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TEAK: AN EXPLORATION OF MARKET PROSPECTS AND THE OUTLOOK FOR COSTA RICAN PLANTATIONS BASED ON INDICATIVE GROWTH TABLES

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THE REPOSA PROJECT

The Research Program on Sustainability in Agriculture (REPOSA) is a cooperation between Wageningen Agricultural University (WAU), the Center for Research and Education in Tropical Agriculture (CATIE), and the Costa Rican Ministry of Agriculture and Livestock (MAG). In addition, REPOSA has signed memoranda of understanding with numerous academic, governmental, international and non-governmental organizations in Costa Rica.
The overall objective of REPOSA is the development of an interdisciplinary methodology for land use evaluation at various levels of aggregation. The methodology, based on a modular approach to the integration of different models and data bases, is denominated *USTED* (*Uso Sostenible de Tierras En el Desarrollo*; Sustainable Land Use in Development).
REPOSA provides research and practical training facilities for students from WAU as well as from other Dutch and regional educational institutions.
REPOSA's research results are actively disseminated through scientific publications, internal reports, students' thesis, and presentations at national and international conferences and symposia. Demonstrations are conducted regularly to familiarize interested researchers and organizations from both within and outside Costa Rica with the *USTED* methodology.
REPOSA is financed entirely by WAU under its Sustainable Land Use in the Tropics program, sub-program Sustainable Land Use in Central America. It operates mainly out of Guápiles where it is located on the experimental station *Los Diamantes* of MAG.

EL PROYECTO REPOSA

REPOSA (*Research Program on Sustainability in Agriculture*, o sea Programa de Investigación sobre la Sostenibilidad en la Agricultura) es una cooperación entre la Universidad Agrícola de Wageningen, Holanda (UAW), el Centro Agronómico Trópical de Investigación y Enseñanza (CATIE) y el Ministerio de Agricultura y Ganadería de Costa Rica (MAG). Además REPOSA ha firmado cartas de entendimiento con organizaciones académicas, gubernamentales, internacionales y non-gubernamentales en Costa Rica.
REPOSA ha desarollado una metodología cuantitativa para el análisis del uso sostenible de la tierra para apoyar la toma de decisiones a nivel regional. Esta metodología, llamada USTED (Uso Sostenible de Tierras En el Desarollo) involucra dimensiones económicas y ecológicas, incluyendo aspectos edafológicos y agronómicos.
REPOSA ofrece facilidades para investigaciones y enseñanza para estudiantes tanto de la UAW, como de otras institutiones educacionales holandesas y regionales.
REPOSA publica sus resultados en revistas científicas, tesis de grado, informes informales, y ponencias en conferencias y talleres. REPOSA regularmente organiza demostraciones para investigadores de Costa Rica y de otros países para familiarizarlos con la metodología USTED.
REPOSA es financiado por la UAW bajo su Programa del Uso Sostenible de la Tierra en los Areas Trópicos. La sede de REPOSA está ubicada en la Estación Experimental Los Diamantes del MAG en Guápiles.

PREFACE

The work presented in this report took place within the framework of the Research Program on Sustainability in Agriculture (REPOSA), a joint program of Wageningen Agricultural University (WAU), the Netherlands, the Tropical Agriculture Research and Graduate Education Center (CATIE), Costa Rica, and the Costa Rican Ministry of Agriculture and Livestock (MAG). It served to fulfill the Master thesis requirements of my study in forestry economics at the forestry department of Wageningen Agricultural University, The Netherlands.

In many aspects, this study is a pilot study on production and economics of Costa Rican teak plantations. Its results can be generally be applied at a high integration level to Costa Rican teak plantations in general. Future research, especially on teak growth and timber prices, can be incorporated in the model presented in this paper. This will largely enhance forecasting of financial outcome of individual teak plantations.

This study was supervised by Dr. N.R. de Graaf and Dr. B. Filius of the forestry department of Wageningen Agricultural University, and by Dr. H. Jansen and Dr. A. Nieuwenhuyse of the REPOSA project in Guápiles, Costa Rica. I would like to express my gratitude for their assistance and their effort to bring this work to a successful completion.

Jelger de Vriend
Wageningen, April 1998

Dedicated to

Maud

for her unabridged support and love.

CONTENTS

SUMMARY

Teak has been extensively studied in Indonesia and Myanmar, but little is known about Costa Rican teak quality and growth. In order to make projections of the financial returns for teak planting farmers, this study thoroughly analyses the world teak market and Costa Rican teak production.

To gain a proper understanding of teak trade, insight in teak quality is of eminent importance. Products of teak include sawnwood for construction, veneer and plywood, moulding, strip and block flooring, furniture components, solid doors and flush doors, door and window frames, laminated boards and panels, carved articles for decoration, and household utensils and kitchenware. Each application has specific quality requirements. General timber quality depends on a multitude of factors, such as site conditions, growth rate, management and age of the trees. Durability, stability, workability and ease of pre-treatment are the major characteristics of good quality teak. Beautiful figure, color, density and rate of growth are other sought-after qualities as are straight grained, knotless and defect free timber.

It is estimated that there is a total of 19 million hectare of natural teak forests and over 1.6 million hectare of teak plantations around the world. The largest volumes of plantation teak come from Java, West Africa, Central America, but numerous other countries in the tropics also have teak plantations.

Absence of a dry period has a negative impact on quality since it increases the weakness and sponginess of the timber and tree. Absence of a dry period and rapid growth, such as in the Atlantic Zone of Costa Rica, may result in chemical, biological, and mechanical effects. Though fast growing plantation teak apparently has different qualities than natural grown teak, it does not mean that it is inferior; plantation teak can still be used for high value applications such as parquet, cabinets, and veneer. However, it will not qualify for yachting applications. Limited specifications are currently a major limiting factor for plantation teak. Additionally, fast growing teak might still achieve financial returns that exceed those from slower grown teak due to the higher volumes produced.

Due to differences in end-use and quality demands, the global teak market is best analyzed as a highly segmented market with rather independent flows from producer to consumer. The markets for plantation teak are diverse and often very competitive (Chavez & Fonseca, 1991; Sein Maung Wint, 1995). Five general sub-markets can be distinguished, namely; (1) yachting industry, (2) doors, window frames, fences, and garden furniture, (3) parquet and indoor staircases, (4) indoor furniture and construction parts, (5) low quality and low value products.

Each sub-market demands a certain teak quality. This, together with the dimensions of the timber, sets the timber price. Prices for natural teak on average range from US$1000-4000, those of plantation teak of 60-90 years from US$1000-2000, and short rotation teak of 20-40 years is currently sold at prices ranging from US$200-2000.

Future teak prices are hard to predict. The World Bank expects an annual real price increase of 2.1 percent for tropical sawnwood. This is more or less in accordance with calculations based on Dutch teak log price changes. From 1979-1992, the actual annual teak log price increase has been 5.8 percent, but only 2.5 percent when corrected for inflation. It can thus be concluded that there is no indication that teak prices will increase strongly in the near future.

Based on current market information, it is concluded that current FOB sawnwood prices for prime quality Costa Rican plantation teak range would range from US$400-500 per cubic meter. Depending on diameter, conversion rates can optimistically be expected to between 30-40 percent, while, based on current price increase, real annual teak price increase will be between 1-3 percent.

Costa Rican timber production has been increasing steadily the last decades, but there are strong indications that natural timber availability in Costa Rica will decrease rapidly during the next 10 years. Teak was first introduced to Costa Rica in 1943 by the Compañía Bananera de Costa Rica. The first plantation was established near Quépos. Since the Costa Rican government initiated a series of subsidies to stimulate establishment of tree plantations in the late 1970s, thousands of hectares of tree plantations were established. It has been estimated that with help of incentives some 4,100 hectares of teak were established between 1990-1994, however an equal amount has been planted without incentives by private investment companies. A side-effect of these incentives has been that many farmers planted teak and other species for the sole purpose of receiving the subsidies. In subsequent years they omitted management of the plantations, which led to mal-formation of the trees and

subsequently low timber quality. This teak is now available, but due to the low quality and the availability of many competing species, there currently does not exist a domestic nor an international market for this low quality teak.

An important feature of this study is the construction and presentation of indicative teak growth tables. Based on climatic data, two major teak production areas can be distinguished, namely; (1) the Pacific lowlands, including Guanacaste and Central and South Pacific, and (2) the Atlantic lowlands of the Zone Norte and the Atlantic Zone, with the Pacific lowlands having lower teak growth rates. Within these regions, teak growth can be considered homogeneous. Based on field measurements and extrapolation of the growth data of the Miller 1969 teak growth tables, this paper presents indicative teak growth tables with 3 growth classes for both teak growing regions. The potential cumulative volume of teak over a period of 20 years is projected to be between 400-710 cubic meter in the Pacific lowlands, while Atlantic teak may potentially produce between 470-770 cubic meter over the same period.

In order to design a model which calculates the profitability of Costa Rican teak plantations, the paper further presents a formula to calculate the conversion rate from log to sawnwood, a function to calculate costs of transport to the sawmill, and a summary of factors that influence profitability of these enterprises. In the model, a distinction is made between variable and constant factors. The variables can be manually altered. A standard set of values for the variables, representing the settings of an 'average' teak farm, is presented and used to derive the cash-flow of this 'standard' farm. Then the cash flow was economically analyzed, using Net Present Value (NPV), Annual Income, Land Expectation Value (LEV), and the Benefit-Cost Ratio (B/C-ratio).

Depending on growth class, B/C-ratio in the Pacific lowlands are between 3.0-3.3 when rotation length is 20 years, while NPV is between US$ 11,700-24,200. For the same rotation length, Atlantic teak investments have a B/C-ratio between 3.4-4.1 and a NPV of US$ 15,800-31,500.

Subsequently, a sensitivity analysis was executed on the variables. It was determined that discount rate and the world market prices for teak were the factor most influencing profitability, while, for instance, labor costs have a minor effect on the financial outcome.

Among the conclusions, it is reported that the present value of establishment and management of a Costa Rican teak plantation can be estimated to be between US$ 6,000-12,000 per hectare. Furthermore, the most important factor influencing profitability which can be influenced to some degree by strategic management decisions is the distance to the sawmill, while the distance to Limón, from where the timber can be shipped, is of minor importance. Finally, labor costs are reported to be of minor importance for the profitability.

Unless the consumer preference for teak drastically changes during the next 20 years, farmers can make large profits from relatively small investments in teak plantations. The basis of these returns will lay in the large teak volumes that potentially can be produced on the excellent growth sites in Costa Rica and in the prices paid for defect-free teak. The exact success of the investments will largely depend on strategic decisions of plantation location and optimized pruning and thinning practices. It will only be a matter of time until we find out what profits really can be made from investments in teak plantations.

INTRODUCTION

Total forest area in the tropics annually decreased during the last decade with 15.4 million hectare, half of global deforestation takes place in Latin America and the Caribbean. It is currently estimated that 1.2 billion hectares of tropical rain forest are left on earth. These forests mainly occur in South America, Central Africa, and Southeast Asia. More or less half of these forests have been affected in some way by agriculture, timber logging, infrastructure, mining, or storage lakes. When discounting the forest land reclaimed by natural succession of pioneer species, the overall tropical deforestation runs at 6.2 million hectares per year. Between 1980-1990, the net area planted per annum was about 12 percent of the area deforested every year (FAO, 1993b, WRI, 1990).

While depletion of natural resources is taking place at a high pace, many countries have become aware of the accompanying negative effects and a strong movement towards nature conservation has developed during the last decades. The Dutch government was among the first to introduce a label for nature conserving investments, so-called "green" projects. As part of these regulations, profits from certain investments qualify for tax concessions. Among them are investments in teak plantations. Simultaneously, the Costa Rican government introduced reforestation subsidies for farmers. Both stimuli led to a major increase of the plantation teak acreage in Costa Rica.

ORIGIN, APPLICATIONS, AND IMPORTANCE OF TEAK

Teak, *Tectona grandis* Linn. f. (*Verbenaceae*), is a tree species indigenous to India, Laos, Myanmar and Thailand. Teak has been introduced from this region to Indonesia as early as the 14th century. Later, it was spread to many other countries, and since the beginning of this century teak is planted in many places in the world. Teak is generally believed to have been introduced to Latin America via Trinidad (Perum Perhutani, 1993; Sein Maung Wint, 1995).

In Europe, teak is well known since colonial times. Many people recognize teak as high quality timber with luxurious applications, such as yacht building, with correspondingly high prices (De Boer & Kuiper, 1996). Products of teak include sawnwood for construction, veneer and plywood, moulding, strip and block flooring, furniture components, solid doors and flush doors, door and window frames, laminated boards and panels, carved products for decoration, and household utensils and kitchenware. Each application has its own specific quality demands.

Sein Maung Wint (1995) estimates that, based on available information, there exists a total of 19 million hectares of natural teak forests and over 1.6 million hectare of teak plantations world-wide. The current teak area in Costa Rica can roughly be estimated to cover about 20,000 hectare.

UNANSWERED QUESTIONS

Although teak has been investigated thoroughly in Indonesia and Myanmar, little is known about growth and quality of teak planted in recently established teak plantations in Costa Rica. Based on available information from other continents and from the first few years of growth of teak in Costa Rica, scientists have been commenting on the assumptions made by Costa Rican teak projects, stressing that, at least to some extent, yield projections are too high with correspondingly inflated profitability expectations (Centeno, 1996a & b). This has induced a downward adjustment of the yield projections by some of these companies of up to 50 percent.

Studying the available literature reveals that many questions regarding teak production and profitability of teak plantations in Costa Rica remain unsolved. The global teak market, for instance, is very heterogeneous with many types of teak and markets varying in volume and quality demands. Stemming from this heterogeneity there are large differences in prices, defined by quality and size, making future price projections very difficult (Manger, 1995; Sein Maung Wint, 1995). This created a fertile ground for speculation on teak yields and prices.

Apart from these market-oriented questions, little is known about some of the factors which influence the profitability of teak plantations and the effect that changes in these factors will have on profitability. This is, for example, the case with length of rotation; whereas teak investors maintain a fixed rotation length, an economically optimal rotation may be calculated. Increasing the length of rotation might result in increased profits.

Finally, future Costa Rican teak is already compared with teak available from other countries, such as Indonesia or Benin. This led leading Asian teak importers, such as WorldWood, to be skeptic about the future quality and value of Costa Rican teak. It is questionable whether this is a fair comparison.

OBJECTIVE OF THE STUDY

The general objective of this study is to construct models which make it possible to provide sound projections of revenues and profitability of Costa Rican teak plantations in general. The study will focus on the factors determining profitability of Costa Rican teak production and will place them in the context of global teak production and marketing. The level of analysis is basically at the farm level while links are made to the investment company level.

Specific objectives can be defined as follows:

(1) assess the structure of the world and Costa Rican markets for teak, including current prices and future price projections for Costa Rican teak;

(2) identify and analyze differences between teak growth and quality in Costa Rica and other countries, as well as differences in growth and quality of teak within Costa Rica;

(3) assess the factors that determine profitability of teak plantations; their relative importance; the effect of changes in these factors (with particular focus on the effect of rotation length on profitability); and which combinations of these factors lead to maximum profitability (including risk scenarios).

Table 1.1 Objectives, Hypothesis, Research Questions and Methodology

Objective	Hypotheses	Research Questions	Method
1	• Costa Rican plantation teak will operate in the same global market as Asian plantation teak.	• Which are the uses of plantation teak; • What are their market shares; • Where are they produced; • What are the global flows of teak?	• Study available literature on Costa Rican and international markets for teak and teak products • Approach traders and saw mill managers for information.
	• Costa Rican teak will have a quality which will command prices that are similar to Indonesian plantation teak.	• What are the prices paid for teak; • Can different quality groups be distinguished; • Which are the factors determining teak prices; • What will future teak prices look like?	-idem-
2	There are significant differences in quality between Pacific and Atlantic teak	• Which factors determine quality; • Can differences in quality be observed between teak from the Pacific and the Atlantic lowlands?	• Study available literature; • Carry out field surveys to fill in data gaps; • Define "teak quality".
3	Length of rotation is the most important factor determining the profitability of teak plantations	• Which are the factors that influence profitability of Costa Rican teak plantations; • What is their relative importance?	• Study available literature; • Filling in data gaps by field surveys; • Develop a model to predict profitability of teak plantations; • Apply a sensitivity analysis on some of the variables in the model.

Table 1.1 indicates hypotheses, research questions and methodology applied in this study to achieve each of these objectives.

LIMITATION OF THE REPORT

Its focus is on the farmers level, because the cost-structures of teak investment companies vary highly and because it is extremely difficult to get access to them. The results of this study may, however, serve as a basis for further analysis of teak investments.

DESIGN OF THE REPORT

This paper consists of two sections. The first explores the structure of global teak markets, studying global teak production and demand while differentiating between markets. As it can be expected that the price of premium quality teak will largely be determined by developments on the world market for teak, the overall objective of section 1 is to derive a sound projection of the future world market value for premium Costa Rican teak.

The second section analyses Costa Rican teak production in terms of production and profitability. This section also discusses national timber production and the Costa Rican timber market.

SECTION 1

THE ANATOMY OF GLOBAL TEAK TRADE

...the timber [...] is excellent. The Persian Gulf traders, who are no fools, buy up the big timber of the windfalls with alacrity; whilst the Moplahs, who are shrewd men of business, will offer fancy prices for the bigger trees as they stand. All this is evidence to show that the plantation teak is good timber, though grown fast on a rich soil.

P.M. Lushington, 8th May 1895
in a letter to The Indian Forester

This section of the study analyses the world teak market and its characteristics. In the first chapter the general characteristics of international timber trade are discussed, resulting in projections regarding future demand for and supply of timber. Chapter 2 and 3 focus on the characteristics of the teak trade, with special emphasis on teak quality as an important determinant of the price. In chapter 4 a distinction is made between the various sub-markets for teak. Finally, chapter 5 deals with the price-forming process in teak markets.

1 INTERNATIONAL TIMBER TRADE

Teak supply and demand can be analyzed along the same lines as for other timber species. This chapter, besides discussing general aspects of timber demand and supply, presents indications on future timber demand and supply. Finally, it discusses the effect of certification and labeling on timber demand and supply.

1.1 GENERAL ASPECTS

Most studies agree that (1) population growth, (2) growth in income per capita, (3) certification, and (4) availability of substitutes are the main factors influencing the trends on the demand side of international timber trade. Increase in economic activity and growth of gross domestic product (GDP) almost immediately lead to an increase in the use of paper and cardboard, as well as to a lagged increase in sawnwood and plywood (Dijkstra *et al.*, 1995; Stolp, 1996).

Costs and the present timber stock will determine the availability of timber in the near future. Therefore, it is of eminent importance to closely monitor current developments in timber stocks. However, area and production data at the species level are generally scarce. Often countries only indicate the total plantation area and the main species, omitting less important species.

1.2 TRENDS IN GLOBAL TIMBER PRODUCTION AND TRADE

Numerous other countries in the tropics have teak plantations. Appendix III gives an indication of the most important teak producing countries. During the past two years there are indications that the market cycle, i.e. the period between maximum and minimum demand, is shortening and intensifying. The effect on timber prices is often severe. Fluctuations between years of up to 40 percent are not exceptional (Dielen, 1996; ITTO, 1996).

One of the most important recent factors influencing global tropical timber trade has been the successful completion of the Uruguay Round of the World Trade Organization (WTO) in 1995. This has led to the agreement that over the next few years trade-restricting tariffs on timber products in consumer countries will gradually be abolished. Appendix I shows the August 1995 situation of tariffs for tropical timber in the consuming countries. Though the European Union has replaced its *Generalized System of Preferences* (GSP) in 1995 with direct import tariffs, still a tariff of 70 percent is levied on intermediate and end products, such as doors and plywood, while primary products can be imported at a zero tariff (Anonymous, 1996; ITTO, 1996). In addition, certain specific countries have the privilege to trade with the European Union under a zero-tariff agreement.

The flow of timber in the world is presented in figure 1.1. It is striking to note that 80 percent of standing timber is lost while harvesting the remainder. An important feature of current trade in tropical timber is the rapid emergence of the Newly Industrialized Countries (NICs) in Asia; firstly as major importers of all types of timber and secondly as major players in logging operations in the world's remaining tropical forests. The pace of economic growth in Asia coupled with the already severe depletion of natural forest resources in most Asian countries is putting significant pressure on the international timber market. African and South American producers find themselves increasingly doing business with the NICs of Asia at a time when growth of demand in the traditional markets, notably in Europe and the USA, is slow. European consumption is even showing an absolute decline in tropical non-coniferous sawnwood. This has been replaced by non-tropical timber and non-timber substitutes, such as synthetics, steal and aluminium. (Anonymous, 1996).

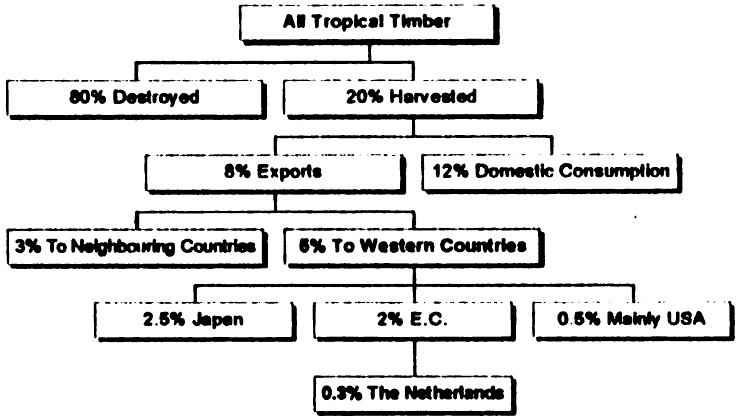

Figure 1.1 Tropical Timber Flow. Source: Broers & Partners (1989)

While international trade in tropical logs and most sawnwood is decreasing, the triplex market remains stable and according to Dielen (1996) and Schmincke (1996) a growing shortage for high quality durable timber for veneer and sawnwood is developing. Due to combined pressures of domestic demand, government policies restricting exports of logs and sawnwood and environmental concern, world sawnwood exports dropped in 1993 and 1994. On the other hand, demand for wood-based products has been increasing, mainly due to increasing population and growing economies (Sein Maung Wint, 1995).

The once apparently clear borders between the markets for hardwoods and softwoods and between the markets for tropical and temperate woods are fading. Traders are faced with increasingly complex demand/supply relationships; for example, some tropical countries are importing temperate woods in unprecedented quantities. Adding to the complexity of the change are the gradually shifting positions of plywood, medium density fiber board, oriented strand board and particle board in the wood-based panel sector (Anonymous, 1996).

