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PLANTATION FORESTRY IN GUANACASTE, COSTA RICA

A LUST description of plantation forestry (teak and melina) in Guanacaste, Costa Rica

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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.

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 desarrollado 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.

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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

This report presents a study carried out during a practical training period within the context of REPOSA (Research Programme on Sustainability in Agriculture), a cooperation between the Centro Agronmico Tropical de Investigacin y Enseñanza (CATIE), the Wageningen Agricultural University (WAU), the Netherlands and the Ministerio de Agricultura y Ganaderiá (MAG), Costa Rica. The program was started in 1986 and its central research theme is exploring options for sustainable land use in the Atlantic Zone and Guanacaste.

Literature research, field work, analyzing the data and writing of the report was carried out from May-September 1996.

The work was supervised by Dr. Stella Efdé and Dr. André Nieuwenhuyse in Costa Rica and by Ir. Theo Guiking from the Department of Agronomy from the Agricultural University Wageningen. I would like to thank them for their good advice and especially André for assisting me during my visists to Guanacaste. Furthermore I would like to thank the MINAE-personnel of Hojancha, Liberia and Cañas for their help and assistance during my field work.

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Summary

REPOSA (Research Programme on Sustainability in Agriculture) is a cooperation between different departments of the Wageningen Agricultural University, Centro Agronmico Tropical de Investigacin y Enseñanza (CATIE) and the Ministerio de Agricultura y Ganaderia (MAG) of Costa Rica.

In this case the creation of LUST's on plantation forestry with teak and melina in Guanacaste, Costa Rica are described. A LUST (Land Use System at a defined Technology) description is formed by a chronological and quantitative description of a particular operation sequence (e.g., nutrient application).

Deforestation rate during the past 60 years has been very high in Costa Rica. In 1986 a subsidy was introduced to promote reforestation. In 1989 an other subsidy for reforestation was introduced especially aiming at reforestation by small farmers. An amount of $600 is paid per hectare for establishment. The subsidy is one of the main reasons why 4000 hectare per year of teak, melina and pochote have been planted in Guanacaste during the past few years.

