability on the internal prices from a reduced boundary.

COMPANY PROJECTION FOR EXPANDING AREAS

The distribution of age types of the BPC project is characterised by a concentration of surface on a restricted range by ages. Since four years ago no new areas have been established. On a trial to organise production during the transitory shift, a deficit of logs from thinning is expected starting on 2006. If the final cut is done according to the first proposal of 25 years, the missing wood production will be projected until the year of 2014. A way to solve this deficit will be planting enough area each year during the next 8 years, annual areas between 200 and 300 ha of effective teak plantations.

In order to profit the IBPC's infrastructure located in Palo Arco, BPC must place the expansion's projections in a ratio around a transforming industrial plant. So the Península de Nicoya must become the ideal zone for the planting activities of BPC.

FAO - Forestry Department
List of Working Papers on Forest Plantation

Working Paper FP/1	*Mean Annual Volume Increment of Selected Industrial Species*. Ugalde L. and Perez O. April 2001.
Working Paper FP/2	*Biological Sustainability of Productivity in Successive Rotations*. Evans J. March 2001.
Working Paper FP/3	*Plantation Productivity*. Libby W.J. March 2001.
Working Paper FP/4	*Promotion of Valuable Hardwood Plantations in the Tropics. A Global Overview*. Odoom F.K. March 2001.
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Working Paper FP/10	*Protecting Plantations from Pests and Diseases*. Ciesla W.M. March 2001.
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Working Paper FP/16S	*Bibliografía Anotada Sobre los Efectos Ambientales, Sociales y Económicos de los Eucaliptos.* Compilación de documentos elaborados en inglés, francés y español entre 1985 y 1994. Marzo de 2002.
Working Paper FP/16E	*Annotated Bibliography on Environmental, Social and Economic Impacts of Eucalyptus.* Compilation from English, French and Spanish Literature, 1985 to 1994. Revised (Combined) Edition, March 2002.
Working Paper FP/17S	*Bibliografía Anotada Sobre los Efectos Ambientales, Sociales y Económicos de los Eucaliptos.* Compilación de documentos elaborados en inglés, francés y español entre 1995 y 1999. Palmberg C., Marzo de 2002.
Working Paper FP/17E	*Annotated Bibliography on Environmental, Social and Economic Impacts of Eucalyptus.* Compilation from English, French and Spanish Literature, 1995 to 1999. Palmberg C., March 2002.
Working Paper FP/18	*Tropical forest plantation areas 1995 data set*. Pandey D. May 2002.
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Working Paper FP/20	*Melina (Gmelina arborea) in Central America*. Alfaro, M.M. and De Camino, R.V. May 2002.
Working Paper FP/21	*Case study of hardwood programmes in Fiji, Solomon Islands and Papua New Guinea*. Hammond, D. May 2002.
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