Stolp (1996) is expecting an increasing globalization of timber transactions in which plantation forestry becomes more important and will increasingly determine the price for timber products. Fast-growing timber plantations, which are able to produce timber(-fibers) at low costs in large quantities in countries such as Argentina, Brazil, Indonesia, New Zealand, and South Africa, can be profitable at current price levels. With increasing timber prices profitability of these plantation will increase and more plantations will most probably be established (Stolp, 1996).

Europe's consumption of tropical timber has halved between 1989 and 1996. This has partly been caused by lower economic growth rates and environmental consciousness. In addition, the most important exporters are producing increasingly more end-products of tropical timber (Dielen, 1996; ITTO, 1996).

Between 1993-1995 the share of Latin America in log production strongly increased. The strong increase in the Latin American share in world log exports to 7 percent in 1995 mainly accrues from the extension of Brazilian log exports. Total Latin American export share has also increased strongly to 10 percent in 1995, while at global scale there has been a decrease of 3 percent in exports of tropical timber between 1993-1995. Latin-American plywood exports, led by Brazil, have increased strongly recently, to 1 million cubic meter in 1995 (ITTO, 1996).

The share of logs in total tropical timber trade of ITTO producing countries has diminished from 60 percent in 1980 to 25 percent in 1993. Africa is the only continent still exporting more logs than processed products. The fastest conversion from log exports to processed product exports is taking place in the Asian-Pacific region. This has mainly been initiated by Indonesian plywood exports and Malaysian exports of sawnwood, veneer and plywood (ITTO, 1996).

Of all plantations in the world by the end of 1990, it has been estimated that the largest area is occupied by Eucalyptus (23.0%), followed by pine species (10.5%) and Acacia species (7.7%) (Pandey, 1995).

1.3 Prospects of Timber Consumption

As a result of increasing populations and continuing economic growth, the FAO foresees an increase in demand for log and sawnwood of 25-30 percent between 1990 and 2010 (Schmincke, 1996).

The most significant feature of current trade in tropical timber is the rapid emergence of Southeast Asian countries as major importers of all types of timber. Substantial rates of growth in per capita GDP are also expected in China and Latin America. The pace of economic growth in Asia's NICs, coupled with the severe depletion of natural forest resources in that region, is fueling tremendous demand for tropical timber in that region (Tropical Forest Update 3, 1996).

Northern European countries are currently developing slowly. It is to be expected that in the Netherlands, the United Kingdom and in the United States the increase in timber demand will be strongest as these countries exhibit stronger economic growth (Dielen, 1996; Stolp, 1996). Looking at the expanding demand for timber and at economic growth in the Asia-Pacific region, it may well be that by the turn of the century, intra-regional trade in timber could account for a major portion of export timber trade, including teak wood (Sein Maung Wint, 1995).

Due to excessive demand and exploitation in the last four decades, India for instance is now considered a timber-deficit country and it has to import both teak and other hardwoods to meet the demand of its growing population and its wood-based industries (Sein Maung Wint, 1995).

1.4 Certification & Labeling of Timber

Currently, certification of sustainable plantations and labeling of its production are the focus of attention in several countries and the ITTO is working towards agreements on trade in certified forest products. The ITTO, representing both timber producing and consuming countries, wants to convert tropical timber trade to trade in certified timber only by the year 2000 (de Boer, 1996; Kiekens, 1995). Agreements along these lines between industry representatives and governments may drastically change timber trade.

However, there are still some drawbacks. For instance, for labeling to be successful it is necessary to use a trade name and to establish a chain of custody from grower to buyer, each part of which is subject to monitoring (Keogh, 1996). The following paragraphs will discuss certification and labeling in more detail.

1.4.1 The Market for Certified Forest Products

Many uncertainties surround the potential market share for certified products. According to Sikod (1996) an assessment of the possible price premium for certified timber should be dissected into two major questions; (1) is there sufficient willingness to pay, and (2) does this willingness translate in actual purchasing decisions?

Actual purchasing behavior of consumers is less sensitive to environmental aspects and more based on price-quality relationships. Both income and price elasticities typically are higher for more highly processed timber products. A timber price increase induced by incorporating costs of sustainable management and certification will induce substitution, if similar price increases do not take place in the competing product (Sikod, 1996).

Market segments where willingness to pay a price premium can be observed could be exploited by trade. Sikod (1996) states that the importance of this segment varies by country, and so using the "willingness-to-pay" argument as a general policy guideline may not be very appropriate. The impact of certification on timber production would largely depend on the scale of operation and local conditions, which vary extensively in terms of type of tenure, type and organization of forest management, and methods of wood procurement.

With regard to the demand for certified timber, Kiekens (1995) states that without government enforced laws, certification would affect timber trade in only a few countries. This concerns mainly the sector of do-it-yourself stores and public markets in countries such as Germany, the Netherlands and the United Kingdom. Outside these niche markets, it is not clear whether certification will be adopted on any significant scale. Compared with world-wide production, the demand for certified woods remains negligible (Kiekens, 1995). Thus it can be expected that without a serious international commitment, certification will only have a slight effect on the international timber trade. It is the paper industry that could have the most significant impact because of the development of eco-labels for paper.

De Boer (1996), using data from the World Bank, indicates that the market share for these certified timber products in Europe might be between 10-20 percent, while in the United States a market-share of 5-10 percent can be expected. In this study it is also assumed that consumers are not willing to pay more than 10 percent extra for a certified product. The Dutch Ecowood Foundation expects that, dependent on the timber species, prices of certified timber will be 10-20% higher than those for non-certified timber. In economic terms, prices could be similar due to avoidance of damage to the environment in the case of certified timber.

Producers and consumers are both interested in maximizing profits and utility. If certified forest products are more expensive than uncertified ones it could turn out to be hard to achieve the indicated market-shares in Europe and the United States. But mostly for certification to succeed, the procedure has to be one that will lead to quality products at competitive prices (de Boer, 1996; Kiekens, 1995; Sikod, 1996). Commercial interest of timber traders and sustainable forestry objectives are becoming increasingly more united and will strengthen each other in the future.

1.4.2 Government Support

It is now generally believed that for certification to be successful, there is a need for government support. The Dutch government decided in April 1997 that investments in sustainable agriculture and reforestation projects in developing countries qualify as fiscally attractive "green investments". Investors in these environmentally friendly projects which have the so-called "green-label", approved by the Dutch ministry of Public Health, Area Planning, and Environment (VROM), do not have to pay taxes over the dividends obtained from their investment. It is likely that this government measure will generate a considerable amount of money for new investments in plantation forestry.

In the tropics, efforts to label timber are proceeding more slowly than in Europe and Northern America. Several countries, such as Indonesia, Mexico and several West and Central African member countries of the African Timber Organization, are seeking to work towards certification. Other tropical countries, in particular Malaysia and Brazil, seem to reject any international certification program before the year 2000, although a number of studies and projects are already being implemented and discussions on timber certification are being held in the context of the ITTO (Kiekens, 1995).

However, it is still unclear whether agreements on certification are to be considered as trade barriers for non-certified forest products. Government measures to stimulate imports of certified products might thus not be in accordance with the General Agreement on Tariffs and Trade (GATT) of the World Trade Organization (WTO).

1.4.3 Determining the Future Success of Labeling

Eventually, growers and processors who produce labeled products, accredited by institutions such as the *Forest Stewardship Council* (FSC), carry advantages in the market place. However, it is unclear to what extent labeling benefits sales. In order to guarantee that a forest product has been produced or harvested from a sustainable forest management system, it is of eminent importance that the entire chain-of-custody can be traced and monitored.

In the long run, the environmental issue is likely to have impact on trade and marketing of teak wood and products. According to Sein Maung Wint (1995), teak wood has a good environmental and commercial reputation, mainly due to the fact a large share of teak comes from natural forests which are under "sustainable" management systems. Most teak traders and teak investment companies favor certification as a marketing instrument to be able to deliver a distinguished product at a higher price. Several Costa Rican and Brazilian teak plantations have recently obtained the SmartWood label, pointing to ecologically and socially sound teak production (Manger, 1995; van Koppen, pers.comm.).

2 TEAK QUALITY

The word "teak" literally means "carpenter's proud" in Burmese, referring to the outstanding quality. Differences in prices paid for teak mainly result from timber quality. The fame of teak wood mainly stems from the superior characteristics of natural teak. Teak is practically the only timber used by the British navy for ship building and the best Myanmar teak is consequently known as "Admiralty" teak. Therefore, in order to develop an understanding of the teak market it is of eminent importance to define and understand the different quality aspects of teak (De Boer & Kuiper, 1996; Sein Maung Wint, 1995; Tint, 1995).

It is also important to distinguish between so-called natural teak and teak grown on plantations. The former is grown in mixed teak forests which can be found in Myanmar and, to a lesser extent, in Thailand, China and Laos. Management of these forest stands is minimal and harvesting takes place in very long rotations with low volumes removed during each harvest. By contrast, plantation teak is grown in mono-cultures in rotations of 20-80 years.

2.1 PROPERTIES OF TEAK

Timber quality depends on a multitude of factors, such as site conditions, growth rate, management, and age of the trees at harvest. The quality of sawnwood is also controlled by the performance of the saws, machines, and operators. Quality aspects which are important to the timber industry include thickness, width, length, grade (color, strength, etc.), and moisture content. Timber quality is positively influenced by timely silvicultural operations, such as thinning. Adequate site selection for plantation establishment is of great importance. Accelerated transportation and processing, choosing the proper cutting season and appropriate drying process are factors which may improve wood quality in post-harvesting operations (De Boer & Kuiper, 1996; Sangal, 1995; Tint, 1995).

Durability, stability, workability and ease of pre-treatment are the major characteristics of good quality teak. Good tree form, color, density and growth rate are other important qualities, as are straight grained, knotless and defect-free timber (Tint, 1995).

Teak is one of the most durable timbers in the world. The level of phenols increases durability due to the anti-biotic nature of this component. It has been reported that in dry areas teak may last for over 700 years. In contact with the earth's surface it can remain serviceable for more than 25 years. The extractives present in the heartwood are believed to be responsible for its durability and it was reported that decay resistance is related to age, rate of growth and extractive content (Rudman, cited in Tint, 1995).

Teak is also exceptionally resistant to changes in temperature and moisture. It is free from warping during drying and dries fairly easily. Specific gravity and shrinkage characteristics of teak are described in Appendix II. It can be observed in Appendix II that wherever teak is grown, the specific gravity of teak is quite similar. Costa Rican teak is slightly heavier, has a slightly higher radial shrinkage, but an average tangential shrinkage.

Similarly, shrinkage of teak in the vicinity of its natural habitat is consistently lower than shrinkage of teak from outside the natural habitat. In general teak is classified as a "low" shrinkage species, with a small movement of 1.2% tangential and 0.7% radial. Movement is an important index for fine-works, cabinet making and parquet flooring. The resistance to splitting when nailed is rather good (Chavez & Fonseca, 1991; Cordoba Foglia & Serrano Montero, 1991; Tint, 1995).

The number of growth rings generally ranges from 1-6 per centimeter. Yet up to 15 rings per centimeter have been found in natural teak, while plantation teak has wide growth rings (Weimann, cited in Tint, 1995). According to Tint (1995) the optimal number of growth rings in terms of optimal strength is 2.5 per centimeter. On the other hand, the growth rate may not be of prime importance if the timber is to be used for ornamental or other use. Recent Indian research has indicated that not the number of growth rings, and consequently the growth rate, but the density of the timber determines the strength properties of the timber (Jagannath Reddy, 1995).

According to Ryan and Kloot (cited in Tint, 1995), the strength of teak is comparatively low during the early years of tree life, but under normal growth conditions it rises steadily for about 20 years to a certain level after which it remains more or less constant.

The color of teak in its final use highly depends on the method of drying. If sawn teak is left drying in the sun, it develops color differences which can be improved by leaving the final product for several months in the sun. But since bursts en shrinkage are not solved by this method, it is better to control drying by applying Kiln drying in ovens (Grimm, pers.comm.).

2.2 PLANTATION TEAK COMPARED TO NATURAL TEAK

When analyzing global differences in teak quality, it is first of importance to differentiate between natural and plantation teak. According to Tint (1995), tests to detect the differences in strength between naturally grown and plantation teak were carried out as early as 1911. Generally no significant difference in strength between plantation and natural grown teak in the region of origin was found. In general, teak grown outside the region of origin has lower strength. Gogate (1995) reports that Indian plantation teak has a specific weight and hardness which are respectively 80 and 73 percent of the values for natural Indian teak. As indicated earlier, Costa Rican plantation teak apparently has totally different features.

It is further important to differentiate among various plantation teak qualities. These differences mainly stems from differences in rotation length and management regime. Java teak, being harvested at age 60-80 years and slowly grown, has good quality properties close to Myanmar teak. On the other hand, West African teak is considered to be inferior to Java teak, due to inferior management practices and faster growth. It is obvious that slow-grown and fast-grown teak have different quality characteristics and are suitable for distinctly different uses (Tint, 1995).

According to Manger (1995), a trader in Myanmar teak, the main problems with plantation teak from outside Asia include the following; (1) coarse and soft texture, (2) heavy sapwood, (3) knottiness, and (4) low oil content. In addition, in regions with a lack of dry period and rapid growth, chemical, biological, and mechanical effects may occur; (1) less phenols are being produced and (2) the timber subsequently has a lower durability. Thus, the absence of a dry period increases the weakness and sponginess of the timber and tree. Teak from regions in the natural habitat generally has durability class I, while teak outside that region, in general, has durability class III (Chowdhury, 1953; Keogh, 1996; Van Koppen, pers.comm.).

The limited availability of larger teak wood dimensions is currently another major limiting factor for plantation teak in international trade. There is a large supply of poor quality logs, that allows the production of *ultrashorts* (4-6cm) and *shorts* (7.5-13cm). Yet the main demand in teak is for *longs* of 15cm length and longer. The result is an excess supply of shorts and ultrashorts, and a shortage of longs. In addition, many buyers demand a range of sizes from the same teak source. This is required for products where matching of color and grain is necessary, such as is the case with furniture. Especially in furniture manufacturing both problems become clear; it is impossible to produce garden chairs if 15cm and 20cm wide benches are not available and it is impossible to mix African with Myanmar teak as colors differ widely (van Buren & Kloos, pers.comm.).

Even though fast grown plantation teak is reported to have different qualities from natural grown teak, it does not mean that it is inferior. In fact, many authors (Anonymous, 1996b; Cordoba Foglia & Serrano Montero, 1991; Sangal, 1995) state that plantation teak can still be used towards high value applications such as parquet, cabinets, and veneer. However, plantation teak most probably will remain unsuitable for yachting applications.

Until recently, African teak was considered to be of too low quality for sawnwood export to Europe and only logs were exported to India. However, it has been reported that several countries in West Africa have recently established export grades of sawnwood from plantation teak and it is expected that this source of supply will steadily grow in importance in the near future (Sein Maung Wint, 1995).

With regard to Costa Rican teak, it can be expected that well-managed premium teak will find its way to high-value niches, although it will probably not be used in the yachting industry. When the plantations are pruned and thinned properly and larger dimensions can be offered to traders, there are no indications to date that premium Costa Rican teak can not be competitive with other quality timber and Asian plantation teak.

3 TEAK TRADE

Sein Maung Wint (1995) estimates that total world area of 'natural' teak forest is about 19 million hectare, while teak plantations occupy an estimated 1.6 million hectare. Unfortunately, there are no data available on actual volumes of teak produced in the world.

Sawmills which are able to supply only relatively small amounts of timber and on an erratic basis, cannot expect to capture future markets which need a continuous supply of relatively large volumes. Under such circumstances, growers supplying to sawmills can not expect to receive prices which will match those available in the better markets, even if the quality of product is first class.

Generally, relatively inferior teak is sold in domestic markets. In Myanmar, shorter lengths and second quality go into the domestic market for construction or furniture exports. At present, the main demand for natural sawn teak is satisfied by Myanmar, both from mills in Yangon, and from offshore mills in Singapore, Hong Kong and China, where logs imported from Yangon are converted. In Myanmar there is only one exporting company, the Myanmar Timber Enterprise (MTE) which fixes the price of the products. The Myanmar Ministry of Forestry regulates the amount of teak harvested by MTE (van Buren, pers.comm; Kloos, 1995; Sein Maung Wint, 1995).

At the same time, many countries restrict the export of logs and sawnwood. In June 1991, the Indonesian government levied a tax of up to US$1,200 per cubic meter on sawnwood exports, effectively eliminating any further sawnwood exports. As a result, processing of teak by several manufacturing enterprises has increased rapidly and Java teak is now exported only as processed products, mostly flooring and garden furniture. As Indonesia only offers these two specifications, they swamp the market and put prices for these products under pressure. Similar measures for log exports have been imposed by several other governments, including those of Thailand, Brazil, Singapore, Cambodia, Laos, Ghana, and Nigeria (de Boer & Kuiper, 1996; Kloos, 1995; Sein Maung Wint, 1995; Vinh Phengdouang, 1993).

3.1 CURRENT TEAK CONSUMPTION

Data on current imports and consumption of teak logs and sawnwood are scarce since many countries do not have separate trade statistics for teak. In addition, it is even more difficult to get an overview of the import and production data of teak products such as furniture.

China is the largest importer of teak logs from Myanmar, with Thailand the second largest. Much of this teak is processed for re-export as furniture and small consumer items. The United States and Europe are the final destinations of large amounts of teak, either as timber or as finished products. Some of the largest buyers in Europe are the Scandinavian furniture manufacturers which supply Scandinavian furniture stores in the US and Europe (Burma News Network (BNN) on the internet, 12 April 1997). However, total timber imports into Europe are relatively small in volume. The Netherlands, Europe's largest teak log and sawnwood importer, has annual imports of about 1,000 cubic meter teak logs and around 500 cu.m sawnwood. This constitutes about 0.15 percent of total annual Dutch timber imports of 1 million cubic meter (De Boer & Kuiper, 1996).

Large shipments of plantation grown teak logs from Africa apparently were recently exported to India. It has also been stated that since recent times plantation grown teak logs and conversions are being exported by Trinidad to Canada (Sein Maung Wint, 1995).

3.2 PROSPECTS OF TEAK PRODUCTION

According to Sein Maung Wint (1995) global teak resources as a whole are likely to expand in the near future, provided that appropriate silvicultural treatments, effective protection and management systems are applied in both natural teak forests and plantations on a long-term sustainable basis.

Changes are mainly governed by plantation forestry investments. Apsey and Reed (1996) assume that African teak production will slightly increase while more rapid increases are to be expected in Oceania and South America.

Because of the increasing population of Java and subsequent increase in demand for agricultural land, Java teak plantations have been decreasing in size while at the same time demand for wood has been increasing. Simultaneously, an extensive reforestation program in Indonesia is establishing teak plantations at a rate of about 10,000 hectare per year (Perum Perhutani, 1993; Sein Maung Wint, 1995). Poor performance of Indonesian teak plantations is often blamed on high social pressure, shortage of land for agriculture, illegal felling, grazing and forest fires (Pandey, 1995).

3.3 The Future of Myanmar Teak

The future of Myanmar teak is rather difficult to predict. According to Van Buren (pers.comm) plantation teak will never be a perfect substitute for natural Myanmar teak. Due to the rather sustainable teak production in Myanmar, the flow of natural teak from that country can be expected to remain steady.

It is unclear if, and to what extent, there exists a decreasing trend in the availability of Myanmar natural teak. According to Van Buren (pers.comm.) there are only annual fluctuations in natural teak production with no decreasing trend, while others, such as De Boer and Kuiper (1996), state that total world supplies of natural teak tend to decrease. Though Sein Maung Wint (1995) claims that Myanmar teak production is sustainable by presenting the average annual production of teak over the last 75 years, his data of the last 30 years reveal that during this period production has been well above the Annual Allowable Cut (AAC), i.e. the maximum harvest which still guarantees sustainable production, of around 600,000 cu.m per year. Simultaneously, however, the teak plantation area in Myanmar has been expanded rapidly since 1980 at a rate of around 12,000 hectare per annum.

However, Myanmar teak is increasingly under attack of human rights groups. Rainforest Relief declared the week from July 1-7 1997 the International Teak Week of Action under the slogan "teak is torture". They state that Myanmar teak forests are being exploited to finance the military ruling, formerly the State Law and Order Restoration Council (SLORC). Also, cases of forced labor have been documented in Myanmar logging operations.

Myanmar is now actively searching for foreign investments in the wood-processing sector and is aiming to decrease the export of logs and roughly sawn timber and increase the export of higher value-added products by downstream processing (Myint Kyu & Hwan-Ok Ma, 1997). At the same time the government is providing assistance to private companies for expansion and investment, having exempted forestry products exports from commercial tax since May 1996. Taking advantage of this situation, Sunwood Industry's holding company, the Sunti Forestry group from Thailand, is building advanced teak processing factories in Myanmar which will provide a steady flow of teak furniture parts for Sun, Thailand's largest exporter of teak furniture (Burma News Network (BNN) on the internet, 12 April 1997).

As teak is an important legal money-maker for the government, Rainforest Relief has called for an international boycott of teak from Myanmar. Since most of the teak exported from Thailand, Singapore and Taiwan is of Myanmar origin, this includes teak from those countries until they can prove it is not from Myanmar (Burma News Network (BNN) on the internet, 12 April 1997).

On 14 March 1997 the European Commission of the European Union voted to exclude Myanmar from the Generalized System of Preferences (GSP) in the light of the human rights situation. A month later, the US government indicated to consider imposing stronger sanctions on Myanmar trade and investments. Such measures are serious threats to the Myanmar teak trade and indicates that the solid status of Myanmar as natural teak producer is not at all secure in the future. On the other hand, ASEAN countries are considering making Myanmar a member of their trade organization. This might increase teak trade among ASEAN countries and make Myanmar less vulnerable to political pressure from the EU and the USA.

To conclude, it seems likely that Myanmar will continue to supply teak logs and sawn timber to the world market until adequate numbers of modern wood-based industries are established to absorb the teak logs annually cut and to manufacture various forms of high quality teak wood products demanded by the international market. According to Sein Maung Wint (1995) it is very likely that Myanmar will maintain its dominant role in production of naturally grown teak wood in the future since 87% of all natural teak forests occur in Myanmar. However, the character of the Myanmar teak supply might change, towards more (certified) plantation grown teak and value-added products, and trade might be hampered by human rights issues.

4 TEAK SUB-MARKETS

Due to differences in end-use and quality demands, the global teak market is best analyzed as a highly segmented market. The markets for plantation teak are diverse and often very competitive (Chavez & Fonseca, 1991; Sein Maung Wint, 1995). Five general sub-markets can be distinguished, namely; (1) yachting industry, (2) doors, window frames, fences, and garden furniture, (3) parquet and indoor staircases, (4) indoor furniture and construction parts, (5) low quality and low value products, such as toys, triplex, and pulp. This last group will not be discussed, because it will most probably not be the core business to produce low value teak products.