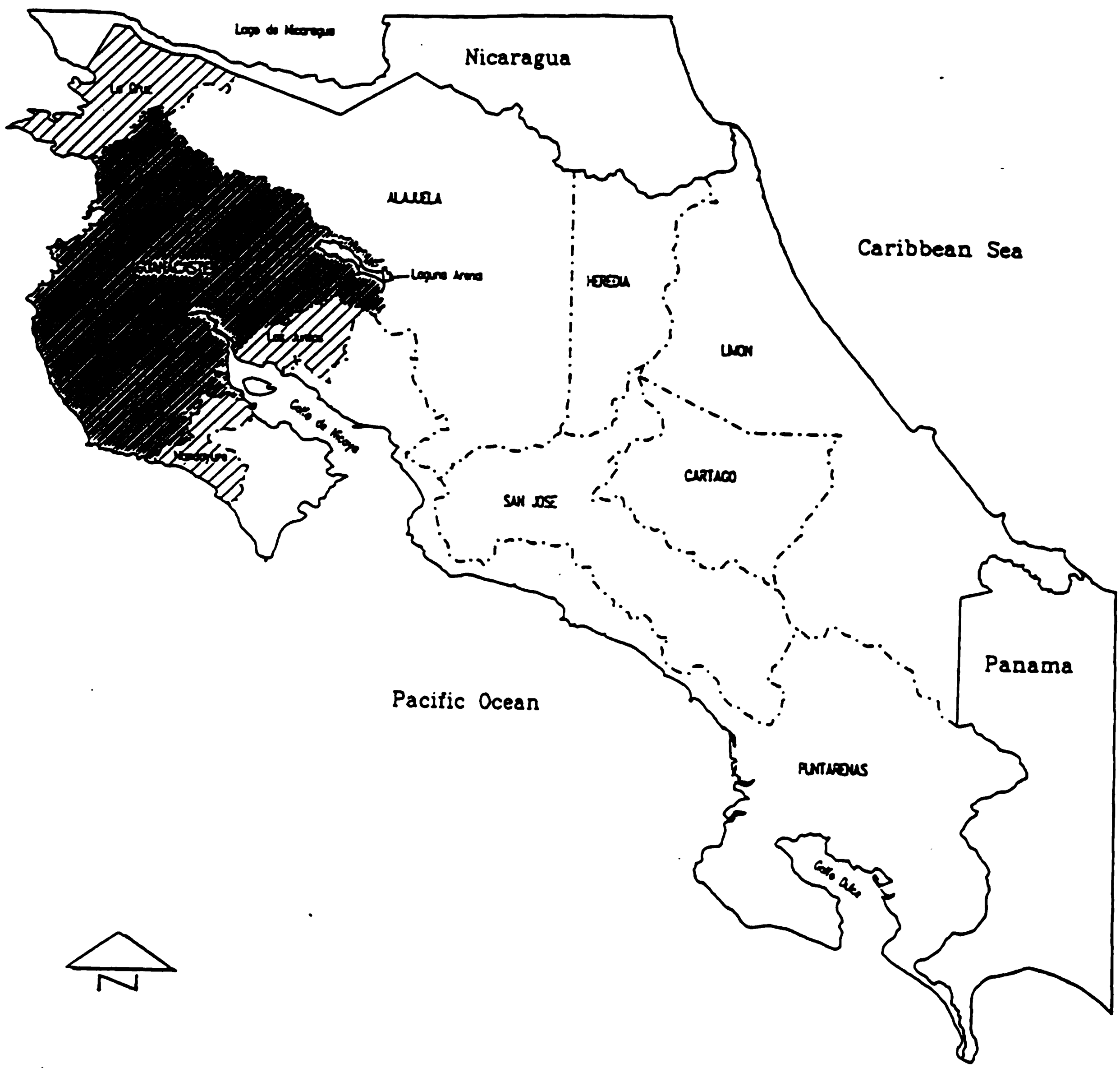
Data on management and production were collected. Each management activity for teak and melina is described for different sites (site index;[1] high, middle or low). Management activities for teak and melina are the same. Differences exist in the period when activities have to be executed. Management activities e.g., thinning and pruning are necessary for an optimal tree growth.

Site index is influenced by environmental factors like climate, soil type and slope. Teak and melina have different prerequisities conserning climate, soil type and slope. Each of these environmental factors is briefly discussed.

Volume estimations for teak and melina were made for thinnings and for the final cut. Corrections for wind and for an irregular tree form are included in the volume estimations.

For major soil types in Guanacaste the suitability for teak and melina was estimated according to field observations.

1 Site index is the suitability for a crop to grow on a certain soil. Site index is influenced by environmental factors (climate, soil type and slope).


Nicaragua
Caribbean Sea
ALAJUELA
Laguna Arenal
HEREDIA
LIMON
CARTAGO
SAN JOSE
Panama
Pacific Ocean
PUNTARENAS

1 Introduction

The work presented in this report was carried out within the context of REPOSA (Research Programme on Sustainability in Agriculture). REPOSA is a project which started in 1986. It is a cooperation between different departments of the Wageningen Agricultural University (WAU), Centro Agronmico Tropical de Investigacin y Enseñanza (CATIE) and the Ministerio de Agricultura y Ganaderia (MAG) of Costa Rica. The program focuses on the formulations of options for sustainable forms of land management at farm and regional level and tries to find agricultural policy options to reach those options (Stoorvogel *et al*, 1995). To develop scenarios for sustainable and economically feasible land use, three hierarchical levels of analÿsis can be distinguished (Atlantic Zone Program, 1992):

1. The Land Use System (LUS) analyses the relations between soil type and crops as well as technology and yield.
2. The Farm System (FS) analyses the decisions made at the farm household regarding the generation of income and on farm activities.
3. The Regional System (RS) analyses the agro-ecological and socioeconomic boundary conditions and the incentives presented by development oriented activities.

The project developed a methodology (USTED) to explore options for land use in Costa Rica. The USTED methodology includes three main modules:

1. A linear programming (LP) model, to calculate optimal land use given a goal, constraints and some technical coefficients reflecting the options for land use.
2. A geographic information system (GIS) for storage and analysis of spatial data.
3. A data management tool, MODUS, to facilitate data transfer with USTED and to calculate technical coefficients for the LP-model.

The methodology has been used to study about 550.000 ha of the Northern Atlantic Zone of Costa Rica. During the first five years the research mainly focused on describing the Atlantic Zone, its climate, soils and farming systems. In 1995 research started in Guanacaste. The idea for this new research area is to test the USTED methodology in a different region using as little data input as possible.

A LUST (Land Use System at a defined Technology) describes a specific form of land use that includes a quantification of the technology. The body of each LUST description is formed by a chronological and quantitative description of a particular operation sequence (e.g. land preparation). Each operation is described by a quantity of biophysical inputs or outputs, split into four groups: labour, traction, equipment and materials. A distinction is made betwèen 'traction' and 'equipment', where the former comprises machines that provide power to equipment. 'Equipment' relates to tools that do not generate power, and that can be used by themselves (e.g., machete), or in combination with traction (e.g., disc plow). The group 'materials' comprises goods that are consumed during use (e.g., biocides). A LUST description serves as a basis for the calculation of required coefficients. LUST descriptions do not necessarily contain all information needed for analysis of the LUST's. This information, e.g., prices, nutrient contents, toxicity of chemical used in the LUST, is stored separately from the LUST descriptions in so-called attribute databases. Users of LUST descriptions need to develop customised procedures to extract information from the LUST descriptions and the attribute databases, and to convert this information into coefficients for further analysis in USTED (Jansen and Schipper, 1995).

REPOSA selected crops on the basis of their typical occurrence in the study region and on their perspectives for future development (Atlantic Zone Programme, 1992). A LUST has to be made for both actual and potential existing land uses. One of these land uses, which are considered interesting for the Guanacaste area, are tree plantations.

1.1 Objectives

This report presents the description of LUST's on plantation forestry in Guanacaste, Costa Rica. In this report the following definition of a forestry plantation is used: a crop or a stand raised artificially either by sowing or planting with as a main goal the production of timber (van Leeuwen and Hofstede, 1995). This definition only includes the pure timber stands. When describing LUST's for forestry plantations, the long time scale has to be considered; forest management must be planned a long time ahead due to the long growth period of a tree. Decisions therefore have an impact on the long run (van Leeuwen and Hofstede, 1995).

The first idea was to look at three tree species: Gmelina arborea (melina), Bombacopsis quinatum (pochote) and Tectona grandis (teak). These species were chosen because some 40000 hectares in the region Guanacaste have been planted mainly with these species (personal communication G. Galloway).

Collecting data in the field, in literature and analyzing these data to describe a LUST are the most important aspects of this practical period. Specific objectives are:
- -to find a relationship between climate, soil type and tree growth;
- -to estimate volumes, for different soil and environmental conditions, at thinning and at the final cut;
- -to make an detailed overview of the management activities (inputs and outputs) necessary for creating a LUST.

1.2 Methodology

For the describtion of a LUST socioeconomic and biophysical conditions of a forestry plantation have to be described. This study consisted of literature research and data collection in the field during May, June and the first two weeks of July 1996. Literature research was mainly done at CATIE, where many data on management of plantation forestry were available.

An overview of the data gathered during the field work is given. These data (like dbh[1], planting date, soil properties, environmental conditions) were used to estimate volumes, at thinning and at the final cut for different soil and environmental conditions. Three classes of site indexes (high, middle and low) were used to estimate these volumes. Based on all the above mentioned data an overview was made of costs and benefits of a forestry plantation.

1 dbh= diameter at breast- high. Breast- high= 1.30 metre

2 Research area

The research area of this study is Guanacaste. Some general information is described below:

2.1 Location

Guanacaste is situated in northwest Costa Rica. The Guanacaste province is bordered by Nicaragua in the north, the Cordillera de Guanacaste in the east, the Pacific ocean in the west and the Golf of Nicoya in the south. Geographic coordinates are 9°16 ' to 11°12 ' N latitude and 84 °30 ' to 85 °56 ' longitude.