4.1 YACHTING

Quality demands for teak are highest in the yachting industry where it is important that the timber can resist extreme weather conditions while still retaining its attractive appearance and color. Dimensions are also of major importance. Finally, the yacht building industry demands more than 4 growth rings per centimeter (Manger, 1995).

For boat-building, Thai and Myanmar teak are preferred, because it splinters less than Indonesian teak and also has a higher oil content (Manger, 1995). In Western European teak trade, naturally grown Myanmar teak is preferred as it is harder and more stable than faster grown plantation teak. Naturally grown teak has more of an oily texture. The color is more uniform and darker or more golden than faster grown, softer and paler plantation teak. Myanmar teak is relatively more stable as the trees are normally felled only after girdling (Sein Maung Wint, 1995).

Most natural teak is used for boat building and demand is increasing. In the United States market, it is estimated by Shwe Baw (1995) that 70 percent of Myanmar sawn timber is used in boat building. In the Netherlands, 75 percent of teakwood goes towards the boat-building industry, 15 percent is used in prestigious private homes and office buildings, and the balance, 10 percent, goes into flooring and furniture (Anonymous, 1997; Manger, 1995).

Table 4.1 Market Segments and Consumption of Teak Logs and Sawnwood in the USA (after Shwe Baw, 1995)

Market Segment	Consumption Share (%)	
	Sawnwood	*Veneer*
Boat Building[1]	70	10
Furniture	6	15
Flooring	9	-
Secondary Manufactures	-	65
Manufactured Products	5	5
Others	10	5

Note: [1] including marine components

Especially in the yachting market, teak has a unique niche which is barely threatened by substitutes such as mahogany (*Swietenia macrophyla*) and afrormosia (*Afrormosia elata*), and thus has a relatively low price elasticity. In addition, this market segment is likely to remain dependent on teak in the future (Sein Maung Wint, 1995).

Table 4.1 indicates the major market segments of imported sawn teak, teak logs, and teak veneer in the USA. The producers of high quality boats tend to buy more raw material and fewer components since the interiors are usually custom built (Sein Maung Wint, 1995).

Of the total sawnwood and log imports of WorldWood, the largest European teak importer, around 60 percent remains in The Netherlands and 40 percent is re-exported mainly to Germany, Denmark and the United Kingdom, and to a lesser extent to Spain, Greece, France, and the Dutch Antilles. Re-exports are sold directly to the yacht wharves and to importers (Van Buren, pers.comm.). As this market demands only the best quality, only natural teak qualifies.

4.2 OUTDOOR FURNITURE, WINDOW FRAMES, FENCES

Slightly lower quality demands have been set for outdoor furniture, window frames, and fences. Unfortunately, little information is available on the latter two markets.

It has been estimated by the Furniture Industry Research Association of the United Kingdom (cited by Sein Maung Wint, 1995) that the total annual value of world furniture trade involves some US$100 billion of which 10 percent are exports. In many countries of Western Europe and the USA, outdoor living has gained popularity, fueling the demand for garden furniture. Durable and light teak furniture is particularly appreciated (Tint, 1995).

The bulk of teakwood garden furniture is manufactured in Indonesia, Thailand, and increasingly in Myanmar. It is expected that teak wood will become more popular as consumers become more familiar with it (Manger, 1995). In Indonesian furniture manufacturing, larger production units are not using solid teak but plywood (Grimm, pers.comm.).

Due to limited supply of teak wood and the change in consumer taste towards lighter finishes in the United States, temperate species, and rubber wood (*Hevea braziliensis*) are becoming more competitive in the furniture market, possibly having a negative influence on the growth of the market of teak furniture (Manger, 1995; Sein Maung Wint, 1995).

It is also likely that larger teak companies which can guarantee stable production of teak will vertically integrate the production and marketing column by, for example, joint ventures with garden furniture manufacturers (Van Koppen, pers. comm.). The first sign of this development can already be seen in Costa Rica where larger plantations are designing their own product and marketing lines.

For these applications, quality demands are comparable to those in the yacht building market, though somewhat less restricting. In this sub-market teak is experiencing competition from species such as meranti (*Shorea*), merbau (*Intsia bijuga*), iroko (*Chlorophora excelsa*), and construction materials other than wood, such as glass, metals and fibers.

Manger (1995) expects that plantation teak will find its way to furniture manufacturers who demand small scantlings. The furniture industry is always searching for lower prices and regular supplies, and top quality teak might penetrate this market.

4.3 PARQUET AND INDOOR STAIRCASES

Due to its attractive appearance and durability, a significant amount of teak is currently used in the parquet industry. However, the quantity of tropical timber used for parquet is still small. Due to economic growth and expanding housing projects in Japan, the USA, and Asia's Newly Industrialized countries (NICs), the market for teak flooring and moldings is also growing (Sein Maung Wint, 1995).

Dutch annual consumption of tropical timber for parquet amounts to 5,000 cubic meter. At the same time, teak is experiencing competition from wengé, afzelia, basralocus, merbau, bilinga, mahogany, and guatambú (Zijlstra *et al.*, 1995).

On the other hand, this sub-market does not demand supply of larger dimensions. Parquet prices are generally good, certainly when taking into account the fact that mostly smaller dimensions are used.

4.4 INDOOR FURNITURE AND CONSTRUCTION PARTS

About 90 percent of all interior teak furniture is still made of Myanmar teak. African plantation teak is neither strong enough, nor of good texture and color. Central American teak is somewhat similar to African teak, though harder and with a higher oil contents (Kloos, pers.comm.). In the teak sub-markets with the lowest teak quality demand, there is major competition from other species since quality demands are not very constraining.

The US market has been the major consumer of Central American teak, but much cheaper African teak has diminished the Central American market share. Especially the high price of teak logs in Central America, at around US$300 per cubic meter, is severely restricting the business potential and some teak mills in Central America have been forced to close (Kloos, pers.comm.).

As a result of a combination of factors, including a faster population growth among those over 40 years of age, and little growth among those under 40, plus stabilized rates of marriage and divorce across the age spectrum, it is expected that the number of households in the United States will grow by 9.5 percent over the next decade. Analysts expect total real disposable income in the USA to grow by around 25.0 percent between 1995 and 2005. On the basis of this assumption, it is anticipated that real household furniture spending will grow by some 19 percent over the same period and that furniture sales will grow from an estimated US$47.7 billion (1995) to a projected US$56.8 billion in 2005 (in constant 1992 dollars) (ITTO Tropical Timber Market Report, Issue 1-15th March 1997).

Higher raw-material costs and increased demand for durable consumer goods has resulted in an upward price movement for furniture and other secondary wood products during the first 6 months of 1997. Wood moldings and living room cabinets have particularly gone up in price. On average, prices for furniture and other secondary wood products experienced higher price increases than the underlying price increases for wood raw-materials; this is largely due to the impact of falling particleboard prices. Price increases of finished products are generally still below the price increases seen for sawnwood (ITTO Tropical Timber Market Report, 1-15th April 1997, posted on internet).

5 TEAK PRICES

A decreasing area of natural forest and an increasing timber demand are the main factors influencing timber prices in the near future. Demand for a particular timber is largely determined by its quality. Together with supply and dimensions, it determines the price. Additionally, products derived from each thinning have their own price-setting mechanism since they are also meant for different markets and end-uses (Centeno, 1997; Sein Maung Wint, 1995).

Between 1970-1992, real roundwood prices increased with 2.2 percent annually, although the last decade (1980-1992) witnessed decreasing real roundwood prices at 0.5 percent per year. On average, the price for sawnwood is twice as high as the price for roundwood (Dijkstra *et al.*, 1995).

Simultaneously, the average annual price increase of sawn teak at Dutch teak wharves has been 2.3 percent during the last 16 years (De Boer & Kuiper, 1996). However, real teak prices have only increased with 1.5 percent annually. It must, however, be stressed that these teak price increases are only valid for natural and Indonesian teak.

Real prices of Latin American sawnwood have been highly variable during the last years, depending on species and price changes of competing products. Yet, these prices are expected to become more stable and even start to increase in the near future in response to economic proliferation of Latin America's main markets, namely the United States and the United Kingdom (ITTO, 1996).

If teak is grown on a suitable location, it can give good quality timber for garden furniture, parquet, and veneer. In this case prices received can be expected to be average. In order to differentiate between different production areas, the following distinction is made:

1. **NATURAL TEAK**
2. **LONG ROTATION PLANTATION TEAK (60-90 YEARS)**
3. **SHORT ROTATION PLANTATION TEAK (20-40 YEARS)**

It has to be stressed that in many reports real and nominal prices are mixed and abusively compared. Comparing annual changes in CIF and FOB prices causes additional problems. Changes in CIF prices may be caused, for instance by changing transportation costs. Unless the cause of change is absolutely clear, CIF and FOB prices should be used as a indication of the value of the timber only. The subsequent paragraphs will briefly discuss the CIF or FOB teak prices paid in each of these groups and finally a FOB price will be determined which is currently valid for prime quality Costa Rican teak.

5.1 NATURAL TEAK

FOB prices of internationally traded natural teak currently range from US$1000-4000 per cubic meter. At present, Myanmar is virtually the only country which still exports natural teak in the form of logs and sawn timber and it thus has a monopolistic market position in the export trade of these products. The average 1994 FOB Yangon prices data are presented in appendix IV. Teak conversions, i.e. sawn teak, such as squares, boards, planks, decks and scantlings, are sold directly in Myanmar to foreign buyers, often agents, at fixed export prices. The FOB Yangon prices range from about US$4,250 per cubic meter for special quality teak decks of 4.5m to about US$665 per cubic meter for 2.5-2.5-75cm second quality teak scantlings.

When Myanmar authorities decided to sell teak logs only by tender, there was a substantial increase in log price. Yangon FOB Prices for board have climbed to US$3,040 per cubic meter in 1995. In this market segment foreign buyers have to pay high prices for boards and planks which are generally available at the "off-shore" mills in Singapore, Hong Kong and Thailand. For this reason European buyers have started to look for a cheaper alternative and have tried to reduce the average price they were forced to pay. This has led to a small shrinkage of the market for these products. On the other hand, fast growing plantation teak from Africa and tropical America is beginning to penetrate into the world teak market at lower prices (Sein Maung Wint, 1995).

Dutch prices for teak logs generally vary from about US$1,110-2,600 per cubic meter depending on volume and quality with extra charges for sawing technique and artificial drying. Here, quality is directly related to volume and expected conversion rate. The highest grade has a conversion rate of between 55 and 60 percent, while the lowest grade is expected to yield only between 20-35 percent useful wood. Yet, conversions of exceptional quality might reach prices of more than US$7,000 per cubic meter (Van Buren, pers.comm.).

5.2 LONG ROTATION TEAK

Currently, slow grown plantation teak of 60-90 years is mainly produced in Indonesia, Myanmar, and Thailand. Indonesia plywood teak logs were domestically sold at US$1050-1250 per cu.m in March 1997, showing a steady increase in 1996 from US$937.50 per cubic meter in May 1996 to US$1,050 per cu.m in December 1996. However, Indonesian prices are less relevant than those from Thailand and Myanmar due to Indonesian export restrictions (ITTO Tropical Timber Market Information Issue 1-15th March 1997; MTC, 1997 on internet).

Table 5.1 gives an indication of plantation teak prices from Myanmar and Thailand between 1988-92.

Table 5.1 Average Real FOB Yangon and Bangkok Value of Myanmar and Thai Sawn Plantation Teak from 1988-92 (US$/cu.m)

Commodity	Average FOB Unit Value (US$/cu.m.)					
	1988	*1989*	*1990*	*1991*	*1992*	Average
Thailand						
Teak Scantlings	976	1140	1061	1232	1207	1123
Teak Board	1202	1388	1306	1075	1273	1249
Teak Plank	1971	1651	1313	1088	1634	1531
Myanmar						
Teak Scantlings	582	686	789	789	789	727
Teak Board	1332	1357	1493	1493	1643	1464
Teak Plank	1200	1225	1346	1346	1482	1320
Teak Deck	1443	1661	1993	1993	1993	1817

Sources: FAO, 1995; Myanmar Timber Enterprise (cited by Sein Maung Wint (1995)).

5.3 SHORT ROTATION TEAK

Roughly, FOB prices for short rotation teak of 20-40 years vary from US$200-2000 per cubic meter. However, the base price for 5 to 8 year old teak poles should optimistically be estimated at US$50-80 per cubic meter roundwood, mainly for consumption in the local market (Centeno, 1997).

West African FOB log prices are around US$200 per cubic meter, while teak logs are sold locally on African markets at US$100 per cubic meter. Orders for logs with a diameter of 17 cm and larger are reportedly being accepted in Ivory Coast for 15,000 cubic meter lots at US$220-250 (FOB) per cubic meter (ITTO Tropical Timber Market Information Issue 1-15th March 1997). Prices for Nigerian teak logs lay between US$200-250, the former for 17-24 cm diameter and the latter for diameters between 25-30 cm, FOB in Nigeria. Squared logs are exported to India and the Middle East at around US$300-350 per cubic meter(CIF). On the wholesale market of Shanghai, China, the price of teak logs is around US$500 per cubic meter (ITTO Tropical Timber Market Report, 1-15th April 1997, posted on internet).

Sawn teak prices from selected West African teak vary considerably. Sawn teak flooring from West Africa range from US$500-900 per cubic meter (FOB) depending on quality and sizes. Prime quality, defect free, flooring material ranges from US$700-1800 per cubic meter depending on size and length. Similar prices are being paid for prime quality Guatemalan teak; from US$950-1900 per cubic meter, depending on sizes and length.

Trinidad teak is a lot cheaper, but at this moment trade is disorganized. Guatemalan teak is considered superior to African teak and should theoretically demand a premium, but for commercial reasons not all international buyers agree (Kloos, pers.comm.).

The Dutch Amazon Teak Foundation (ATF) considers Benin prices, as given in table 5.2, for parquet to be representative for future prices of ATF teak plantations in Mato Grosso, Brazil. Round wood prices expected by ATF for 10, 15, 20, and 25 year old teak are respectively US$50, 300, 500, and 800 per cubic meter. Recently, another Mato Grosso teak plantation, Caceres FPI, sold logs of 15 centimeter, without bark, at US$187 per cubic meter and lower quality sawnwood from the same logs at US$265 per cubic meter F.O.B. Santos. The timber was exported to Hong Kong and India to be used for window and door frames (*Gazeta Mercantil*, 20-10-96).

Table 5.2 Benin Cotonou FOB Parquet Prices (US$)

Dimensions (mm)	A Quality (US$/cu.m)	B Quality (US$/cu.m.)
10·50·250	790	550
10·60·300/350	880	620
14·70·350/400/450/500	1065	750

Source: ONAB Industrie Benin

5.4 PRICE PROJECTIONS FOR PLANTATION TEAK

It is difficult to make sound projections of the future demand for timber and corresponding prices. Additionally, estimating prices is also very complicated due to the large number of sizes and qualities (De Boer & Kuiper, 1996).

Dielen (1996) indicates that Wood Resources International is expecting a timber scarcity by the year 2010 and consequently increasing timber prices, while the Timber Committee, according to their fifth Timber Trend study (ETTS 5), is not expecting any timber shortage at least until the year 2020. These differences in projections may be caused by differences in methodology used. Wood Resources International is foreseeing a shortage of coniferous wood in the near future, but a surplus of non-coniferous wood. Consequently they expect pressure on the fiber market and perhaps increasing coniferous timber prices. This might also be instigated by certification of sustainably managed forests. Among the most important findings of the ETTS 5 research are an expected increase in demand for timber products, increasing imports from outside the EU, and unchanged timber prices (Dielen, 1996; Stolp, 1996).

Table 5.3 Projected Teak Roundwood Prices in 15-25 years and Price Increase per Teak Fund

Teak Fund	Expected Teak Price (US$/cu.m.)[1]	Assumed Annual Price Increase (%/year)
Tropeco	890	4
Eurogreenmix	670	6
Ecodirecta	600	0
ATF	530	3
Green Fund	500	4
Teca Verde	470	5
Ohra	460	2
Forestales	450	8
Global Green	375	8

Note: [1] calculated at US$1=Hfl1.80

Under increasing import restrictions and increasing demands, the World Bank (1990) is expecting an annual real price increase until 2005 of 1 percent for Asian roundwood and 2.9 percent for African roundwood. Additionally the World Bank expects an annual real price increase of 2.1 percent for tropical sawnwood. This is more or less in accordance with calculations based on historical Dutch teak log price data. From 1979-1992, the actual annual teak log price increase in the Netherlands has been calculated from data of Dutch Association of Timber Traders (NVvH) to be 5.8 percent in nominal terms, but 2.5 percent in real terms, i.e. corrected for inflation. A tentative conclusion may therefore be that there is no indication that teak prices will increase strongly in the near future.

The price of timber from managed forests is likely to keep on rising in real terms and access to environmentally-discriminating markets will eventually turn in favor of well-managed certified forests and plantations. However, competition from sustainable temperate hardwoods will continue (Keogh, 1996).

It is unlikely that South and Central American teak will reach the same quality as old-growth Indonesian plantation teak, but since the Indonesian government has increased teak prices during the last years there might at least be some degree of price competition. According to Grimm (pers.comm., 1997) teak furniture manufacturers are increasingly more interested in relatively low-priced lower-quality teak, and with Central American prices of approximately 50% of Indonesian prices this timber might pose a serious threat to Indonesian teak.

There still is little experience with the processing of young plantation teak from fast growing plantations. De Boer and Kuiper (1996) estimate that from a 20 year old tree with a diameter of 30cm, a maximum of 25 percent of the log volume will be marketable as sawnwood. Improving the quality of small parts by finger jointing techniques may be an option, though a expensive one.

Teak investment companies have to sell their teak after 20-25 years to pay their investors. This makes their position on the timber market vulnerable. Especially for lower qualities, large flows of teak could put a downward pressure on prices. Besides, due to their large area of teak countries such as Indonesia and India could influence those teak prices (De Boer & Kuiper, 1996). Table 5.3 indicates the widely varying price projections of 9 teak funds.

Unless there will be a valuable application for plantation teak, prices can be expected to remain relatively low. Leaving the trees in the plantation for a longer period will definitely improve the marketability of the plantation product. New markets will have to be found, but that can not be expected to cause large increases in teak prices.

5.5 Price Outlook for Costa Rican Export Teak

Based on the market information presented in previous sections, it can tentatively be concluded that current FOB sawnwood prices for prime quality Costa Rican plantation teak would range from US$450-500 per cubic meter. From recent data the real annual teak price increases can be expected to be between 1-3 percent.

From a global perspective, it is further expected that the quality differences between teak from the various teak producing regions in Costa Rica is so small, that a differentiation of teak prices within the country is not to be expected. These finding will be used in the financial model presented in the subsequent chapters.

SECTION II

COSTA RICAN TEAK

DEVELOPING A PROFITABILITY MODEL FOR COSTA RICAN TEAK PLANTATIONS

Teak was first introduced to Costa Rica in 1943 by the Compañía Bananera de Costa Rica, currently known as United Fruit Company, i.e. Chiquita. The first plantation was established near Quépos, near the Pacific coast of Costa Rica. Until the 1980s, teak was planted on a small scale, mainly in the Pacific lowlands. Rising government interest in reforestation and the subsequent creation of incentives led to a drastic increase in reforestation in general throughout the country. It has been estimated that with the help of these incentives some 4,100 hectares of teak were established between only 1990-1994 (Moya Roque, 1996). However, a similar area has been planted without incentives by private investment companies. The total current Costa Rican teak area is likely to cover about 20,000 hectare.

This section discusses the development of a profitability model for teak plantations in Costa Rica. In order to place Costa Rican teak production in a broader framework, it first gives a brief introduction on Costa Rican timber and teak production. This section subsequently discusses the elements of the model and the applied methodology. In the final chapters the results are presented and discussed.

6 COSTA RICAN TIMBER PRODUCTION AND TRADE

6.1 GENERAL

As stated in chapter 1, increase of economic activity and growth of GDP lead almost directly to increased timber consumption. Currently, Latin America is experiencing strong economic growth, the strongest increase in GDP in the world after South East Asia, while trade is liberalized. This growth is expected to continue during the next 10 years (Latin Trade, June 1997). According to FAO (1993b) and WRI (1990) studies, Latin American and Caribbean deforestation amount to half the annual global deforestation. Subsequently, Latin American timber demand can be expected to rise.

In addition to economic development, development of timber stocks is also of major importance (See chapter 1). Compared to global deforestation, the deforestation rate has been relatively very high in Costa Rica. In 1966, forests covered 58.5 percent of the country, but in 1989 only an estimated 42.9 percent, 1.4 million hectare, remained in forest. WRI (1990) and FAO (1993b) calculated that between 1977-1985 annual rate of loss of Costa Rican forest cover was roughly between 4-8 percent. At this rate, Costa Rica is among the countries with the highest deforestation rate in the world.

However, there is much debate over recent trends in Costa Rican deforestation. Currently, strongest deforestation takes place in the Tortuguero, Talamanca, and Peninsula de Osa area. However, a large amount of timber is also extracted from revisited secondary forest growth and there is no up-to-date study available on the remaining timber volume in Costa Rica's forests. There are strong indications, however, that natural timber availability in Costa Rica will decrease rapidly during the next 10 years (Kaimowitz, 1990; Solórzano et al., 1991; Tico Times, July 25, 1997, p1+12).

It is difficult to draw a conclusion on future timber demand in Costa Rica. Even at low economic growth rate, demand can still be expected to increase. However, it is unclear whether these effects can already be measured in the near future. This chapter therefore extensively describes the current Costa Rican timber production and trade and the position of teak therein.

6.2 COSTA RICAN TIMBER PRODUCTION, HARVEST & CONSUMPTION

Costa Rican timber harvest has been increasing steadily the last decades. Total harvested timber volume in 1957 was 256.686 cubic meter (Porras & Villarreal, 1986), while DGF, in Lux & von Platen (1995), estimates the amount of timber processed by sawmills to have increased with 14 percent from 1986-1992 to 944,721 cubic meter roundwood in the latter year. There is also a discrepancy of about 30 percent between the government allowed timber logging and the amount of timber processed by the sawmills. This can at least partly can be explained by illegal harvests and it indicates the weakness of the statistics on Costa Rican timber production.

The composition of the Costa Rican timber stock has been changing drastically the last decades. In 1992, 17 percent of Costa Rican timber extraction came from the Atlantic Zone and 73 percent from the Northern Region (Lux & von Platen, 1995). However, there are strong indications that the timber stock in the Northern Region is almost depleted, while, as table 6.1 indicates, most remaining Costa Rican forests are situated in protected areas now. Simultaneously, there are projections that Costa Rican timber consumption may reach 3.500.000 cubic meter roundwood by the year 2020, indicating that at least halve of the national timber harvest should come from plantations (Moosmayer, 1993).