Guanacaste is an area of 10.141 km^2 (Herrera, 1985). It is one of the 7 provinces in Costa Rica. Guanacaste is divided in 11 districts (Liberia, Nicoya,Santa Cruz, Bagaces, Carrillo, Cañas, Abangares, Tilaran, Nadayure, La Cruz and Hojancha). The districts La Cruz, Nadayure and Abangares are not included in the study area, because of soil and climatic similarities that exists with other regions in Guanacaste and due to logistic reasons. The study area has an area of 7,649 km^2 (see figure 2.1).

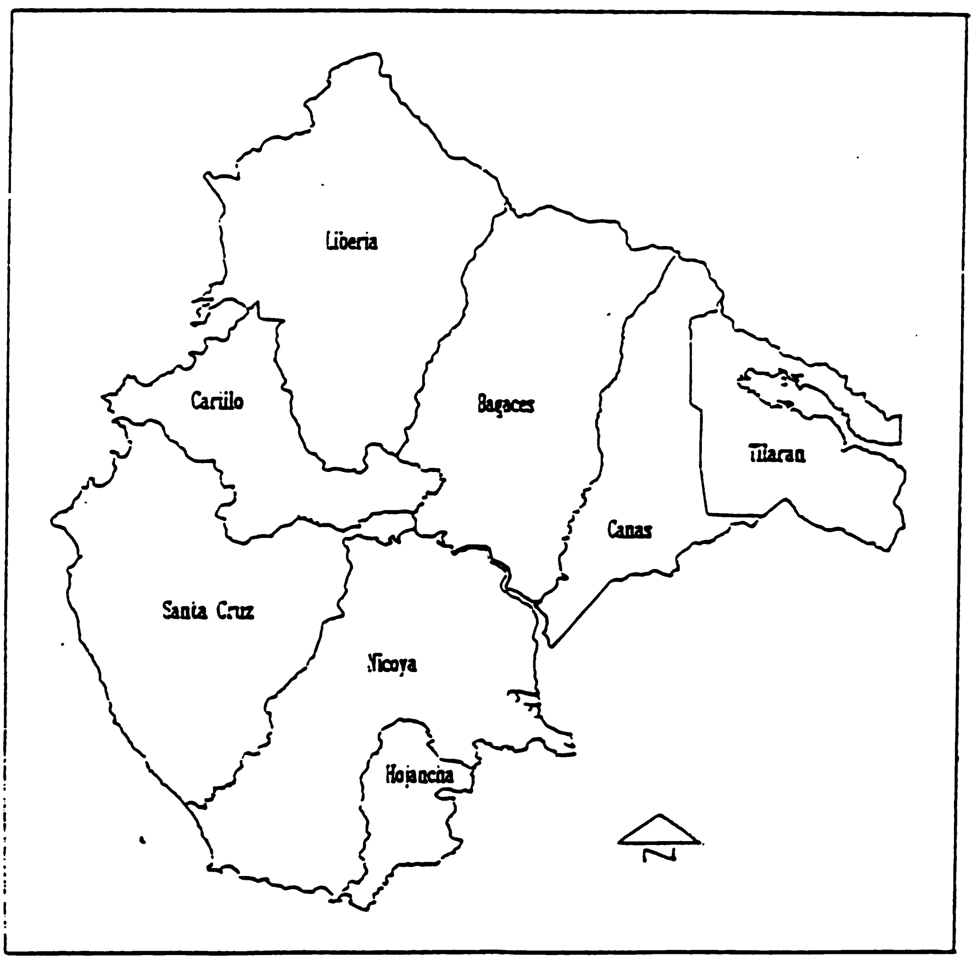


Figure 2.1: Administrative subdivision of the study area

2.2 Climate in Guanacaste, the northern Pacific region

The lower areas of the northern Pacific region are characterized by a prolonged dry season of 5 to 7 months during which strong, dry northeastern winds cause a strong evaporation. The rainy period is from May until November.