Table 6.1 Classification of Forests in Costa Rica

Classification	Hectares	Percentage (%)
Forest in protected areas	893.352	57
Forest in non-protected area:		
in buffer zones	215.100	14
for production	218.274	14
Secondary forest	155.380	10
Planted forests	74.196	5
Total	1.556.302	

Source: Gonzales, 1992

It can thus be seen that while natural timber resources are rapidly depleted, Costa Rican timber harvest steadily increases. The first reforestation projects were initiated only recently. By 1993, forest companies had planted 36,750 hectare of tree plantations in Costa Rica, more or less halve of the total reforested area (Gonzales, 1992; Moosmayer, 1993). Currently, it may be estimated that total reforestation reached 100,000 hectares. The species used in tree plantations are indicated in appendix V. Most important species are eucalyptus, teak, and melina.

6.3 Costa Rican Timber Prices

Prices for more valuable Costa Rican timber species are slowly increasing and this may have repercussion on the teak price in the near future. Table 6.2 indicates that the average FOB Limón sawnwood price was US$728 per cubic meter, while timber was imported at US$356 per cubic meter Although the value of the exported timber apparently diminished between 1989 and 1992, the prices paid are still high. This value drop might be explained by shifts in the species composition of exports towards less valuable species.

Table 6.2 Costa Rican Timber Exports and Imports

	Exports			Imports		
		FOB Limón value			CIF Limón value	
year	*vol. (cu.m.)*	*mill. US$*	*US$/cu.m.*	*vol. (cu.m.)*	*mill. US$*	*US$/cu.m.*
1989	29,640	23.1	781	14,634	3.9	268
1990	24,853	22.1	887	8,280	3.6	454
1991	27,077	16.9	625	4,770	1.9	397
1992	34,814	22.6	648	7,929	3.2	409
Average	29,096	21.2	728	8,903	3.2	356

Source: Lux & von Platen (1995)

Based on data provided by the Costa Rican *Caméra Forestal* (CCF) average real roundwood 'at sawmill' price increase during 1996 was 4 percent. Table 6.3 gives indications on prices and price changes per wood type and region, making a distinction between 'classified' and 'general' (*común*) semi-hardwoods. It can clearly be seen that, based on the national averages, softwoods have diminished in price while the prices of more precious woods have strongly increased. This could indicate increasing scarcity of valuable timber species and Costa Rican plantation teak could fill in this niche in the near future. Furthermore, it is also clear that prices vary according to region. Differences between regions can partly be explained by differences in species composition per wood type for each region and by differences in distance to major markets.

Table 6.3 Average 1996 Real Roundwood 'at Sawmill' Prices and Changes per Wood Type and Region

Type	Atlantic Zone		Zona Norte		Zona Sur		National Average	
	Price[1]	*Change*[2]	*Price*[1]	*Change*[2]	*Price*[1]	*Change*[2]	*Price*[1]	*Change*[2]
Softwoods	42	-20%	41	-6%	59	-1%	47	-9%
Semi-hard. Class.	92	+9%	75	-4%	108	+28%	92	+11%
Semi-hard. Gen.	92	+20%	70	+4%	98	+29%	87	+18%
Hardwoods	133	+22%	93	-8%	277	+39%	168	+18%

Based on data provided by CCF, for species see appendix VI
Note: [1] US$/cu.m. April 1997
[2] 1996 real price change

While the price of softwoods was still decreasing during 1996, the real value of (semi-) hardwoods is apparently increasing slowly.

6.3 Domestic Market for Teak

According to Brenes (pers.comm.), there actually does not exist a domestic market for teak in Costa Rica. There are many native species which have similar wood characteristics, that are better known by the consumers, and which are sold at lower prices. Yet, it is also foreseen that within 5 years domestic harvests will start to change with decreasing supplies of the most favored species. It can therefore be expected that there will be a domestic market for teak in 15-20 years.

Currently, most teak offered to sawmills in the Pacific lowlands shows mal-formations and conversion rates are consequently low, at approximately 20 percent for export quality. Due to an artificially high price, set by Bosque Puerto Carillo sawmill's high demand for teak, in addition to low quality, it can be stated that a domestic market for teak in Costa Rica is currently absent.

Pacific teak farmers are unwilling to sell teak to sawmills at prices lower than US$110/cu.m, which is comparable to US$80-120 per cubic meter paid for teak in the Southern Pacific region (Costa Rican Camera Forestal). This discrepancy finds it origin in the high teak prices previously offered by former Bosque Puerto Carillo's sawmill. However, sawmills are currently unable to sell teak sawnwood at competitive prices, as conversion rates are below 40 percent and competition from other, superior timbers, is large. To give an indication; at these high teak log prices, quality teak sawnwood would have to be sold by the sawmills at US$700 per cubic meter, while timber from *pochote* and *cedro* is currently sold at prices of US$440 per cubic meter.

6.5 Subsidies

Since 1977 the Costa Rican government initiated a series of subsidies under the Law on National Reforestation (nr.4465). There are three subsidies available; (1) the Forestry Subsidy Certificate (*Certificado de Abono Forestal*, CAF) and (2) the Advanced Forestry Subsidy Certificate (*Certificado de Abono Forestal Adelantado*, CAFA) since 1986, and (3) the Forestry Development Fund (*Fondo de Desarrollo Forestal*, FDF) since 1989. According to van Leeuwen and Hofstede (1995) with both CAF and CAFA the amount of US$845 per hectare can be obtained, while the FDF amounts to US$435 per hectare. Of the FDF subsidy 15 percent is subtracted and of the CAF 20 percent for administration costs. CAF is completely paid in one term, 9 months after planting, while FDF and CAFA are paid over a period of 5 years with a distribution of 50, 20, 15, 10, 5 percent subsequently (Brouwershaven, 1993; van Leeuwen & Hofstede, 1995).

There are some requirements to obtain government subsidies. A map of the farm and a reforestation plan drawn up by a registered forestry engineer is needed. For both CAF and CAFA a land title is required, though many smaller farmers do not have one. The minimum density required to obtain subsidy is 1,111 trees per hectare. CAF regulation requires weeding twelve times in the first two years after planting, and twice in the third, the fourth, and fifth year (van Leeuwen & Hofstede, 1995).

The effect of these incentives has been that many farmers planted teak and other species for the payment of the subsidies only. In subsequent years they omitted management of the plantations, which led to poor growth, mal-formation of the trees, and subsequently high conversion losses at the sawmill.

7 COSTA RICAN TEAK PRODUCTION

7.1 TEAK PRODUCING REGIONS

To reach a better understanding of Costa Rican teak production a distinction is made between the teak producing regions in the country. Teak production takes place in the lowlands of 4 regions: (1) the Atlantic Zone, (2) the Zona Norte, (3) Guanacaste and (4) Central and South Pacific. The basis of this distinction mainly stems from climatic differences displayed in table 7.1.

Table 7.1 Climatic Data of Teak Producing Regions

Region	mean annual temp. (°C)	mean annual precipitation (mm)	dry period (months)
Atlantic Zone	23-27	3400-4500	0
Zona Norte	25-27	2700-3500	0-2
Northern Guanacaste	>27	1300-1800	5-7
Peninsular Guanacaste	26-27	1800-2400	5
Central and South Pacific	24-27	2000-3200	3-5

c.f. Herrara, 1985

Based on these climatic data two major teak production areas can be distinguished, namely (1) the Pacific lowlands, including Guanacaste and Central and South Pacific, and (2) the Atlantic lowlands, which include the Zona Norte and the Atlantic Zone. This distinction mainly stems from the difference in the length of the growing season; the Pacific lowlands have a distinct dry season of 3-7 months, while growth in the Atlantic lowlands is only halted during 1 or 2 months. On average, the climatic effect on growth is considered to be generally the same within these supra regions.

7.2 TEAK MANAGEMENT

Management of teak plantations has strong repercussions on the quality of the final product. Bad management is reflected in cruel stem shapes, making it more difficult to optimally saw the logs, and incorporation of knots and other defects.

There are many disappointing teak plantations throughout the world. These are based on poor-quality genetic material, or located on poor sites, and/or badly managed. According to Kloos (pers.comm.), older West African plantations have been less looked after, not being thinned nor pruned. This has had strong repercussions on the quality of teak currently available from that region. A similar phenomenon is currently seen in Guanacaste.

In general, there is much room for improvement. What is mostly needed are good seed sources, appropriate soils and topographic conditions, good drainage, appropriate heat, humidity and precipitation, and a good management. Under such conditions, successful projects can be established, with rotations of preferably from 25-40 years (Centeno, 1997).

This paragraph subsequently describes the different aspects of Costa Rican teak production.

7.2.1 PROVENANCE

Teak trees found in Costa Rica are believed to stem from two ancient provenances: (1) the Tenasserim (Myanmar)-Trinidad and (2) the Sri Lanka-Panama provenance (Chavez & Fonseca, 1991). Teak currently planted in Costa Rica stems from seed trees in the Quépos region, along the Pacific coast. Teak provenances generally differ in form and color of leaves, color and structure of the bark, and stem form (Lamprecht, 1989). There are some indications that stem form of the trees is better in the Pacific than in the Atlantic lowlands. However, there are no clear data available to verify that.

7.2.2 INFRASTRUCTURE AND DISTANCE TO MARKETS

Together with growth rates, transport costs are a critical factor in the final profitability of a plantation. If timber can be processed close to the growing area and it can be dried and sawn accurately to the dimensions required by the target market, then considerable savings can be made and higher prices can be obtained, compared to the situation where material must be transported over long distances in the round or in semi-processed state without drying. It is therefore not advisable to start plantations in areas which are difficult to access due to natural barriers.

By processing the material close to the growing area, more benefits accrue to the growers. Returns may be further enhanced by producing value-added items (Keogh, 1996). Large teak plantations, such as Flor y Fauna, have invested in sawmills for the sole purpose of increasing the value of their produce.

7.2.3 ESTABLISHMENT

Teak plantations are established either with *pseudo-estacas*, i.e. uprooted stumps, or seedlings in bags, i.e. container stock. The uprooted stumps ideally have a basal diameter of 1-2 centimeter when their stem is cut back to about 5 centimeter and their roots to about 20 centimeter (Lamprecht, 1989).

Usually, teak planted from container stock is not replanted because mortality is practically zero and drop-outs are considered part of the first thinning. Mortality with stumps is little. Data from Changuinola, Panama, and Talamanca, Costa Rica, indicate that within the first 6 months 6 percent of these plants had to be replaced, followed by about 8 percent mortality within the first 5 years after planting (Luján Ferrer, 1994; Luján Ferrer *et al.*, 1997). In the Pacific lowlands, dryer than usual years occasionally cause higher mortality in the first year after planting, or may even force to postpone planting for a year or more.

Initial spacing has marked effects on growth, quality and cost of establishment of the plantation. Under poor site conditions the teak plantation should be established at closer spacing (Kaosa-ard, 1995b). Most Costa Rican teak is planted at 1110 or 1800 trees per hectare.

7.2.4 WEEDING

As teak is a light-demanding species, intensive weeding in 1-5 year-old plantations is very important (Kaosa-ard, 1995b). On slopes it might be advisable to be careful with weeding since the undergrowth reduces erosion caused in teak plantations on slopes.

7.2.5 THINNING

Thinning is done for a multitude of reasons, including an increase of marketable volume production, improvement of stand hygiene, accessibility, liquidity, to favor non-timber functions of the forest, to maximize financial results or make the stand less prone to wind damage (Filius, 1992). According to Sánchez (1993) selection takes place based on stem form, diameter, commercial height, phytosanitary state, and size and vitality of the crown. As thinnings advance there are progressively less trees to choose from and greater effort should be made to avoid felling the best trees that will constitute the final crop.

Early thinning reduces the costs of maintenance in the sense that less trees have to be pruned and taken care of. It also partly pays back the burden of the investment at establishment of the plantation. However, if thinnings are delayed too long mean annual increment of the plantation will decrease and the final crop will not reach its maximum dimensions. As a result, delayed thinning will harm the financial returns and thinnings have to be planned carefully.

For Costa Rican reforestation projects with teak, MINAE officials promoted the Miller regime of thinning from Trinidad with a discrimination of site suitability for teak. The first two thinnings are based on top height; the mean height of the 100 largest diameter trees per hectare. The first thinning takes place when top height is 8 meter and the second is executed when the trees reach 15-16 meter top height. Subsequent thinnings are based on the total basal area. When basal area reaches 20-21 m^2/ ha, the thinning reduces the area to 14-15 m^2/ ha. (Chavarria & Valerio Valerio, 1993; Keogh, 1987). Appendices IX and X indicate the thinning schemes in the model.

Trees have to be marked for thinning. At smaller diameters, thinning takes place with machete, while at larger diameters a chain saw is used. Unfortunately, there are not enough data available to model the effect of prolonged thinning and different thinning regimes on teak production in Costa Rica.

On slopes, the manager might decide to increase the intensity of thinning in order to stimulate the growth of weeds. This ground cover might reduce erosion under teak planted on slopes.

7.2.6 PRUNING

Keogh (1987) and Lamprecht (1989) recommend to start pruning early. This improves the quality of the wood and increases the marketable height on the best trees. Teak does not respond well to pruning and wounds heal slowly. Therefore, great care should be taken to minimize damage.

Absence of annual pruning in the first years after planting of wider plantings leads to the formation of sprouts and branching of the tree thus indirectly leading to lower timber qualities. There are ample examples of bad pruning practices in Costa Rican teak stands. In the model, pruning is expected to take place during the first years and the years following a thinning.

7.2.7 PESTS AND DISEASES

Teak is considered to be very resistant to pests and diseases and reported manifestations are generally of minor importance (Chavez & Fonseca, 1991). However, insecticide is sometimes used to prevent leaf-cutter ant attacks. Appendix VII indicates reported pests and diseases in Costa Rica. In the plantations of the Atlantic lowlands it can clearly be observed that phytosanitary state of the trees is worse in these regions than in the Pacific lowlands. Leaves are scarred and show fungal blemishes. Recently, a manifestation of *Nectaria* was observed on teak in the Atlantic lowlands. This disease causes opening of the bark of the teak tree and subsequent mal-formation of the trunk. These phytosanitary problems have led to the conclusion that threat from pests and diseases can be considered to be significant in the Atlantic lowlands and could seriously hamper production of quality teak. To date, however, quantitative data of these phytosanitary threats are lacking.

7.2.8 FERTILIZATION

It is common practice to apply fertilizer as a start application before planting of teak. However, data on the effect of fertilization on teak growth are scarce. Recently some research plots were established in the Atlantic lowlands to investigate the effect of fertilization on teak growth in 3 year old plantations. However, to date no significant differences in growth have been found.

Poels (1994) states that when starting a teak plantation on former grassland or agricultural land, which is often the case in Costa Rica, large nutrient shortages will develop during development of the trees because of immobilization of nutrients in biomass. Shortages will be larger during the first years after establishment. In order to replenish shortages, it is advisable to apply 50 kg P, 200 kg K, and 300 kg Ca per hectare. in the second year on the well drained low fertility soils. Poels also reports large N-shortages, though he states that artificial fertilizing could prove to be too expensive.

7.2.9 FIRE AND STORM CONTROL

Fire and wind control are important in Costa Rican teak production. Wind problems are severest during the dry season in parts of the Guanacaste region. Fire control includes the formation of clean fire lanes in the plantation.

In spite of the low average wind velocities, teak in the Atlantic lowlands is occasionally suffering from severe wind gusts during thunderstorms. Storms bend the younger trees which subsequently have to be fixed by ropes in order to prevent further damage. This is rather labor intensive. According to De Graaf (pers.comm., 1998), bending of the stem is an indication of unbalanced growth between crown volume and timber composition of the stem.

8 CONSTRUCTION OF GROWTH TABLES AND A MODEL FOR FINANCIAL ANALYSIS

This chapter describes the applied methodology. It first discusses he construction of indicative growth tables for the model. Then it discusses the elements of the model and presents applied formulas for the financial analysis.

8.1 CONSTRUCTION OF INDICATIVE TEAK GROWTH TABLES

Volume growth of teak is an elementary part of the model presented in this paper. To date, however, Costa Rican teak growth has had only marginal attention and reliable growth tables are still lacking. Therefore, preliminary growth tables were constructed within the framework of this study. These tables give the maximum attainable teak volume under optimal management. Optimal management is interpreted in this study as well pruned and well thinned stands. Plantations on slopes were excluded as their growth is generally poorer and not representative for the region.

Costa Rican teak plantations have been established largely during the last 8 years. Only few well-managed and representative stands can be measured that surpass that age. Therefore, it has to be stressed on forehand that the presented tables could only be based on data gathered from relatively few plots. The tables thus serve as an indication of teak growth classes in the two regions analyzed in the model, rather then that they represent well-analyzed and sound teak growth tables for Costa Rica. As such, these preliminary tables can only be used to indicate teak growth in general terms. Extensive future research should aim at producing well-based growth tables.

Teak growth was measured in thirteen well-managed teak plantations in the Pacific and Atlantic lowlands of which the age could be determined from records. Per plot of 20-60 trees stand density, height and diameter at breast height (DBH) were determined. Together with previous CATIE and REPOSA teak growth measurements of the same plots, these measurements served as the basis of the indicative teak growth table. A summary of these field data is presented in appendix XI.

The indicative teak height and diameter growth presented in the preliminary growth tables of this report have been derived from these field plots and from Miller's 1969 growth tables for Latin America. The formulas for Miller's height and diameter growth were derived from his tables by regression analysis. Although it is more sound to derive growth from the basal area (Jansen, pers. comm., 1998), diameter was chosen because it is also used in the calculations of volumes paid to the farmer at the sawmill.

The Miller yield tables were used to derive two new growth classes, for which the highest growth class of Miller formed the basis of the lowest growth class presented in this report. For the medium and high growth class, height and diameter growth are based on a multiplication of the highest growth class data of Miller with 1.2 and 1.4 respectively. This decision is based on the field observations depicted in appendix XI.

Based on experience, Miller's height growth was slightly adjusted for growth after 20 years. Height and diameter growth are depicted in figures 8.1 and 8.2. Standing volumes are depicted in figure 8.3. Whereas the thinnings clearly can be distinguished in figure 8.3, the former two are smoothened for use in the model.

Formulas for the model were derived from the newly established tables by regression analysis. The DBH formulas presented in appendix XII were further used in the model to calculate conversion rates.

With the height and diameter, 'basal area' (G) and 'volume per hectare' were calculated. Although the form factor is dependent on genotype, age, stocking, crown size, and site factors such as wind exposure, it has been set to 0.5 in the model in order to simplify volume calculations (Philip, 1983). Future research should provide more detailed information on the variation of the form factor of Costa Rican teak.

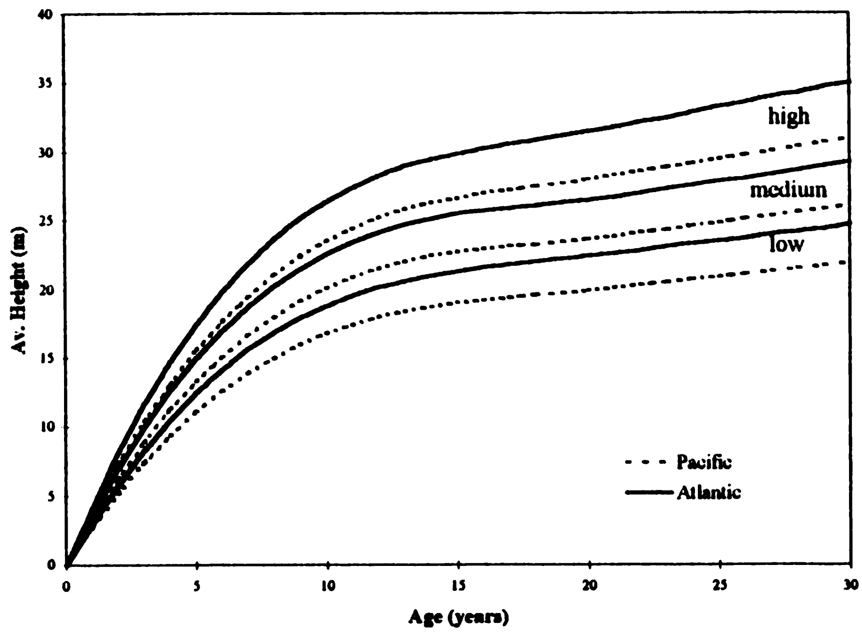

Figure 8.1 Indicative Height Growth in Atlantic and Pacific Lowlands

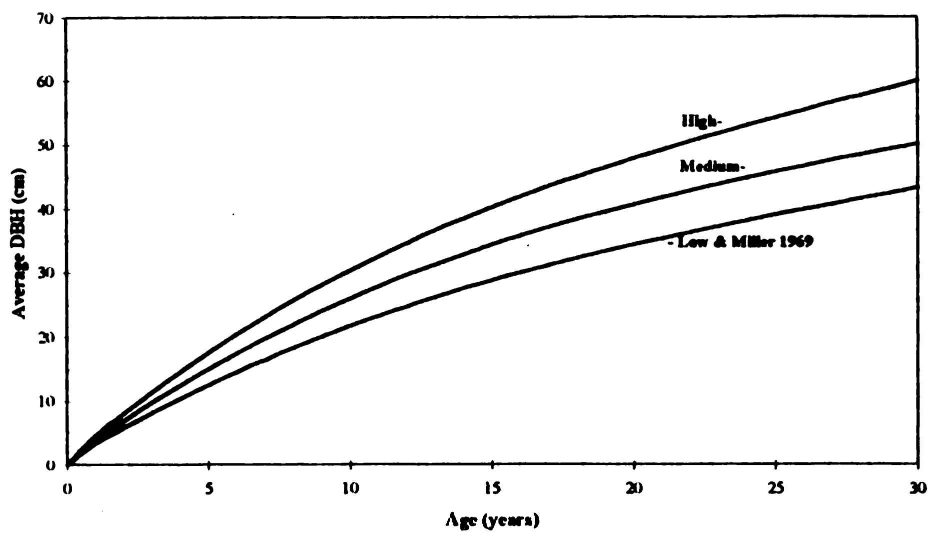

Figure 8.2 Indicative Growth of Diameter at Breast Height 'over bark' (DBH)

Soil fertility and climate are strongly reflected by height growth at a given age (Philip, 1983). The high height growth values thus suggest that Costa Rican teak plantations generally are established on fertile soils and under favorable climatic conditions.

Additionally, it was observed from the field data that height growth is less in the Pacific lowlands. Therefore, height growth has been reduced with a factor 0.89. This conversion factor was derived from the observation that the height data at a certain DBH did not fit the table, unless the data were adjusted by multiplying the data with a factor of 0.89 on average. Diameter growth is equal in both Atlantic and Pacific growth table. Based on experience, teak height growth in the high, medium, and low growth classes in the Pacific lowlands is assumed to remain constant at respectively 0.3, 0.25, and 0.2 m per year from year 20-30, while it is assumed to remain stable at respectively 0.35, 0.28, and 0.23 m per year for the Atlantic lowlands.

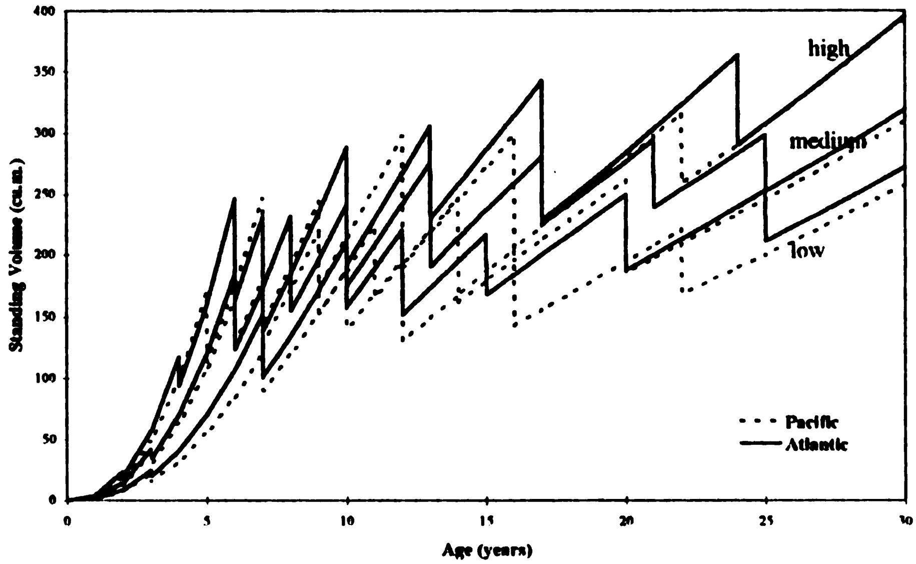

Figure 8.3 Standing Volume

In addition, since teak in the Pacific lowlands is susceptible to wind damage, a wind correction factor has been introduced. These reductions have been arbitrarily established by Nieuwenhuyse (pers.comm., 1997) and are based on the relation between wind charts and observations in the field of the wind effect on teak growth. The correction factors used in the model are presented in table 8.1.

Table 8.1 Estimated Volume Reduction due to Wind Damage

Wind Effect	Reduction (%)
no effect (0)	0
slight effect (1)	10
moderate effect (2)	25
strong effect (3)	45

Nieuwenhuyse, pers.comm.

The generated indicative teak growth tables, divided in high, middle and low growth class, used in the model are presented in appendix IX and X. These tables assume optimal management, especially optimal timing of thinnings. Thinnings were introduced according to the 'rule' that the first 2 thinnings are based on height, while the subsequent thinnings are based on basal area. In practice however, thinnings are retarded and often stronger, making sub-optimal use of the growth potential. Thus, teak growth for most plantations will in practice be lower. However, it is impossible to give sound indications as to how much the actual yield in moderate teak plantations deviates from the potential yield presented in these tables.

DETERMINING THE VOLUMES FARMERS ARE PAID FOR AT THE SAWMILL

In order to calculate how much is actually paid to the farmer several corrections have to be made. First the volume per tree has to be adjusted to the real volume the farmer can sell to the sawmill. Sawmills only accept logs with a minimum top diameter of 15cm. It has been calculated that of the total volume per tree calculated from the formula, 0.012 cubic meter has to be subtracted in order to correct for the top part of the log with diameters below 15 centimeter (Nieuwenhuyse, pers.comm, 1997).

8.2 Deriving Future Log Prices & Conversion Rates

Future timber price is dependent on timber quality and its dimensions. Age and growth class are input in the diameter growth function (appendix XII), giving the diameter at a certain age. The diameter largely determines the conversion rate at which a log is sawn; logs with a larger diameter have a higher conversion rate and, consequently, relatively less second grade timber and waste. Conversion rate, annual price increase, distance to the port of Limón, and a current basic timber price finally determine the future log price paid to the farmer by the saw mill. Several formulas have to be derived to enable price projections.

The average price of transportation from sawmill to Limón is calculated to be about US$350 per 40 feet container from the Atlantic lowlands and US$500 if the sawmill is situated in the Pacific lowlands. A container can carry 30 cubic meter of sawnwood.

In order to facilitate conversion from roundwood to sawnwood in sawmills, function 1 was derived by regression analysis from the data on teak conversion rates presented by Moosmayer (1993). It assumes trees to be well-managed and relates round wood volume to prime export quality sawnwood. Mal-formations due to bad pruning and thinning management and wind effects are not included in this formula and lead to additional losses.

$$cr = 0.9579DBH^3 - 2.0529DBH^2 + 1.3915DBH + 0.2012 \qquad (1)$$

with: cr conversion rate
DBH log diameter at breast height (m)
($R^2 = 0.99$)

This function is valid for logs with a DBH of 10-50cm. Local sawmills only accept logs with top diameter 15cm or larger. Logs with top diameters larger than 50cm are assumed to have a constant conversion rate of 0.5. However, if only small dimensions are needed, the conversion rate further increases. Greentree S.A., a consortium of forestry enterprises in the Atlantic lowlands of Costa Rica, states that it is able to convert 3 year old teak logs at a maximum rate of 0.54 for producing small lumber sizes for making bird cages.

Furthermore, prices paid to farmers by sawmills are constant in Costa Rica. Therefore, a fixed price per cubic meter is used in this model. This is an artificial adjustment of the market conform payment, i.e. where logs of a larger diameter are paid more per cubic meter, which benefits the sawmills.

8.3 The Model

The profitability model presented in this section is composed of several components namely; (1) a labor input section, (2) a material input section, (3) an output section, and (4) a summary, variables, and results section. It is written in Microsoft Excel. Input to the model is based on surveys executed during previous research of CATIE and WAU (Nieuwenhuyse and Floors, pers.comm., 1997). Table 8.2 indicates the actors included in the model and whether they are variable or constant. Overhead costs have been omitted.

Table 8.2 Variable and Constant Input (per Hectare) of the Model

Variables:

Region; Atlantic or Pacific;
Growth class; high, medium, or low;
Discount rate, including a risk premium;
Minimum wage as shadow price of labor;
Future price increase and basic export quality FOB Limón sawnwood price for teak;
In- or exclusion of Government reforestation subsidies;
Output correction for wind damage;
Timber conversion rate;
Transport costs from sawmill to Limón;
Labor input;
  storm or fire control;
  container stock or stumps;
Material input;
  container stock or stumps;
  land preparation.

Constant:

Labor input;	
field preparation;	70 hours in year 1;
distribution of plants in field;	6 hours in year 1;
fertilization;	7 hours in year 1 and 2;
maintenance;	71 hours in year 1, 112 in year 2, 79 hours in year 3, 31 hours in year 4, and 27 hours in year 5-20;
disease control;	6 hours in year 1-3;
thinning;	dependent on volume to be thinned; 1 cubic meter equals 1 hour of labor.
pruning;	28 hours in years 1-3, subsequently pruning takes place following each thinning at 14 hours per thinning.
Material input;	
herbicide;	2.8 l at US$ 4.19 per liter in year 1-3;
pesticides;	1.3 l at US$ 2.07 per liter in year 1-3;
fertilizer;	100 kg at US$ 0.30 per kg in year 1 and 2.

The model returns 4 financial indicators as output in order to quantify financial returns. These four indicators are; (1) benefit-cost ratio (B/C-ratio), (2) Net Present Value (NPV), (3) the Annual Income, and (4) the Land Expectation Value (LEV). Where possible the Internal Rate of Return (IRR) was calculated. The following paragraphs describe the formulas used to calculate these indicators.

8.3.1 Discount Rate and Discount Factor

Discount rate is a derivative of bank interest rates corrected by inflation and reflects the opportunity cost of capital. Choice of discount rate is an important element in financial and economic analysis. Choice of discount rate not only determines whether a project is acceptable from an investment point of view, it also influences its ranking as compared to other projects. Additionally the impact is especially felt in the situation of long-term investments and large initial costs. The discount rate is dependent on the origin of invested capital. If capital originates from Costa Rica an appropriate discount rate is 10 percent because in Costa Rica the nominal interest rate, derived from the dollar discount rate, is more or less 12 percent (Jansen, pers.comm., 1997). Schipper (pers.comm., 1998) suggests that currently the discount rate may be estimated at 7 percent. Dutch capital investments in Costa Rica can be discounted at 5 percent. However, since discount rates are not prescribed a sensitivity analyses is executed (Filius, 1992; Price Gittinger, 1982).

Formula 2 shows the applied calculation of the discount factor in this study.

$$df = \frac{1}{(1+i+r)^n} \qquad (2)$$

with: i interest (discount) rate
r premium for risk
n number of years

8.3.2 Net Present Value and Annual Income

The Net Present Value (NPV) is the most straightforward discounted cash flow measure of project worth. It can be summarized as the present worth of the income stream generated by an investment. Its limitation is that it can only be used when plantations of equal rotation length are compared. The formula of the NPV is presented as formula 3. This can partly be surpassed by calculating Annual Net Revenues or Annual Income. Projects can be accepted if the NPV is larger than zero. It is an absolute, non-relative measure, and ranking of acceptable, alternative independent projects is not possible with this criterion. However, the NPV is the preferred selection criterion to choose among mutually exclusive projects assuming that these projects are of equal length (Filius, 1992; Price Gittinger, 1982).

$$NPV = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \qquad (3)$$

with: B_t benefit in year t
C_t cost in year t

NPV also enables the calculation of the Annual Income. Annual Income can be calculated by multiplying NPV with the Capital Recovery Factor (CRF) for the length of rotation. The formula for the CRF is presented in formula 4 (Price Gittinger, 1982).

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \qquad (4)$$

with: n number of years

8.3.3 Land Expectation Value

The Land Expectation Value (LEV), depicted in formula 5, is used as a decision criterion for selecting the optimum rotation. The LEV assumes that land is forested in perpetuity and determines that rotation which gives the (bare) land its maximum value. LEV includes the NPV of all future rotations (Filius, 1992).

$$LEV = \frac{V_0(1+i)^T}{(1+i)^T - 1} \qquad (5)$$

with: V_0 net present value of the first rotation
T length of rotation

8.3.4 Benefit-Cost Ratio

The benefit-cost ratio (BC-ratio) is the ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. The general rule is that projects can be accepted which have a BC-ratio larger than one. The following formula (6) is used in the model.

$$BC - ratio = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \qquad (6)$$

8.3.5 Internal Rate of Return

The Internal Rate of Return (IRR) is the discount rate which makes the net present value of the incremental net benefit stream, i.e. the incremental cash flow, equal to zero. It is literally the maximum interest a project could pay for the resources used if the project is to recover its investment and operating costs and still break even. The model calculates the IRR through 20 iterations. Where there is more than one IRR, the model returns an error value and IRR can consequently not be used as a criterion.

The IRR is considered to be very useful and the World Bank, for instance, uses it for all its economic and financial analysis. Formally, all projects should be selected which yield an interest rate equal or greater than the opportunity cost of capital. However, the IRR can not directly be used to compare mutually exclusive projects or project with different rotation length (Price Gittinger, 1982). Filius (1992) and Price Gittinger (1982) summarize a series of other constraints which to some extend devaluate the IRR.

8.4 Assessing Risk

Risk assessment and knowledge are strongly related. Gathering information and improving management eventually decreases risk. In addition, uncertainty increases with length of rotation and therefore uncertainty in forestry enterprises is considerable. Unrealistic assumptions about yield, the trend of future prices, and the relative effect of inflation can make the outcome of the analysis useless. Filius (1992) distinguishes the following groups of risk factors: biotic, abiotic, socio-cultural, political, and market.

Unfortunately, risk often can not be quantified and since it is often related to human behavior it is even more difficult to predict. In this study risk is assessed by inclusion of a risk premium in the formula of the discount factor (formula 1) which is used in sensitivity analysis.

In Costa Rican practice, several types of risk are discerned. In the Atlantic lowlands there is a considerable risk imposed by pests and diseases. This stems from the absence of a dry period. Such a dry period drastically diminishes disease and pest pressure on the trees as it does in The Pacific lowlands. This makes close monitoring and disease control measures a prerequisite for teak growing in these regions. To date, it is unclear if diseases can cause so much damage as to effectively lower the timber yield.

During the dry season, The Pacific lowlands suffers from a serious threat of forest fires. With appropriate measures taken in plantation management and design this threat is largely minimized. Drought also causes problems for teak survival after planting. The Liberia plain is notorious for its harsh dry season climate combined with strong winds.

On the other hand, the Atlantic lowlands are prone to storm damage. This threat to mainly young plantations is severe and it is unclear to what extent trees suffer from storm damage. Additionally these Zones regularly suffer from floodings. Prolonged inundation kills the trees. These risks can largely be minimized by proper site selection.

Independently from province, earth quakes form a threat to plantations in the entire country. Severe earth quakes, such as the Limón earth quake in 1991, also indirectly influences teak plantations since it can destroy infrastructure limiting timber transport.

Another risk related to teak planting stems from the danger of expropriation by the State government. This risk is not likely to be high in Costa Rica. Together with economic and social stability, it is a major factor influencing the decision to invest in teak in a certain country. The last decade, Latin America has witnessed political and economic stability, economic growth, privatization, commercial opening and regional integration.

Finally, there always is the risk of theft and vandalism. The later is also instigated by social unrest. Teak plantations therefore also have to be guarded carefully.

9 RESULTS

9.1 INDICATIVE TEAK GROWTH

Based on the generated teak growth table, depicted in appendices IX and X, it is calculated how large the indicative teak volume is after the standard rotation length of 20 years. These data are displayed in table 9.1. Again, it has to be stressed that these data are preliminary and indicative.

Table 9.1 Indicative Teak Stand Volumes (cu.m./ha) after 20 Years for 1 Hectare of Teak per Region

	Pacific Region			Atlantic Region		
	Low	*Medium*	*High*	*Low*	*Medium*	*High*
Standing Volume	194	261	278	249	276	284
Cumulative Volume	403	564	711	474	630	772

Figure 9.1 gives an indication of the predicting capacity of the teak growth tables. It depicts the measured average height in the field versus the height derived from the growth tables.

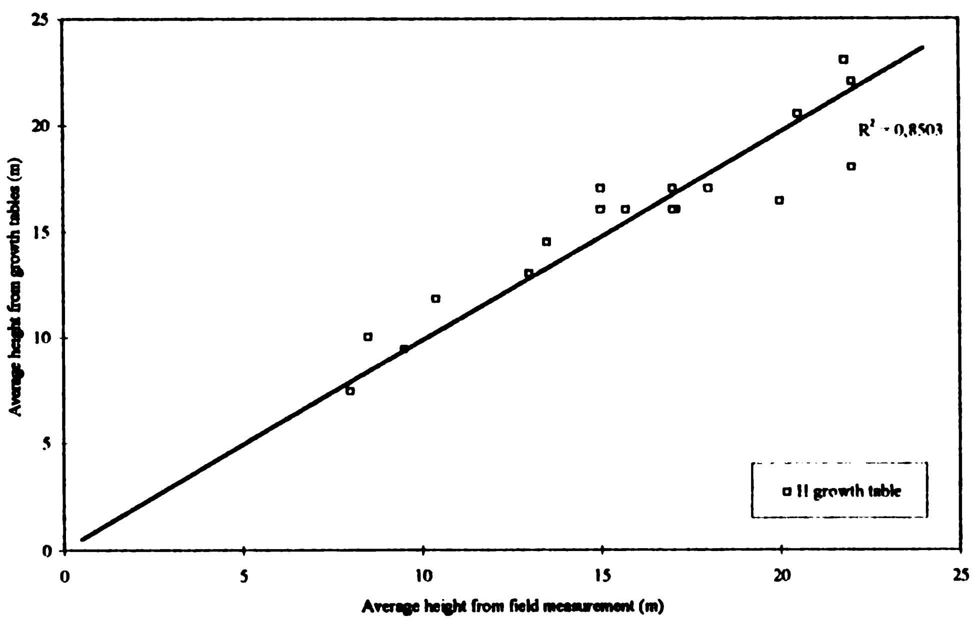

Figure 9.1 Height measured in the field versus height derived from the tables

9.2 STANDARD SCENARIOS

In order to facilitate a sensitivity analysis for both the Pacific and Atlantic Region, a standard set of values is used to calculate a standard scenario. This standard represents the average settings of variables on an average teak plantation in the Pacific or Atlantic Region. In the calculations, labor costs are assumed to be 1 US$ per hour. The discount rate is fixed at 0.08, equal to the real discount rate in Costa Rica. Furthermore it is assumed that managers apply for government subsidies, CAF, CAFA and FDF. Fire and storm control are a necessity and are incorporated in the calculations. In the standard calculations it is assumed that farmers use container stock. Therefore, replanting is not included since the number of drop-outs can be assumed to be so small that they can be considered to be part of the first thinning. In the standard scenario, it is assumed that land preparation is omitted. Average distance to the sawmill is assumed to be 15 km, resulting in a price of US$20 per cubic meter for transport to sawmill. Annual price increase is set at 2.3 percent and the FOB sawnwood price in Limón is assumed to be US$ 400 per cubic meter for prime quality export teak (See chapter 5). Finally, most Pacific teak is suffering from slight wind effects. Therefore, the wind factor for the Pacific Region is on average set at 1, or a reduction of 10 percent of marketable volume. The standard length of rotation is 20 years.

The results of the standard calculations are indicated in table 9.2. MsExcel is unable to calculate the IRR for the standard setting. This may either be caused by the inclusion of subsidies in the first years, which renders the NPV in the first years positive and disables the calculation of the IRR, or it may be caused by the limited number of iterations the model is making for calculations.

Table 9.2 Financial Indicators of the Standard Calculations per Growth Class and Region for 1 Hectare of Teak (dr = 0.08)

		Pacific Region			Atlantic Region		
		Low	*Medium*	*High*	*Low*	*Medium*	*High*
B/C-ratio		3.03	3.25	3.33	3.40	4.13	3.56
NPV	*US$*	11727	18535	24194	15850	23793	31555
Annual Income	*US$*	1114	1817	2464	1505	2332	3214
LEV	*US$*	13923	22713	30803	18817	29156	40174

Prices paid at the sawmill for premium quality teak were derived from the Limón sawnwood prices calculated in section 5.4. It is estimated that current log prices paid to the farmer at the sawmill range from US$ 115-155 per cubic meter, depending on diameter and with minimum top diameter accepted at sawmill of 15cm.

Table 9.3 Total Labor and Material Input for 1 Hectare of Teak per Region

	Pacific Region			Atlantic Region		
	Low	*Medium*	*High*	*Low*	*Medium*	*High*
Total Material Input (US$)[1]	13299	18514	23257	15577	18159	30209
Total Labor Input (US$)[1,2]	1683	1845	1970	1761	1911	2087

note: [1] *not discounted*
[2] *at US$1 per hour*

Most important labor task is annual maintenance; demanding 38 percent on average of total labor input. With decreasing growth rates, maintenance becomes more important. Plantation establishment requires 10-12 percent of total labor input, while executing the thinnings and final cut demands 24-37 percent of total labor input, depending on growth rates, or rather timber volume to be cut. The difference between the labor input in the lowest and highest growth class within regions is about 18 percent (table 9.3). Considering the large differences in output, this indicates that there are relatively little differences in labor input between growth classes.

Of total costs in the Pacific and Atlantic Region, material costs are much more important then labor costs. It can be derived from table 4.3 that material costs amount to 84-91 percent of total production costs. With decreasing teak growth, material costs become relatively less important. Material costs are dominated by the costs of logging, transport to the landing, and loading (L-T-L), amounting to 37 percent, and transport costs to the sawmill, covering 61 percent of total costs. It has to be stressed that these data are based on an average distance from farm to sawmill of 15 kilometer. The remainder, approximately 2 percent is covered by the planting material and inputs such as herbicides, pesticides, and fertilizer.

The present value of total costs of 20 years of teak production, including establishment, ranges from US$ 5,787-10,391 in the Pacific Region and from US$ 6,608-12,323 in the Atlantic

Region. Differences again are due to differences in timber volumes, while the cost of land purchase is excluded from the calculations.

9.3 Sensitivity Analyses

In order to rank the importance of the variables, a sensitivity analysis of 20, 40, and 60 percent increase of the value of the variables was executed. Table 9.4 displays the change of the NPV when the standard value of the variable is increased with 40 percent. Percentage of change of NPV, annual income, and LEV are equal.

Table 9.4 Change of NPV at 40 Percent Deviation from Standard Value

Variable	-40%	Standard	+40%	Change (%) of NPV
Discount rate	0.05	0.08	0.11	-60 - -69
Increase of FOB sawnwood price (US$)	240	400	560	+40 - +41
Increase in real annual price increase (%)	1.4	2.3	3.2	+13 - +16
Increasing distance landing to sawmill (km)	9	15	21	-5 - -7
Increasing shadow price of labor	0.6	1	1.4	-2 - -4
Increase in transport costs Sawmill-Limón				-2
Omission of fire and storm control				+1
Choice of plant material				0
Inclusion of land preparation				0

The effect of the discount rate is strongest on the outcome of the investment. Figure 9.1 depicts the effect of the discount rate on the NPV and figure 9.2 displays the effect of the log price paid to the farmer at the sawmill in relation to the NPV.