The mean annual temperature is about 26 to 28°C[1] and diminishes with altitude at a rate of 0.57°C every 100 m (Herrera, 1985). The hottest month is usually April with mean temperatures of 28 to 29°C, the coolest months are December and January with mean temperatures of 26 to 27°C.

Wind speed is strongest on the footslopes of the Cordillera de Guanacaste and northern plains. During the dry season mean wind speed in this area is about 20 km h^{-1} (station Liberia IMN '77-'93), while in the sheltered Nicoya peninsula this is about 10 km h^{-1} (station Nicoya IMN '71-'83). During the rainy season wind speed diminishes to about half of these values (IMN).
Relative air humidity varies from 60% during the dry period to 85% during the rainy season. Mean Penman potential evapotranspiration in the flat northern area varies from 4.0 mm day^{-1} during the rainy season to 9.0 mm day^{-1} during the dry months(station Liberia), while in the area less effected by strong winds it varies from 3.5 to 6.0 mm day^{-1} (station Nicoya).

2.3 Soils in Guanacaste

Although soil scientists may distinguish many more soils, for practical reasons soils of the REPOSA study area have been grouped into 15 mayor soil groups, as follows (Nieuwenhuyse, personal communication):

1 Thick clayey Alfisols of a moderate soil fertility, well drained except deeper layers, often stony. Soils of this subgroup occur mainly on less sloping areas on Nicoya complex rocks (in the Nicoya peninsula) and older (Tertiary and early Quaternary) volcanic rock (Cordillera de Tilaran and Cordillera de Guanacaste), and on pediment deposits derived from these geologic formations.

2 Thin loamy to clayey Alfisols and Inceptisols of a moderate (sometimes even low) soil fertility, well drained, often stony. Occur mainly on steeper sloping areas on the same geologic formations as subgroup 1.

3 Thick loamy Andisols of a moderate soil fertility, well drained. These soils are found in the more rainy areas covered by volcanic ash from the Arenal volcano around Lake Arenal.

4 Thick sandy Andisols of a high soil fertility, excessively drained. These soils occur in the dryer areas covered by ash from the Arenal volcano (around the town of Tilaran) as well as northwest of the Rincon de la Vieja volcano.

5 Thin sandy Andisols of a high soil fertility, well drained. These soils have developed on top of older existing soils, often clayey, which influence drainage of the overlying Andisols. They occur west of soils of the former soil subgroup (west of the town of Tilaran, around the village of Tierras Morenas and around the village of Quebrada

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1 Weather data were extracted from the Costa Rican "Instituto Meteorológico Nacional"

Grande)

6 Thick clay soils dominated by swelling and shrinking clays (Vertisols) of a high soil fertility. They occur mainly in large areas in the Tempisque valley as well as in small areas on the ignimbrite plateaux, associated with other soils.

7 Well drained, deep Mollisols, loamy to light clayey, of a high soil fertility. Mainly found throughout the Tempisque valley, but also on the distal parts of pediment deposits.

8 Well drained, moderately deep Inceptisols/Mollisols of moderate to high soil fertility and a loamy to clayey texture. Found on ignimbrite plateaux where extremely variable at short (< 100 m) distances and on slopes of volcanoes.

9 Moderately well to imperfectly drained Inceptisols of a high soil fertility and of a loamy to clayey texture. Located throughout the Tempisque lowland. Upon drainage, these soils become highly productive

10 Swamp soils, having a high soil fertility but dominated by a poor drainage which hinders their agricultural use. Found in the lower areas of the Tempisque valley, as well as in poorly drained areas of Guayabo caldera.

11 Thin, calcareous clay loam Mollisols of a high soil fertility, often stony. Found on slopes of calcareous rocks on the Nicoya peninsula and on limestone.

12 Very shallow, loamy to clayey soils on rock of a variable soil fertility, often stony. Found throughout the study area on steep slopes or very broken terrain.

13 Barren rock, found in some small volcanic areas (Rincon de la Vieja).

14 Sandy alluvial soils (Inceptisols) of a high soil fertility. Found close to the Tempisque river in its middle reach.

15 Thin loamy soils of a moderate soil fertility, often stony. Found on slopes of the Cordillera de Guanacaste.

2.4 Agriculture

The most important agricultural products of Guanacaste are rice and sugarcane (see table 2.1).