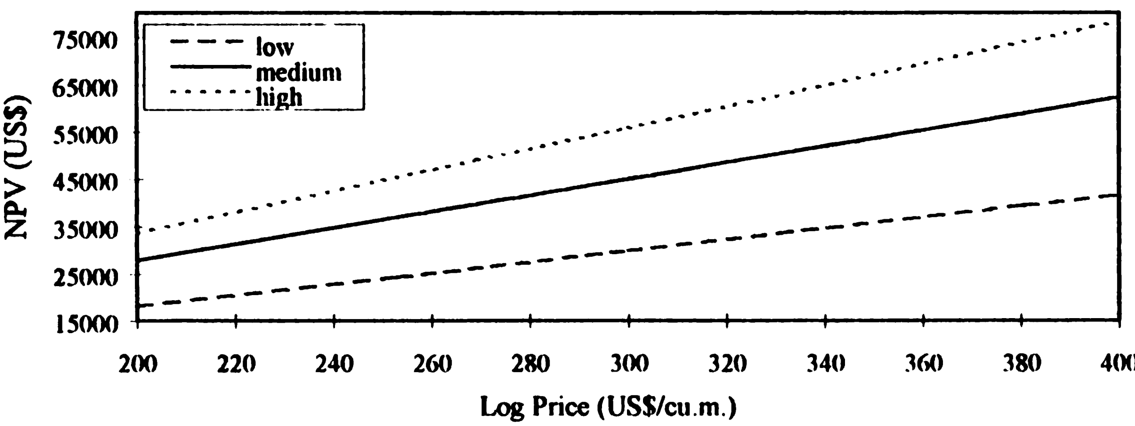

Figure 9.1 Relationship between FOB Limón Log Price and NPV

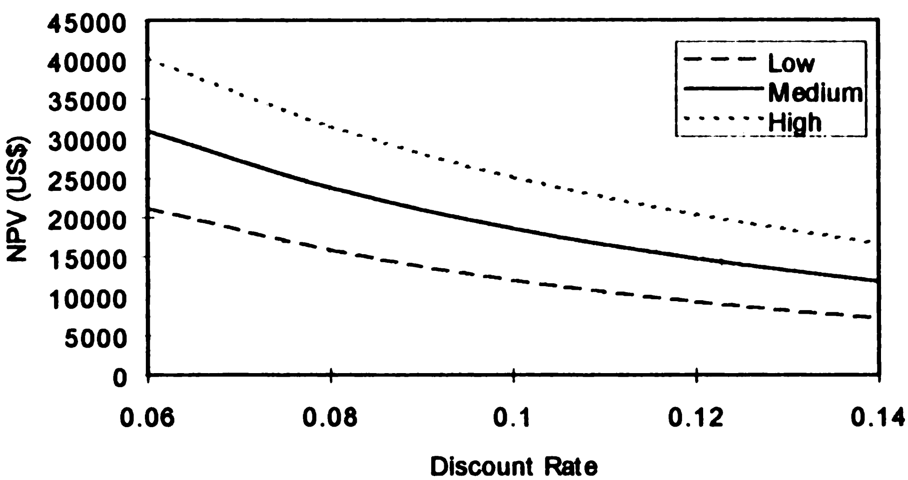

Figure 9.2 Relationship between Discount Rate and NPV for Atlantic lowlands

Both FOB sawnwood price and the real annual price increase determine the future price of teak paid to the farmer at the sawmill. Of these two factors, changes in FOB Limón sawnwood price have the largest effect on profitability. An increase of 20 percent to US$ 480 per cubic meter, results in an increase of 26 percent of the NPV. A sawnwood price of US$ 640 per cubic meter, 60 percent increase, results in an average increase of the NPV of 51 percent.

An increase of the annual price increase with 20 percent to 2.7 percent annually, results in a subsequent increase of the NPV of around 8 percent. If the annual price increase equals 3.7 percent, or 60 percent above the standard value of 2.3 percent, the NPV is around 21 percent higher.

According to financial indicators generated by the model, the choice of using container stock or stumps has no effect on the financial outcome of the project. Applying for government subsidies, on the other hand, does have a marked effect on the financial indicators. In the Pacific Region the NPV diminishes 5-10 percent if subsidies are not included, while NPV diminishes 4-7 percent in the Atlantic Region. On the worse growth sites, application for subsidies has a larger effect. Additionally, it is found that the FDF subsidy of US$ 435 is the most influential subsidy as NPV diminishes 7 percent if this subsidy is omitted.

Wind corrections are only relevant for the Pacific Region, and especially Guanacaste Province. Increasing wind factors have a strong effect on the results of the plantation. Wind factor 2 and 3 subsequently lead to a decrease of 32 and 114 percent of the NPV as compared to the standard wind factor 1 in the Pacific Region. In addition, fire and storm control have a neglectible effect on the profitability. If these measures are omitted, the NPV increases 1 percent.

Increasing conversion rates at the sawmill would increase the profitability strongly with and increase of 9-17 percent of the NPV if a conversion rate of 0.5 percent can be guaranteed, and with an increase of 28-34 percent if conversion is possible at a rate of 0.6.

9.4 Rotation Length

Rotation length has a marked effect on the financial outcome of the project. Table 9.5 indicates the annual income at rotations of 20, 25, and 30 years of the standard senario.

Table 9.5 Annual Income (AI) at Different Rotations (i=0.08)

Rotation Length	Low		Medium		High	
	Atlantic	*Pacific*	*Atlantic*	*Pacific*	*Atlantic*	*Pacific*
20 years	1505	1114	2332	1768	3214	2464
25 years	1530	1135	2261	1715	3105	2306
30 years	1458	1083	2142	1621	2943	2185

It can be observed that with in the lower growth class extension of the rotation period results in additional annual income, while apparently the economic optimal rotation of the medium and high growth class is before 20 years. Increase of rotation length with 50 percent, from 20 to 30 years, results in a decrease of annual income ranging from 3-11 percent.

10 Discussion and General Conclusions

This final chapter will present the discussion and conclusion.

10.1 Teak Production & Yield Tables

Keogh (1996) indicates that, relative to previously established yield tables, increased growth rates can still be achieved by increasing crop nutrition. Most Costa Rican teak is planted on fertile soils and under extremely favorable climatic conditions of high rainfall and a short dry period. This is generally believed to lead to increased timber yields (Philip, 1983). Indian research has yielded similar findings (Jagannath Reddy, 1995; Prasad, 1995).

Centeno's (1997) projections of average teak growth are that the total accumulated teak volume, i.e. including all thinned timber, over a production period of 20 years roughly is between 180-400 cubic meter per hectare. In this study it is presented that total accumulated volume may potentially range from 400-800 cubic meter per hectare, depending on site, climate, and optimized management. While it has to be stressed that these projections are based on a limited number of field measurements of mainly young Costa Rican teak plantations, they also represent optimal management with many well-timed thinnings and absence of growth-limiting factors, such as wind effects and disease problems.

Strong teak growth in Costa Rica has previously not only been indicated by teak investment companies. Unpublished work of Keogh, presented in Chavarria and Valerio Valerio (1993), indicates that at 20 years the dominant height of teak trees in the northern part of the Atlantic lowlands roughly ranges from 20-28 meter. When the dominant height is roughly assumed to be about 1 meter above the average height of the teak trees, the average height can subsequently be estimated to range from 19-27 meter. Based on recent measurements on fast-growing teak, the average height growth in the same region in this study is projected to be ranging from 22-32 meters.

Maessen (1994) presents several measurements from La Parrita of 12 year old Pacific teak. His findings are that at that age the dominant height is about 25 meter, while the diameter (DBH) ranges between 30-39 centimeter. With a diameter of 34.7 centimeter and an average height of 25.2 these measurements fall neatly in the highest growth table presented for the Pacific region. Chaves and Fonseca (1991) present measurements from Quebrada Ancha and the Los Santos region in Panama. Height and diameter data from measurements of 10-17 years old teak stands also fit in the presented teak growth tables for Costa Rica.

Similar high yields have been reported from India. Gogate (1995) reports that 7 year old fertilized teak trees attained a height of about 11 meter and an average diameter of 28.5 centimeter (!). Similar high yield potentials have been reported by Prasad (1995) from the Nilambur area. Prasad projects maximum Indian teak growth to reach 458 cu.m. per hectare in 40 years on the best sites with 170 trees per hectare.

The yield tables in this study have been constructed at a fixed form factor of 0.5, while Wouters (1993), for instance, uses a form factor of 0.7 for his calculations of Costa Rican teak growth. As form factor is variable, extensive study is needed to make more accurate projections and it might be made variable in future Costa Rican yield tables.

Naturally, most teak plantations will not reach the maximum attainable teak growth indicated in this paper. The accumulated yield over 20 years can roughly be estimated to be between 300-600 cubic meter per hectare, while exceptional plantations will surpass those yields. While Centeno's projections for Costa Rican teak growth seem conservative, it has to be stated that only ongoing research on Costa Rican teak growth can clarify this controversy. It is clear that potential growth of teak in Costa Rica surpasses the upper limits of any previously established teak growth table for Trinidad (Miller, 1969; Streets, 1962), Indonesia (Wolff von Wülfing, 1932), Ivory Coast (Dupuy & Verhaegen, 1993), and India (Pandey, 1983). This can mainly be attributed to the fertile, deep, and well-drained sites and on the very favorable climate of high rainfall and high temperatures year-round in both the Pacific and the Atlantic lowlands.

10.2 EXPLORING THE TEAK MARKET

Teak is used for a wide range of applications. Products of teak include sawnwood for construction, veneer and plywood, moulding, strip and block flooring, furniture components, solid doors and flush doors, door and window frames, laminated boards and panels, carved articles for decoration, and household utensils and kitchenware. Only the finest natural teak is used in the yachting industry. Unfortunately, little information is available about the teak volume used for each application.

Due to differences in end-use and quality demands, the global teak market is best analyzed as a highly segmented market with rather independent flows from producer to consumer. The markets for plantation teak are diverse and often very competitive. Five general sub-markets can be distinguished; (1) yachting industry, (2) doors, window frames, fences, and garden furniture, (3) parquet and indoor staircases, (4) indoor furniture and construction parts, (5) low quality and low value products.

Each sub-market demands a certain teak quality. This, together with the dimensions of the timber, sets the timber price. Prices for natural teak on average range from US$1000-4000, those of plantation teak of 60-90 years from US$1000-2000, and short rotation teak of 20-40 years is currently sold at prices ranging from US$200-2000.

Future teak prices are hard to predict. The World Bank (1990) expects an annual real price increase of 2.1 percent for tropical sawnwood. This more or less in accordance with calculations based on Dutch teak log price changes. From 1979-1992, the actual annual teak log price increase has been 5.8 percent while real price increase was only 2.5 percent. Boer and Kuiper (1996) reported a real annual price increase of only 1.5 percent over the last 16 years. Depending on the time lap which is studied varying results can be found. It can, however, be concluded that there is no indication that teak prices will increase strongly in the near future. This view is supported by Dielen (1996) and Stolp (1996).

Based on current market information, it is concluded that current FOB sawnwood prices for prime quality Costa Rican plantation teak range would generally range from US$400-500 per cubic meter. When offered at larger dimensions, prime quality Costa Rican teak can optimistically be estimated to demand prices comparable to prices currently offered for Indonesian plantation teak. It remains, however, unclear to what extend fast-growth of Costa Rican teak will affect timber quality and, subsequently, its price. Depending on diameter, conversion rates can optimistically be expected to between 30-40 percent, while, based on current price increase, real annual teak price increase will be between 1-3 percent.

10.3 TEAK QUALITY

General timber quality depends on a multitude of factors, such as site conditions, growth rate, management and age of the trees. Durability, stability, workability and ease of pre-treatment are the major characteristics of good quality teak. Beautiful figure, color, density and rate of growth are other sought-after qualities as are straight grained, knotless and defect free timber.

Absence of a dry period reportedly has a negative impact on certain quality aspects since it increases the weakness and sponginess of the timber and tree. Though fast growing plantation teak apparently has different qualities than natural grown teak, it does not imply that it is inferior. Recent Indian research indicated that has stressed this (Jagannath Reddy, 1995).

While authors like Manger (1995) stress that plantation teak will not substitute natural teak, plantation teak will be used for high value applications like parquet, cabinets, and veneer as their manufacturers will search for relatively cheaper teak suppliers. It will not qualify for yachting applications unless the market for natural teak drastically changes in the near future. Limited specifications are currently a major limiting factor for plantation teak.

Based on its appearance and quality characteristics, Costa Rican teak will most likely be handled by teak traders as a good plantation product. If, however, this timber can be offered defect-free, at larger specifications and be steadily supplied, it is very likely that traders will offer a premium for this timber in the future. Premium Costa Rican teak will then operate on the most of the markets which are now still dominated by Asian teak.

This study could not reveal significant differences in teak quality between the various teak growing regions in Costa Rica. With regard to the large global differences in teak quality, differences within Costa Rica will most likely not lead to a further diversification of teak prices. Further research is however needed to study Costa Rican teak quality more profoundly.

10.4 Costs and Benefits of Teak Plantations

Total present value of costs of establishment and management of an average teak plantation at farm level with a rotation of 20 years ranges broadly from US$6,000-12,000 per hectare, depending on teak growth rates. These costs do not include land purchase. Based on a maximum land price of US$ 3,000-4,500 for fertile and easily accessible land, it can thus be concluded that total cost of establishment and management does not have to exceed US$15,000.

Depending on region and growth class, Net Present Values of the plantation over a 20 year rotation period ranges from US$ 11,700-31,500 per hectare. Under similar circumstances, benefit-cost-ratios range from 3.03-4.13, Land Equivalent Ratio ranges from US$ 13,900-40,200, and Annual Income is calculated to range from US$ 1,110-3,200.

Unfortunately these findings can not be verified with findings from previous research on the costs and benefits of teak plantations. It is however clear that large benefits can be made from relatively small investments by the farmers, but as these results are valid for optimally managed plantations most farmers will have more conservative returns. Although it is noted that farmer's tree management is still sub-optimal, similar reports of high returns from teak trees for farmers have been come from the Gujarat State in India (Jagannath Reddy, 1995).

10.5 Relative Importance of Revenue-Determining Factors

Applying for subsidies is important for plantation establishment as it renders the cash-flow positive in the important first years of the rotation. This softens the impact of the first year investments. The effect is larger in the Pacific Region as yields are lower there.

The most important economic factor determining the profitability of teak investments is the discount rate. This underlines the importance of establishing a plantation in a country where the discount rate is not largely influenced by risk factors. Furthermore, changes in the world teak prices will have a profound effect on the profitability of teak investments. Both are external factors and can not be influenced by management. This depicts the uncertainty of the outcome of teak plantations.

When assuming that farmers apply perfect plantation management practices, the most important factor which can be influenced by strategic management decisions is the location of the plantation. The plantation must be as close as possible to the sawmill in order to minimize transportation costs. Logging costs can be minimized by harvesting in the dry season, when the terrain is more easily accessible and the truck can be driven as close as possible to the logging site. However, it does not really matter in which region, Pacific or Atlantic, the plantation is established. The transport costs to Limón hardly influence profitability.

Conversion rates at the sawmill have a profound effect on the profitability of the enterprise. Significantly larger profits can be made by the farmer at conversion rates of 0.5 or 0.6. Conversion rates can be influenced by improvements in stand management and sawing techniques. It has to be born in mind, however, that investments to increase the conversion rate have a marked effect on processing costs of the sawmill. In addition, the conversion rates used in the model assume optimal management of the plantation. It can thus be assumed that actual conversion rates will generally be lower.

Based on the cost structure and the relatively small differences in labor input between growth classes, it can be concluded that labor input is of minor importance to teak cultivation. The shadow price of labor has little effect on the profitability of the plantation.

From a subjective evaluation of available timber, it is concluded that there is no remarkable difference between teak quality from the Pacific Region and the Atlantic Region. Therefore, there is no necessity to differentiate between prices paid for teak from these regions. Choice of region of establishment therefore does not depend on expected timber quality differences, but on other factors such as risk.

Several conclusions can be drawn with regard to risk factors. It has been observed and reported that the phytosanitary state of teak plantations in the Atlantic region is worse than in the Pacific. Not only are leaves more affected by fungi infections, but there are also some worrying bacterial infections on the stem. This potential threat can not be neglected. Research in Indian teak plantations of the Nagpur Forest Project Division revealed a high mortality rate in potentially good teak stands. To date, the cause of this mortality is unknown and therefore, general concern has been expressed about the establishment of timber mono-cultures (Jha, 1995).

However, wind effects on teak yield and subsequently on the financial results of the plantation are larger in the Pacific region. Therefore, regions with wind factor 2 and 3 should be avoided. On the other hand, the Atlantic region incidentally suffers from wind gusts.

Although there is no difference in financial outcome between the use of container stock and stumps, container stock should be particularly preferred in Pacific lowlands as it lowers establishment risks. The same conclusion can be drawn on the inclusion of land preparation; it is very desirable to include the practice as the financial effect is minimal, but it strongly decreases risk.

Finally, this study showed that the economically optimal rotation of medium and high growth classes is shorter than 20 years, while low growth classes have their optimal rotation between the 20th and the 25th year. Increase of rotation length with 50 percent, from 20 to 30 years, results in a decrease of annual income ranging from 3-11 percent. This implies that rotation length is not the factor which most determines revenues.

10.6 Concluding Remarks

Unless the consumer preference for teak drastically changes during the next 20 years, farmers can make large profits from relatively small investments in teak plantations. The basis of these returns will lay in the large teak volumes that potentially can be produced on the excellent growth sites in Costa Rica and in the prices paid for defect-free teak. The exact success of the investments will largely depend on strategic decisions of plantation location and optimized pruning and thinning practices. It will only be a matter of time until we find out what profits really can be made from farmer's investments in teak plantations.

RECOMMENDATIONS FOR FUTURE RESEARCH

Based on this study, several recommendations can be made for future research;

1 To improve the accuracy of the presented model, teak growth tables should be improved by long-term measuring of teak growth in a large diversity of plots in the Pacific and Atlantic lowlands;

2 The form factor for Costa Rican teak may be further studied by sound measurements and differentiation between different zones and tree age;

3 In order to improve the prospects for future teak prices, timber stocks and price development on the national and international timber market for hardwoods and semi-hardwoods from the tropics should be carefully monitored;

4 Future research may also aim at a good analyses of the quality aspects of Costa Rican teak, while differences between the two zones in Costa Rica are simultaneously studied. It may also study the effect of bad pruning practices on teak quality in general. This may also place Costa Rican teak in a wider frame of a global study of teak quality and growth rates;

5 Thorough analysis of the phytosanitary state of the Costa Rican plantations could be made as there are strong indications in the field that certain diseases impose a serious threat;

6 Try to analyze more thoroughly the relationship between conversion rate at sawmill, diameter, and management practices.

7 Study more thoroughly and quantify the effect of wind on teak growth and later conversion rates at the sawmill;

8 In order to simulate more closely the actual state of many teak plantations, a study on the quantitative effect of sub-optimal teak management, such as delayed thinning, on teak growth may shed more light on actual costs and benefits;

9 Closely monitor timber quality of Costa Rican teak.

BIBLIOGRAPHY

Akindele, S.O., 1989. Teak Yields in the Dry Lowland Rain Forest Area of Nigeria, *Journal of Tropical Forest Science* 2(1): 32-36.

Anonymus, 1996. Changing Trade Flows: ITTO Producers and Consumers Discussed Market Trends at the Last Council Session, *Tropical Forest Update* Volume 6 (3).

Anonymus, 1996b. Braziliaanse en Aziatische Teak even Geschikt voor Dekfineer, *Houtwereld*, No.23: 28-29.

Anonymous, 1997. Teakholz Gewinnt in Europa wieder an Marktbedeutung, *Holz-Zentralblatt*, No.44: 648

Apsey, T.M. & F.L.C. Reed, 1996. World Timber Resources Outlook; Current Perceptions with Implications for Policy and Practice, *Commonwealth Forestry Review* 75(2):155-9.

Arguedas Gamboa, M., 1996. Enfermedades Forestales en Costa Rica, *Serie de Apoyo Academico*, No.19, Instituto Tecnologico de Costa Rica, Cartago.

Arguedas Gamboa, M., & P. Chaverri, 1996. Plagas Forestales en Costa Rica, *Serie de Apoyo Academico*, No.22, Instituto Tecnologico de Costa Rica, Cartago.

Barkow, A., 1993. Analisis Financiero de la Produccion Forestal en la Zona Norte, Proyecto COSEFORMA DGF/GTZ, *Documento del proyecto*, No.28: 48p.

Boer, R.C. de, 1996. Certificering van Duurzaam Bosbeheer, *Bos en Hout Berichten*, Stichting Bos en Hout, No. 9: 4p.

Boer, R.C. de & L.C. Kuiper, 1996. Teak, Mooi Goudbruin Kernhout, *Bos en Hout Berichten*, Stichting Bos en Hout, No.12: 4p.

Boerboom, J.H.A., W.G. Wielemaker, J.F. Wienk, K. Zijderveld, 1986. *De Atlantische Zone van Costa Rica; Enige Achtergrond Informatie*, WWO Werkgroep Costa Rica i.o., Landbouw Hogeschool Wageningen, Wageningen, 30p.

Broers & Partners, 1989. *Onderzoek naar de Gevolgen van de Subsitutie van Tropisch Hardhout in de Woning- en Utiliteitsbouw*, Baarn.

Brouwershaven, A.S. van, 1993. Plantation Forestry in the Northern Atlantic Zone of Costa Rica, Atlantic Zone Programme, *Report No.54, Field Report No.100*, CATIE-UAW-MAG, Turialba, 43p.

Centeno, J.C., 1996a. Trends and Prospects for Industrial Plantation Forestry in the Tropics, In: ATF & IIED, *Hardwood Plantations, Investment and Sustainable Development, with Reference to Teak: Summary of the Speeches Held at the Seminar*, Amsterdam, 1996, p4-5.

Centeno, J.C., 1996b. *Teak Sting?*, posted to internet.

Centeno, J.C., 1997. Handel in Illusies; Opbrengstverwachtingen van Teakplantages, *Nederlands Bosbouw Tijdschrift* Vol.1: 2-8.

Chaturvedi, A.N., 1995. The Viability of Commercial Teak Plantation Projects, *Indian Forester*, June 1995: 550-552.

Chakrbarth, S.K. & K.S. Gaharwar, 1995. A Study on Volume Estimation for Indian Teak, *Indian Forester*, June 1995: 503-509.

Chavarria E., M.I. & R. Valerio Valerio, 1993. *Guia Preliminar de Parametros Silviculturales para Apoyar los Projectos de Reforestacion en Costa Rica; Primer Version*, Ministerio de Recursos Naturales, Energia y Minas, Direccion General Forestal, San Jose, p95-100.

Chavez, E. & W. Fonseca, 1991. Teca (Tectona grandis): Especie de Arbol de Uso Múltiple en America Central, *Serie Técnica, Informe Técnico No.179*, CATIE, Turrialba, 48p.

Chinese Academy of Forestry, 1993. Development of Teak in China, In: FORSPA, Teak in Asia, *FAO publication* No.4.

Chowdhury, 1953. Rate of Growth and Quality of Tropical Wood, *Forestry Abstracts*, No.14.

Cordoba Foglia, R. and R. Serrano Montero, 1995. *Verslag Inzake de Eigenschappen en Kenmerken van Teakhout (*Tectona grandis*) Afkomstig uit de Plantages gelegen aan de Atlantische Kust; in Opdracht van El Buen Precio*, Instituut voor technologie van Costa Rica, San Jose, 28p.

Dielen, L.J.M., 1996. Heftige en Snelle Schommelingen op de Internationale Houtmarkt, *Bos en Hout Berichten*, No.10, Stichting Bos en Hout, 4p.

Departement van Economische Zaken in Nedelandsch-Indië, 1938. Opstandtafels voor Djatiplantsoen (Tectona grandis, L.f.) bewerkt naar de gelijknamige tafels van 1932 van H.E. Wolff von Wülfing, *Korte Mededeelingen van het Boshouwproefstation*, No.63.

Dijkstra, E., M. Muusse & R. de Wijn, 1995. *Duurzaam Verbouwd Teak uit Costa Rica; Een Onderzoek naar de Marktmogelijkheden en Prijsverwachtingen voor Costaricaanse Teak*, Milieuvereniging Atlas, Erasmus Universiteit Rotterdam, Rotterdam, 45p.

Drigo, R., Md. Shaheduzzaman, & J.A. Choudhary, 1988. *Inventory of Forest Resources of Southern Syhet Division, Assistance to Forestry Sector of Bangladesh*, FAO/UNDEP Project BGD 85/085.

Evans, J., 1982. *Plantation Forestry in the Tropics*, Clarendon Press, Oxford.

FAO, 1993a. Forest Products; FAO Yearbook 1982-1993, *FAO Forestry Series No.28/FAO Statistics Series*, No.122, Rome, p109+117+134+141+143+389.

FAO, 1993b. Forest Resources Assessment 1990; Tropical Countries, *FAO Forestry Paper*, No.112, Rome.

FAO, 1995. Forest Product Prices, 1973-1992, *FAO Forestry Paper*, No.125, Rome.

FAO, 1996a. Forest Products Statistics 1991-1995, *Timber Bulletin*, Vol.XLIX (1996) No.2, New York/Geneva, p24+25.

FAO, 1996b. Forest Products Markets in 1996 and Prospects for 1997, *Timber Bulletin*, Vol.XLIX (1996) No.6, New York/Geneva, p15+17.

Filius, A.M., 1992. *Investment Analysis in Forest Management; Principles and Applications*, Syllabus, Department of Forestry, Wageningen Agricultural University, Wageningen, 192p.

Fretz, L. & P. Moura Costa, Institutional Investors and Forestry Investment, In: ATF & IIED, *Hardwood Plantations, Investment and Sustainable Development, with Reference to Teak: Summary of the Speeches Held at the Seminar*, Amsterdam, 1996, p2-3.

Gogate, M.G., 1995. Evaluation of Growth Response of Teak to High Inputs, *Indian Forester*, June 1995: 578-580.

Gonzales, L., 1992. *Algunos Datos Estimados para el Comportamiento del Manejo y Aprovechamiento Forestal en 1992*, Departamento del Manejo y Producción Forestal, DGF, San José, 5p.

Herrera, W., 1985. *Clima de Costa Rica*, EUNED, San José.

ITTO, 1996. *Annual Review and Assessment of the World Tropical Timber Situation 1995*, Yokohama.

Jagannath Reddy, C., 1995. The Bounty from the Teak Tree, *Indian Forester*, June 1995: 573-575.

Jann, R., 1996. A Successful Case from the Field, In: ATF & IIED, *Hardwood Plantations, Investment and Sustainable Development, with Reference to Teak: Summary of the Speeches Held at the Seminar*, Amsterdam, 1996, p3-4.

Jansen, H.G.P. & A. van Tilburg, 1996. Agricultural Marketing in the Atlantic Zone of Costa Rica; a Production, Consumption and Trade Study of Agricultural Commodities Produced by Small and Medium-Scale Farmers, *Serie Técnica Informe Técnico* No.271, CATIE, Turrialba, 120p.

Jha, M., 1995. Mortality in Pure Teak Plantation, *Indian Forester*, p576-7.

Kaimowitz, D., 1995. *Livestock and Deforestation in Central America in the 1980s and 1990s: A Policy Perspective*, San Jose, 45p.

Kaosa-ard, A., 1995a. Teak Breeding and Improvement Strategies, The Second Regional Seminar on Teak 29 May - 3 June 1995 Yangon, Satellite Paper 1, document 3, Myanmar, Myanmar Ministry of Forestry & FAO, 39p.

Kaosa-ard, A., 1995b. Overview Problems in Teak Plantation Establishment, The Second Regional Seminar on Teak 29 May - 3 June 1995 Yangon, Resource Paper 2, document 2, Myanmar, Myanmar Ministry of Forestry & FAO, 22p.

Kiekens, J.P., 1995. The Tropical Wood Trade in Europe, *Ecodecision*, autumn 1995.

Keogh, R.M., 1987. *The Care and Management of Teak (*Tectona grandis L.f.*) Plantations; a Practical Field Guide for Foresters in the Caribbean, Central America, Venezuela and Colombia*, Universidad Nacional, Turrialba, 46p.

Keogh, R.M., 1992. *Manejo de Plantaciones Forestales; Region Huetar Norte*, Proyecto COSEFORMA DGF/GTZ, Documento del proyecto No.27, 32p.

Keogh, R.M., 1996. *Teak 2000; A Consortium Support Model for Greatly Increasing the Contribution of Quality Tropical hardwood Plantations to Sustainable Development*, IIED Forestry and Land Use Series, no.9, IIED & ATF, 26p.

Kloos, S., 1995. Teak-Down but not Out, In: *Asian Timber 1995*, Singapore, posted to internet (http://www.mtp-online.com.sg/asiantimber/htmfiles/forest/teak1.htm).

Kotler, P., 1994. *Marketing Management: Analysis, Planning, Implementation, and Control*, Prentice Hall International Editions, 8th edition, London, p61-90.

Lamprecht, H., 1989. *Silviculture in the tropics; Tropical forest ecosystems and their tree species-possibilities and methods for their long-term utilization*, GTZ, Eschborn, 296p.

Lanly, J.P., 1982. *En annexe, extrait de la 'Planning Newsletter' publiée par le departement des Fôrets de la FAO*. BFT 195.

Leeuwen, A.C.J. van & J.C. Belt, 1994. Reestructuración de la Industria del Aserrío de la Zona Atlántica en Costa Rica. *Revista Forestal Centroamericana*, No.10: 20-26.

Leeuwen, A.C.J. van & A.M. Hofstede, 1995. Forests, Trees and Farming in the Atlantic Zone of Costa Rica; An Evaluation of the Current and Future Integration of Trees and Forests in Farming Systems in the Atlantic Zone of Costa Rica, CATIE, *Serie Técnico No.257*, Guápiles, 48p.

Luján Ferrer, R., 1994. Manejo y Crecimiento de Linderos; Resultados de Ensayos del Proyecto Agroforestal CATIE/GTZ, de Tres Especies Maderables en la Zona de Talamanca, Costa Rica, *Serie Técnica/Informe Técnico* No.224, *Serie Generación y Transferencia de Tecnología* No.3, CATIE-GTZ, Turrialba, 94p.

Luján Ferrer, R., J. Beer, & G. Kapp, 1997. Manejo y Crecimiento de Linderos de Tres Especies Maderables en el Distrito de Changuinola, Panama, *Serie Técnica/Informe Técnico* No.242, *Serie Generación y Transferencia de Tecnología* No.20, CATIE-GTZ, Turrialba, 41p.

Lux, M. & H. von Platen, 1995. Consumo y Commercialización de la Madera en Baja Talamanca, *Costa Rica, Serie Técnica/Informe Técnico* No.258, CATIE-GTZ, Turrialba, 98p.

Maddugoda, P., 1993. Teak in Sri Lanka, In: FORSPA, Teak in Asia, *FAO publication No.4*.

Maessen, P.P.Th.M., 1994. Werkbezoek aan teakplantages in Costa Rica, oktober 1994, Holtland Dendroconsult, Veenendaal. 7p.

Manger, H., 1995. Trade and Marketing of Teakwood and Products, *Satellite Paper* 8 , Doc 11, Proc. of the Teak Symposium, Yangon, March 1995, MTE, Yangon.

Moosmayer, H., 1993. Recommendaciones para el Aserrio de Madera de Pequeño Diametro, Proyecto COSEFORMA DGF/GTZ, *Documento del proyecto* No.29, 58p.

Moya Roque, R., 1996. *Aprovechamiento en Aserrio de un Segunda Raleo, en una Plantacion de Teca*, Tectona grandis, *de 8 Anos de Edad Ubicada en Monterrey de San Carlos*, Boletín Informativo Mensual de la Camara Costarricense Forestal, CCF, No..20: 3-5.

Myint Kyu Pe, U & Hwan-Ok Ma, 1997. Myanmar Furniture Manufacturing: Improving Productivity, *Tropical Forest Update*, ITTO, Vol.7(4): 12+17.

Pandey, D., 1995. Forest Resources Assessment 1990; Tropical Forest Plantation Resources, *FAO Forestry Paper* 128, FAO, Rome, 81p.

Parameswarappa, S., 1995. Teak - How fast can it grow and how much can it pay?, *Indian Forester*, June 1995: 563-565.

Perum Perhutani, 1993. Teak in Indonesia, In: FORSPA, Teak in Asia, *FAO publication* No.4.

Philip, M.S., 1983. *Measuring trees and forests: A textbook written for students in Africa*, Dar es Salaam, 338p.

Poels, R.L.H., 1994. Nutrient Balance Studies to Determine the Sustainability of Management Systems of Natural and Plantation Forests in Costa Rica, *Atlantic Zone Programme, Phase 2 Report* No.82, CATIE-UAW-MAG, Turialba, 36p.

Porras, A. and B. Villareal, 1986. *Deforestacion en Costa Rica (Implicaciones Sociales, Económicas y Legales)*, San José, 120p.

Prasad, R.S.R., 1995. *Tectona grandis* - Elite Management, *Indian Forester*, June 1995: p558-562.

Price Gittinger, J., 1982. *Economic Analysis of Agricultural Projects*, EDI Series in Economic Development, Second edition, London, 505p.

Ratan hal Banik, 1993. Teak in Bangladesh, In: FORSPA, Teak in Asia, *FAO publication* No.4.

Rawat, J.K., 1995. Value of a 20-Year Old irrigated Teak Plantation, , *Indian Forester*, June 1995: 553-557.

Romeijn, P.C., 1987. Driving Forces behind the Deforestation of Costa Rica's Atlantic Zone; A Socioeconomic Evaluation, *Field Report* No.11, Atlantic Zone Programme, CATIE-UAW-MAG, Turialba.

Sánchez, O., 1993. Manual Tecnico para el Manejo de Plantaciones Forestales, Proyecto COSEFORMA DGF/GTZ, *Documento del proyecto* No.31, 39p.

Sangal, S., 1995. Processing and Development Technology and Future Trend dor Utilization: *Satellite Paper* 6, Doc 9, Proc. of the Teak Symposium, Yangon, March 1995, MTE, Yangon.

Schmincke, K.H., 1996. Global Demand and Supply for Wood Products, In: ATF & IIED, *Hardwood Plantations, Investment and Sustainable Development, with Reference to Teak: Summary of the Speeches Held at the Seminar*, Amsterdam, 1996, p1.

Sein Maung Wint, U., 1995. *Trade and Marketing of Teak Wood and Products; Resource Paper 3*, The Second Regional Seminar on Teak 29 May - 3 June 1995 Yangon, document 8, Myanmar, Myanmar Ministry of Forestry & FAO, 23p.

Shwe Baw, 1995. *Teak Marketing*, Proc. of the Teak Symposium, Yangon, March 1995, MTE, Yangon.

Sikod, F. 1996. *Certification Process in Sustainable Forest Management: Economic Concepts and Indicators*, Paper for the Conference on Economic, Social and Political Issues in Certification of Forest Management, Malaysia May 12-16, 1996, draft.

Sluys, F.R. van, H. Waaijenberg, W.G. Wielemaker, and J.F. Wienk, 1987. *Agriculture in the Atlantic Zone of Costa Rica; Summerizing Report of an Exploratory Survey*, Programme Paper No.1, Informe Técnico No.123, Atlantic Zone Programme, CATIE-UAW-MAG, Turialba.

Solórzano, R., R. de Camino, R. Woodward, J. Tosi, A. Vásquez, C. Villalobos, J. Jiménez, R. Repetto, & W. Cruz, 1991. *Accounts Overdue: Natural Resource Depreciation in Costa Rica*, Tropical Science Centre/World Resource Institute, Washington, 111p.

Stolp, J.A.N., 1996. Toekomstige Beschikbaarheid van Hout 1, *Bos en Hout Berichten*, No. 5, Stichting Bos en Hout, 4p.

Streets, R.J., 1962. *Exotic forest trees in the British Commonwealth*, Oxford.

Tint, S., 1995. Wood Quality and End-User Requirements; Satellite Paper 7, The Second Regional Seminar on Teak 29 May - 3 June 1995 Yangon, document 10, Yangon, 29p.

UN, 1996, Forest Products Statistics 1991-1995, *Timber Bulletin Volume* XLIX (1996) No.2: 25-25.

Vásquez, W. & L. Ugalde, 1995. Rendimiento y Calidad de Sitio para Gmelina arborea, Tectona grandis, Bombacopsis quinatum y Pinus caribea en Guanacaste, *Seria Técnica, Informe Técnico* No.256, CATIE/FAO, Turrialba, 32p.

Vinh Phengdouang, 1993. Teak in Laos PDR, In: FORSPA, Teak in Asia, *FAO publication* No.4.

White, K.J., 1991. Teak: Some Aspects of Research and Development, *FAO RAPA Publication* No.17.

World Bank, 1990. *Price Prospects of Major Primary Commodities*, The World Bank, Washington.

WRI, 1990. *World Resources 1990-91*, The World Resources Institute, New York/Oxford, p101-102.

APPENDICES

Appendix I 1995 Tropical Timber Import Barriers of ITTO Countries

COUNTRY	PRODUCT	DESCRIPTION
Australia	Sawnwood	2-7 percent, depending on species and country of origin; some reductions apply as of 1 July 1995
Canada	Logs sawn ven.	None
	Plywood	8-9 percent import tariff, depending on species
China	Logs	3 percent import tax, 17 percent value-added tax
	Sawnwood	6 percent import tax, 17 percent value-added tax
	Veneer	20 percent import tax, 17 percent value-added tax
	Plywood	20 percent import tax, 17 percent value-added tax
Egypt	Sawnwood	5 percent customs tariff on lumber imports, plus 5 percent sales tax and 3 percent customs service fee (tariff reduced in 1994 to promote domestic industry)
EU:		
France	Logs and sawn	None
	Plywood	10 percent
Netherlands	Logs	None
	Sawnwood	0-2.5 percent import tariff, depending on species
	Veneer	4-6 percent import tariff, depending on species
	Plywood	10 percent import tariff, depending on species
Portugal	All	None
U.K.	Logs, sawn.	None
	Plywood	9.4-10 percent, depending on species
Japan	Veneer	Tariff base rate 15 percent (subject to GSP scheme), to be reduced to five percent by 1999
	Plywood	Tariff base rate 17-20 percent (subject to GSP scheme)
New Zealand	All	None
Norway	All	None
Rep. of Korea	Logs	2 percent import tariff
	Sawnwood	5percent import tariff
	Veneer	5 percent import tariff
	Plywood	8 percent import tariff
U.S.	All	None (GSP scheme)

Appendix II Specific Gravity and Shrinkage of Teak

LOCALITY	**CONDITION**	**SPECIFIC GRAVITY**	**SHRINKAGE (%) GREEN TO OD**	
		(g/cm³)	*Radial*	*Tangential*
Myanmar	Green	0.586	2.1	3
Myanmar	Girdled	0.594	2.2	3
Malabur (India)	Natural	0.614	2.5	6
C. provinees (India)	Natural	0.526	2.2	4
Bihar & Orissa (India)	Natural	0.536	1.8	4
Angul (India)	Natural	0.609	2.6	4
Hoshangabad (India)	Natural	0.554	2.3	4
C. Puri (India)	Natural	0.580	1.8	4
Honduras	Plantation	0.560	2.1	5
Phillipines	Plantation	0.490	2.2	4
Thailand	Plantation	0.640	2.5	5
Indonesia	Plantation	0.646	0-2	0-3.5
Nigeria	Plantation	0.509	0-3	0-5
Paua (New Guinea)	Plantation	0.509	2.1-3	3.6-5
Trinidad[1]	Plantation	0.570	-	-
South Africa	Plantation	0.646	2.1-3	3.6-5
Costa Rica[2]	Plantation	0.654	2.9	4.0

Note: Data from Tint (1995), except for;
[1] Data from Altuve in Chavez & Fonseca (1991)
[2] Average data from Zijlstra et al. *(1995), Cordoba Foglia and Serrano Montero (1991), and from samples analyzed by the author*

Appendix III Area of Teak Plantations and Natural Teak Forest

	Plantation Area (ha)	Natural Teak Forest (ha)	Plantation Area Increase (ha/year)	Source
Asia				
Bangladesh	62,700			Ratan hal Banik, 1993
Philippines	21,550			Sein Maung Wint, 1995
China		9,000		Chin. Ac. For., 1993
India	276,000			Sein Maung Wint, 1995
Sri Lanka	70,000			Maddugoda, 1993
Thailand	170,250	2,500,000[1]		Sein Maung Wint, 1995
Vietnam	500			Sein Maung Wint, 1995
Laos	5,000	16,000		Vinh Phengdouang, 1993
Myanmar	214,189	16,517,000	12,000	Sein Maung Wint, 1995
Malaysia	4,328			ITTO Asia-P. Reg. Off.
Indonesia	675,000		10,000	Perum Perhutani, 1993
Africa				
Ivory Coast	21,000		600	White, 1991
Tanzania	5,000			Sein Maung Wint, 1995
Togo	unknown		650	White, 1991
Nigeria	21,300[2]			Akindele, 1989
Tropical America & Caribbean				
Brazil	1,500		2,500	ITTO Lat. Am. Reg. Off.
Ecuador	1,000			Sein Maung Wint, 1995
Panama	800			Sein Maung Wint, 1995
Puerto Rico	800			Sein Maung Wint, 1995
Trinidad	9,710			Sein Maung Wint, 1995
Costa Rica	20,000			*Estimation by the author*

Note [1]: *1982 data*
[2]: *1980 data*

Appendix IV Average 1994 FOB Yangon Price of Teak Logs in Myanmar

TEAK LOG	US$/CU.M
Second Quality	3,090
Third Quality	1,912
Fourth Quality	1,337
Sawing Grade (1)	1,034
Sawing Grade (2)	788
Sawing Grade (3)	651

c.f. Sein Maung Wint (1995)

Appendix V Most Planted Plantation Species in Costa Rica

LATIN NAME	FAMILY	LOCAL NAME
Cordia alliodora	*Boraginaceae*	Laurel
Gmelina arborea	*Verbenaceae*	Melina
Eucalyptus deglupta	*Oleaceae*	Eucalipto
Tectona grandis	*Verbenaceae*	Teca
Pinus caribbaea	*Pinaceae*	Pino
Cedrela odorata	*Meliaceae*	Cedro dulce
Tabebuia rosea	*Bignoniaceae*	Roble de sabana
Bombacopsis quinata	*Bombacaceae*	Pochote
Carapa quianensis	*Meliaceae*	Caobilla
Hyeronima oblonga	*Euphorbiaceae*	Pilon
Terminalia oblonga	*Combretaceae*	Surá
Virola spp.	*Myristicaceae*	Fruta dorada
Minquartia quianensis	*Olacaceae*	Manu negro

in order of importance

elaborated from Leeuwen & Hofstede (1995).

Appendix VI Most Traded Tree Species in Costa Rica

GROUP	LATIN NAME	FAMILY	LOCAL NAME
SOFTWOODS			
	Cynometra hemitomyphylla	*Caesalpiniaceae*	Cativo
	Virola spp.	*Myrsticaceae*	Fruta dorada
	Gmelina arborea	*Verbenaceae*	Melina
	Ceiba pentandra	*Bombacaceae*	Ceiba
	Ficus werckleana	*Moraceae*	Chilamate
	Talauma gloriensis	*Magnoliacaea*	Magnolia
	Hura crepitans	*Euphorbiaceae*	Jabillo
	Brosimum utile	*Moraceae*	Baco, Lechoso, Mastate
CLASSIFIED SEMI-HARDWOODS (*SEMIDUROS CLASSIFICADOS*)			
	Terminalia amazonia	*Combretaceae*	Amarillón (Roble Coral)
	Cupressus lusitanica	*Cupressaceae*	Ciprés
	Enterolobium cyclocarpum	*Mimosaceae*	Guanacaste
	Elaeoluma sp.	*Sapotaceae*	Carey
	Vochysia ferruginae	*Vochysiaceae*	Botarrama, Chancho
GENERAL SEMI-HARDWOODS (*SEMIDUROS COMÚNES*)			
	Hymenolobium mesoamericanum	*Papilionaceae*	Cola de Pavo
	Vantanea barbourii	*Humiriaceae*	Chiricano
	Anacardium excelsum	*Anacardiaceae*	Espavel
	Pentaclethra macroloba	*Mimosaceae*	Gavilán
	Ocotea sp.	*Lauraceae*	Ira
	Alnus acuminata	*Betulaceae*	Jaúl
	Calophyllum brasiliense	*Guttifereae*	María
	Hieronyma oblonga	*Euphorbiaceae*	Pilón
	Tabebuia rosea	*Bignoniaceae*	Roble Sabana
	Sacoglottis trychogyna	*Humriaceae*	Titor, Danto Plomillo,Campano
HARDWOODS (*FINAS*)			
	Cedrela odorata	*Meliaceae*	Cedro Amargo
	Cordia alliodora	*Boraginaceae*	Laurel
	Platymiscium pinnatum	*Papilionaceae*	Cristóbal, Cachimbo
	Astronium graveolens	*Anacardiaceae*	Ron Ron, Jovillo
	Peltogyne purpurea	*Caesalpiniaceae*	Nazareno

c.f. Schinkel (1995) and data from CCF (unpublished)

Appendix VII Reported Teak Diseases in Costa Rica

SPECIES	*FAMILY*	*LOCAL NAME*	*EFFECT*
INSECTS			
Atta sp.	*Formicidae*	*zompopa*	defoliation
Neoclytus cacicus	*Cerambycidae*		xylem perforation
Phyllophaga sp.	*Scarabaeidae*	*joboto*	destruction of roots
Plagiohammus spinipennis	*Cerambycidae*		xylem and cambium perforation
VERTABRATES			
Orthogeomys underwoodi	*Geomyidae*	*taltuza*	destruction of seedlings
PATHOGENS			
Agrobacterium tumefaciens			base of the stem
Aphelenchus sp.			stem and roots
Cercospora rangita			leaves
Fusarium oxysporum			stem and roots
Nigrospora sp.			apical meristems
Nectria sp.			stem
Pestalotia sp.			leaves
Phomopsis sp.			leaves
Pseudoepicoccum tectonae			leaves
Pseudomonas sp.			stem and roots

Source: Arguedas Gamboa, 1996; Arguedas Gamboa & Chaverri, 1996; Chavarria & Valerio Valerio, 1993; Luján Ferres, 1994.

Appendix VIII Dimensions and FOB Prices of Export Teak Sawnwood from Benin

DIMENSIONS (D x W x L, mm)			PRICE (US$/CU.M.)
13	50	300	500
19	50	300	500
25	50	450	620
		600	620
		750	620
		900	715
		1050	715
		1200	715
25	63	450	650
		600	650
		750	650
		900	745
		1050	745
		1200	745
25	75	450	715
		600	715
		750	715
		900	810
		1050	810
		1200	810
32	63	450	620
		600	620
		750	620
38	50	450	680
		600	680
		750	680
		900	745
		1050	745
		1200	745
38	75	450	680
		600	680
		750	680
		900	810
		1050	810
		1200	810

(c.f. ONAB Industrie, August 1996)

Appendix IXa Low Growth Indicative Table for the Pacific Region

Pacific **form factor** **0.5**

Age	Remaining Volume N/ha	DBH	H_{av}	G/ha	V_{tot}/ha	Thinnings %G	%N	N/ha	Dave	G/ha	V_{tot}/ha	Cum V_{tot}/ha	Growth CAI_{vol}	CAI_h
0	1110	0	0.0	0	0							0	0	0
1	1110	3.3	2.7	0.9	1.3								0.001	2.7
2	1110	5.8	5.2	2.9	7.6								0.006	2.5
3	1110	8.2	7.4	5.8	21.5								0.013	2.2
3	800	8.2	7.4	4.2	15.5	28	28	310	8.16	1.6	6.0	22		
4	800	10.4	9.4	6.8	32.0								0.021	2.0
5	800	12.6	11.1	9.9	55.2								0.029	1.7
6	800	14.6	12.6	13.4	84.6								0.037	1.5
7	800	16.5	13.9	17.2	119.7								0.044	1.3
7	800	16.5	13.9	12.9	89.8	25	25	200	16.5	4.3	29.9	126		
8	800	18.4	15.0	15.9	119.6								0.050	0.2
9	800	20.1	16.0	19.1	152.4								0.055	0.9
10	800	21.8	16.8	22.3	187.2								0.058	0.8
10	450	21.8	16.8	16.7	140.4	25	25	150	21.8	5.6	46.8	223		
11	450	23.3	17.4	19.2	167.6								0.060	0.7
12	450	24.8	18.0	21.8	195.3								0.062	0.5
12	300	24.8	18.0	14.5	130.4	33	33	150	24.8	7.2	64.9	278		
13	300	26.2	18.4	16.2	146.9								0.062	0.4
14	300	27.6	18.7	17.9	167.5								0.062	0.3
15	300	28.8	19.0	19.6	186.0								0.062	0.3
16	300	30.0	19.2	21.3	204.3								0.061	0.2
16	210	30.0	19.2	14.9	143.0	30	30	90	30	6.4	61.3	352		
17	210	31.2	19.4	16.1	155.7								0.060	0.2
18	210	32.3	19.6	17.2	168.4								0.060	0.2
19	210	33.4	19.7	18.4	181.1								0.061	0.2
20	210	34.4	19.9	19.5	194.1								0.062	0.2
21	210	35.4	20.1	20.6	207.3								0.063	0.2
22	210	36.3	20.3	21.7	220.8								0.064	0.2
22	160	36.3	20.3	16.6	168.2	24	24	50	36.3	5.2	52.6	430		
23	160	37.2	20.5	17.4	178.6								0.065	0.2
24	160	38.1	20.7	18.3	189.1								0.066	0.2
25	160	39.0	20.9	19.1	199.8								0.067	0.2
26	160	39.9	21.1	20.0	210.8								0.069	0.2
27	160	40.7	21.3	20.8	222.1								0.070	0.2
28	160	41.6	21.5	21.7	233.7								0.072	0.2
29	160	42.4	21.7	22.6	245.6								0.075	0.2
30	160	43.3	21.9	23.6	258.1								0.078	0.2

Appendix IXb Medium Growth Indicative Table for the Pacific Region

Pacific **form factor** **0.5**

	Remaining Volume					*Thinnings*						*Cum*	*Growth*	
Age	**N/ha**	**DBH**	**H_{av}**	**G/ha**	**V_{tot}/ha**	**%G**	**%N**	**N/ha**	**Dave**	**G/ha**	**V_{tot}/ha**	**V_{tot}/ha**	**CAI_{vol}**	**CAI_h**
0	1110	0	0	0	0							0	0	0
1	1110	3.9	3.2	1.3	2.2								0.002	3.2
2	1110	6.9	6.2	4.2	13.1								0.010	3.0
3	1110	9.8	8.9	8.4	37.2								0.022	2.7
3	900	9.8	8.9	6.8	30.1	19	19	210	9.79	1.6	7.0	37		
4	900	12.5	11.3	11.0	62.2								0.036	2.4
5	900	15.1	13.3	16.1	107.0								0.085	4.4
6	900	17.5	15.1	21.7	164.1								0.113	3.9
6	700	17.5	15.1	16.9	127.6	22	22	200	17.5	4.8	36.5	171		
7	700	19.8	16.7	21.6	180.3								0.075	1.6
7	500	19.8	16.7	15.4	128.8	29	29	200	19.8	6.2	51.5	224		
8	500	22.0	18.0	19.0	171.5								0.085	1.3
9	500	24.1	19.2	22.8	218.1								0.179	2.5
9	350	24.1	19.2	15.9	152.7	30	30	150	24.1	6.8	65.4	313		
10	350	26.0	20.1	18.6	187.3								0.099	0.9
11	350	27.9	20.9	21.4	223.1								0.102	0.8
11	260	27.9	20.9	15.9	165.7	26	26	90	27.9	5.5	57.4	384		
12	260	29.7	21.5	18.0	192.8								0.104	0.6
13	260	31.3	22.0	20.0	220.0								0.104	0.5
14	260	32.9	22.4	22.1	246.9								0.103	0.4
14	170	32.9	22.4	14.5	161.6	35	35	90	32.9	7.6	85.3	465		
15	170	34.4	22.7	15.8	178.9								0.103	0.3
16	170	35.8	22.9	17.1	195.7								0.099	0.2
17	170	37.1	23.1	18.4	212.3								0.096	0.2
18	170	38.4	23.2	19.7	228.7								0.096	0.2
19	170	39.6	23.4	20.9	244.9								0.096	0.2
20	170	40.7	23.6	22.2	261.3								0.096	0.2
20	120	40.7	23.6	15.6	184.4	29	29	50	40.7	6.5	76.8	564		
21	120	41.8	23.8	16.5	196.5								0.101	0.3
22	120	42.9	24.1	17.3	208.7								0.101	0.3
23	120	43.9	24.3	18.2	220.9								0.102	0.3
24	120	44.9	24.6	19.0	233.1								0.102	0.3
25	120	45.8	24.8	19.8	245.5								0.103	0.3
26	120	46.7	25.1	20.6	258.0								0.104	0.3
27	120	47.6	25.3	21.4	270.7								0.106	0.3
28	120	48.5	25.6	22.2	283.6								0.106	0.3
29	120	49.4	25.8	23.0	296.8								0.110	0.3
30	120	50.2	26.1	23.8	310.3								0.113	0.3

Appendix IXc High Growth Indicative Table for the Pacific Region

Pacific **form factor** **0.5**

Remaining Volume						Thinnings						Cum	Growth	
Age	N/ha	DBH	H_{av}	G/ha	V_{tot}/ha	%G	%N	N/ha	Dave	G/ha	V_{tot}/ha	V_{tot}/ha	CAI_{vol}	CAI_h
0	1110	0.0	0.0	0	0							0		
1	1110	4.6	3.8	1.8	3.5								0.003	3.8
2	1110	8.1	7.3	5.7	20.7								0.016	3.5
2	900	8.1	7.3	4.6	16.8	19	19	210	8.09	1.1	3.9	21		
3	900	11.4	10.4	9.2	47.9								0.035	3.1
4	900	14.6	13.1	15.0	98.8								0.057	2.8
5	900	17.6	15.6	21.9	170.2								0.079	2.4
5	600	17.6	15.6	14.6	113.5	33	33	300	17.6	7.3	56.7	174		
6	600	20.5	17.7	19.7	174.7								0.102	2.1
7	600	23.1	19.5	25.2	246.2								0.119	1.8
7	350	23.1	19.5	14.7	143.6	42	42	250	23.1	10.5	102.6	307		
8	350	25.7	21.1	18.2	191.3								0.136	1.6
9	350	28.1	22.4	21.8	243.6								0.149	1.3
9	250	28.1	22.4	15.5	174.0	29	29	100	28.1	6.2	69.6	407		
10	250	30.4	23.5	18.2	213.7								0.159	1.1
11	250	32.6	24.4	20.9	255.0								0.165	0.9
12	250	34.7	25.2	23.6	297.3								0.169	0.7
12	160	34.7	25.2	15.1	190.2	36	36	90	34.7	8.5	107.0	530		
13	160	36.7	25.8	16.9	217.7								0.172	0.6
14	160	38.5	26.3	18.6	244.6								0.340	1.1
15	160	40.3	26.6	20.4	271.8								0.170	0.4
16	160	42.0	27.0	22.1	298.2								0.165	0.3
16	110	42.0	27.0	15.2	205.0	31	31	50	42	6.9	93.2	638		
17	110	43.6	27.2	16.4	223.2								0.165	0.3
18	110	45.1	27.5	17.6	241.3								0.164	0.2
19	110	46.5	27.7	18.7	259.5								0.165	0.2
20	110	47.9	28.0	19.9	278.0								0.168	0.3
21	110	49.3	28.3	21.0	297.1								0.174	0.3
22	110	50.6	28.6	22.1	316.3								0.174	0.3
22	90	50.6	28.6	18.1	258.8	18	18	20	50.6	4.0	57.5	749		
23	90	51.8	28.9	19.0	274.6								0.176	0.3
24	90	53.0	29.2	19.9	290.6								0.178	0.3
25	90	54.2	29.5	20.8	306.9								0.181	0.3
26	90	55.4	29.8	21.7	323.6								0.185	0.3
27	90	56.6	30.1	22.6	340.6								0.189	0.3
28	90	57.7	30.4	23.5	358.0								0.194	0.3
29	90	58.8	30.7	24.5	376.0								0.200	0.3
30	90	60.0	31.0	25.4	394.7								0.207	0.3

Appendix Xa Low Growth Indicative Table for the Atlantic Region

Atlantic **form factor** **0.6**

	Remaining Volume					Thinnings						Cum	Growth	
Age	N/ha	DBH	H_{av}	G/ha	V_{tot}/ha	%G	%N	N/ha	Dave	G/ha	V_{tot}/ha	V_{tot}/ha	CAI_{vol}	CAI_h
0	1110	0.0	0.0	0	0							0	0	0
1	1110	3.3	3.0	0.9	1.4								0.001	3.0
2	1110	5.8	5.8	2.9	8.5								0.006	2.8
3	1110	8.2	8.3	5.8	24.2								0.014	2.5
3	900	8.2	8.3	4.7	19.6	19	19	210	8.16	1.1	4.6	24		
4	900	10.4	10.5	7.7	40.5								0.023	2.2
5	900	12.6	12.5	11.2	69.7								0.033	1.9
6	900	14.6	14.2	15.1	107.0								0.041	1.7
7	900	16.5	15.7	19.3	151.3								0.049	1.5
7	600	16.5	15.7	12.9	100.9	33	33	300	16.5	6.4	50.4	206		
8	600	18.4	16.9	15.9	134.4								0.056	1.3
9	600	20.1	18.0	19.1	171.2								0.061	1.1
10	600	21.8	18.8	22.3	210.3								0.065	0.9
10	450	21.8	18.8	16.7	157.7	25	25	150	21.8	5.6	52.6	318		
11	450	23.3	19.6	19.2	188.3								0.068	0.7
12	450	24.8	20.2	21.8	219.5								0.069	0.6
12	310	24.8	20.2	15.0	151.4	31	31	140	24.8	6.8	68.1	327		
13	310	26.2	20.6	16.7	172.9								0.070	0.5
14	310	27.6	21.0	18.5	194.5								0.070	0.4
15	310	28.8	21.3	20.2	216.0								0.069	0.3
15	240	28.8	21.3	15.7	167.4	23	23	70	28.8	4.6	48.6	372		
16	240	30.0	21.6	17.0	183.7								0.069	0.2
17	240	31.2	21.8	18.4	200.0								0.068	0.2
18	240	32.3	22.0	19.7	216.2								0.068	0.2
19	240	33.4	22.2	21.0	232.5								0.068	0.2
20	240	34.4	22.4	22.3	249.2								0.069	0.2
20	180	34.4	22.4	16.7	186.9	25	25	60	34.4	5.6	62.3	468		
21	180	35.4	22.6	17.7	199.7								0.071	0.2
22	180	36.3	22.8	18.6	212.7								0.072	0.2
23	180	37.2	23.1	19.6	225.9								0.073	0.2
24	180	38.1	23.3	20.5	239.3								0.074	0.2
25	180	39.0	23.5	21.5	252.9								0.076	0.2
25	150	39.0	23.5	17.9	210.7	17	17	30	39	3.6	42.1	514		
26	150	39.9	23.7	18.7	222.4								0.077	0.2
27	150	40.7	24.0	19.5	234.3								0.079	0.2
28	150	41.6	24.2	20.4	246.6								0.082	0.2
29	150	42.4	24.4	21.2	259.3								0.085	0.2
30	150	43.3	24.7	22.1	272.4							533	0.088	0.2

Appendix Xb Medium Growth Indicative Table for the Atlantic Region

Atlantic			form factor		0.5									
	Remaining Volume					Thinnings						Cum	Growth	
Age	N/ha	DBH	H_{av}	G/ha	V_{tot}/ha	%G	%N	N/ha	Dave	G/ha	V_{tot}/ha	V_{tot}/ha	CAI_{vol}	CAI_h
0	1110	0.0	0.0	0	0							0	0	0
1	1110	3.9	3.6	1.3	2.4								0.002	3.6
2	1110	6.9	7.0	4.2	14.7								0.011	3.4
3	1110	9.8	10.0	8.4	41.8								0.024	3.0
3	900	9.8	10.0	6.8	33.9	19	19	210	9.79	1.6	7.9	42		
4	900	12.5	12.7	11.0	69.9								0.040	2.7
5	900	15.1	15.0	16.1	120.3								0.058	2.3
6	900	17.5	17.0	21.7	184.3								0.071	2.0
6	600	17.5	17.0	14.4	122.9	33	33	300	17.5	7.2	61.4	184		
7	600	19.8	18.8	18.5	173.7								0.085	1.8
8	600	22.0	20.3	22.8	231.2								0.096	1.5
8	400	22.0	20.3	15.2	154.2	33	33	200	22	7.6	77.1	308		
9	400	24.1	21.5	18.2	196.1								0.105	1.3
10	400	26.0	22.6	21.3	240.5								0.111	1.0
10	290	26.0	22.6	15.5	174.3	28	28	110	26	5.9	66.1	384		
11	290	27.9	23.4	17.7	207.7								0.115	0.9
12	290	29.7	24.1	20.0	241.7								0.232	1.6
13	290	31.3	24.7	22.3	275.7								0.117	0.6
13	200	31.3	24.7	15.4	190.1	31	31	90	31.3	6.9	85.6	504		
14	200	32.9	25.1	17.0	213.6								0.117	0.4
15	200	34.4	25.5	18.6	236.5								0.232	0.8
16	200	35.8	25.7	20.1	258.7								0.111	0.3
17	200	37.1	25.9	21.6	280.6								0.110	0.2
17	160	37.1	25.9	17.3	224.5	20	20	40	37.1	4.3	56.1	566		
18	160	38.4	26.1	18.5	241.8								0.106	0.2
19	160	39.6	26.3	19.7	259.0								0.107	0.2
20	160	40.7	26.5	20.9	276.3								0.108	0.2
21	160	41.8	26.7	22.0	294.0								0.110	0.3
21	130	41.8	26.7	17.9	238.8	19	19	30	41.8	4.1	55.1	634		
22	130	42.9	27.0	18.8	253.6								0.113	0.3
23	130	43.9	27.3	19.7	268.4								0.114	0.3
24	130	44.9	27.6	20.5	283.3								0.115	0.3
25	130	45.8	27.9	21.4	298.3								0.116	0.3
25	110	45.8	27.9	18.1	252.4	15	15	20	45.8	3.3	45.9	684		
26	110	46.7	28.1	18.9	265.3								0.117	0.3
27	110	47.6	28.4	19.6	278.3								0.119	0.3
28	110	48.5	28.7	20.3	291.6								0.121	0.3
29	110	49.4	29.0	21.1	305.2								0.123	0.3
30	110	50.2	29.3	21.8	319.1								0.127	0.3

Appendix Xc High Growth Indicative Table for the Atlantic Region

Atlantic **form factor** **0.5**

	Remaining Volume					*Thinnings*						*Cum*	*Growth*	
Age	**N/ha**	**DBH**	**H_{av}**	**G/ha**	**V_{tot}/ha**	**%G**	**%N**	**N/ha**	**Dave**	**G/ha**	**V_{tot}/ha**	**V_{tot}/ha**	**CAI_{vol}**	**CAI_h**
0	1110	0.0	0.0	0	0							0		
1	1110	4.6	4.2	1.8	3.9								0.003	4.2
2	1110	8.1	8.2	5.7	23.3								0.017	3.9
2	950	8.1	8.2	4.9	19.9	14	14	160	8.09	0.8	3.4	23		
3	950	11.4	11.7	9.7	56.8								0.039	3.5
4	950	14.6	14.8	15.9	117.2								0.064	3.1
4	750	14.6	14.8	12.6	93.1	21	21	200	14.5	3.3	24.1	121		
5	750	17.6	17.5	18.2	159.4								0.088	2.7
6	750	20.5	19.9	24.7	245.4								0.115	2.4
6	500	20.4	19.9	16.4	163.0	34	33	250	20.5	8.3	82.4	273		
7	500	23.1	21.9	21.0	230.5								0.135	2.1
7	300	23.1	21.9	12.6	138.3	40	40	200	23.1	8.4	92.2	340		
8	300	25.7	23.7	15.6	184.3								0.153	1.8
9	300	28.1	25.2	18.7	234.6								0.321	3.2
10	300	30.4	26.4	21.8	288.2								0.179	1.2
10	200	30.4	26.4	14.6	192.1	33	33	100	30.4	7.3	96.1	490		
11	200	32.6	27.4	16.7	229.2								0.186	1.0
12	200	34.7	28.3	18.9	267.2								0.190	0.8
13	200	36.7	29.0	21.1	305.4								0.191	0.7
13	150	36.7	29.0	15.8	229.4	25	25	50	36.6	5.3	76.1	604		
14	150	38.5	29.5	17.5	257.7								0.191	0.5
15	150	40.3	29.9	19.1	288.4								0.191	0.4
16	150	42.0	30.3	20.7	314.1								0.185	0.4
17	150	43.6	30.6	22.4	342.0								0.185	0.3
17	100	43.6	30.6	14.9	228.0	33	33	50	43.6	7.5	114.0	716		
18	100	45.1	30.9	16.0	246.4								0.185	0.3
19	100	46.5	31.2	17.0	265.0								0.186	0.3
20	100	47.9	31.5	18.0	283.9								0.189	0.3
21	100	49.3	31.8	19.1	303.4								0.195	0.4
22	100	50.6	32.2	20.1	323.0								0.197	0.4
23	100	51.8	32.5	21.1	342.9								0.199	0.4
24	100	53.0	32.9	22.1	363.1								0.202	0.4
24	80	53.0	32.9	17.7	290.5	20	20	20	53	4.4	72.6	851		
25	80	54.2	33.3	18.5	307.4								0.211	0.4
26	80	55.4	33.6	19.3	324.1								0.210	0.4
27	80	56.6	34.0	20.1	341.3								0.214	0.4
28	80	57.7	34.3	20.9	358.9								0.220	0.4
29	80	58.8	34.7	21.8	377.1								0.227	0.4
30	80	60.0	35.0	22.6	395.9								0.235	0.4

Appendix XI Field teak growth data

Plot Code

034j established 30-6-1986

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	1600	0	0	0	0	0
112	0.2	544	16.8	17.1	144	15.5	1.84
137	0.21	396	14.2	20	142	12.4	1.75

Alfonso established 1983

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	884	0	0	0	0	0
168	0.25	249	12.8	22	140.6	10.0	1.57

219L established 15-6-1989

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	1110	0	0	0	0	0
67	0.15	533	10.0	13.0	64.5	11.6	2.3
80	0.18	533	13.8	17.0	117.6	17.6	2.6
92	0.20	311	10.3	17	87.3	11.4	2.2

219L-b established: 15-6-1989

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	1110	0	0	0	0	0
92	0.19	312	8.6	15	83.8	10.9	2.0

012J-b etablished: 15-6-1989

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	1600	0	0	0	0	0
92	0.19	312	8.6	15	64.4	8.4	2.0

012J established: 30-6-1986

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	1600	0	0	0	0	0
108	0.20	416	12.9	15.7	101.3	11.3	1.7
121	0.23	336	13.6	15	102.0	10.1	1.5
133	0.22	336	13.1	18	117.5	10.6	1.6

003J established: 31-7-1991

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	1110	0	0	0	0	0
47	0.11	566	4.9	8.5	20.8	5.3	2.2
60	0.13	566	7.7	10.4	40.7	8.1	2.1
72	0.17	566	12.3	13.5	82.9	13.8	2.25

Canateca established: 6-1993

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	1110	0	0	0	0	0
50	0.10	951	7.17	9.5	34.1	8.2	2.3

Canateca established: 6-1993

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	1110	0	0	0	0	0
50	0.08	1025	4.6	8	18.3	4.4	1.9

Puerto Carillo established: 3-1988

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	876	0	0	0	0	0
98	0.27	341	20.1	22	287.5	35.2	2.7
110	0.29	341	23.3	21.8	329.3	35.9	2.4

Guápiles BP established: 12-1990

age (months)	DBH	# Trees	G	H	Vol	MAI-vol	MAI-H
0	0	?	0	0	0	0	0
79	0.23	720	29.9	20.5	306.6	46.6	3.1

note: form factor used for calculations was estimated to be 0.5

Appendix XII Formulas for Diameter Growth

Relationship between diameter 'over bark' (DBH) and age (A)

Production	Formula	R^2
high	$DBH=0.0011A^3+0.0932A^2+3.7755A+0.7029$	1
medium	$DBH=0.0009A^3+0.0799A^2+3.2361A+0.7744$	1
low	$DBH=0.0008A^3+0.0665A^2+2.6968A+0.6454$	1

DBH Diameter at Breast Height (cm)
A Age (year)
$R^2 = 1.00$