Sugarcane covers an area of about 19000 ha. In the Tempisque valley sugarcane is found under a high level of technology. In other parts of Guanacaste sugarcane is grown also but the plots are a lot smaller and the level of technology is lower. Most of this small scale sugarcane is used for fodder (Guiking, 1996).

Rice, occupies an area of about 40.000 ha. Irrigated rice can be found in the Tempisque valley. Most of this rice is grown on a large scale. Rice is not transplanted but is sown directly. When enough water is available during the year 2-3 crops can be grown (Guiking, 1996).

Maize has lost much of its importance with the abolishment of the subsidies. Still several thousands of ha of maize can be found in the Guanacaste area.

Beans cover an area of about 6000 ha in Guanacaste.

Coffee, grown on a small scale (about 1800 ha.).

Other crops grown are melon, mango, oranges (for the juice industry), coconuts and cashew. (Guiking, 1996)

Table 2.2: Area and production of different crops in Guanacaste (1984)

crop	area(ha)	production(tons)/ha
rice	41169.9	2.96
sugarcane	18828.6	64.25
maize white	7371.8	0.88
maize sweet	1053.3	1.02
beans	5845.7	0.37
coffee	1791.0	4.30
platano	410.4	2.52
oranges	329.7	1.59
banana	225.5	2.39
yucca	216.0	6.09
avocado	206.9	4.79
coconut	55.8	4.86
pineapple	87.6	0.11

(DGEC, 1987)

3. Reforestation in Guanacaste

3.1 General information on reforestation

Deforestation rate during the past 60 years has been very high in Costa Rica (table 3.1):

Table 3.1: Forest area change (km^2) in Costa Rica

Total area	1940	1950	1961	1977	1980
50,990	34,206	28,642	23,035	16,154	8,711

(Sader&Joyce, 1988)

From 1977 onwards, after the introduction of a tax exemption incentive, farmers and enterprises in Costa Rica started to become interested in reforestation. The objectives of reforestation were:
-Soil conservation.
-Production of wood for industrial and household use.
-Lowering the pressure on the natural forest regarding wood supply.
-The creation of work for the rural population.

The Ministry of Energy and Mining (MINAE, formerly MIRENEM) is responsible for the management of the natural resources of Costa Rica which includes natural forests and plantation forestry.

In 1986 the Certificado de Abono Forestal (CAF) was introduced which coexists with a tax exemption incentive which was constituted in 1977 to promote reforestation. In 1989 the Fondo de Desarrollo Forestal, a subsidy for reforestation especially aiming at reforestation, by small farmers, was introduced. The main difference between the two funds are the prerequisites (for CAF a land title is required). The amount that is paid over a five year time period is roughly $600 per hectare for establishment plus a little extra for tending. The amount of money is divided as follows: 50% in the first year, 20% for the second year, 15% in the third year, 10% fourth year and finally 5% in the last year.

In 1987 the government of Costa Rica created DECAFOR (DEsarrollo CAmpesino FORestal), a department within MINAE which concentrates on reforestation projects on small and medium sized farms. The main goals of DECAFOR are (van Leeuwen and Hofstede, 1995):

- changing the mentality of farmers towards a better understanding of the need for reforestation.
- strengthening of farmers organizations and farmers unions.

During the past few years plantations of teak, melina and pochote have been established in the Guanacaste area at a rate of nearly 4000 ha per year (personal communication G.Galloway). Probably most of this land would never have been planted to trees if a government program to plant trees had not been in place. From the total area that has been reforested in Guanacaste the largest part belongs to small farmers. Table 3.2 shows the reforested area in Hojancha by small farmers. The Hojancha canton is probably the region of Guanacaste where reforestation rate is highest.

Table 3.2: Reforested area in the region Hojancha by small farmers (1978-1991)

year	number of farmers	area
1978	3	2.0
1979	8	8.0
1980	8	8.0
1981	17	3.0
1982	40	10.0
1983	60	14.0
1984	48	38.2
1985	60	59.7
1986	69	92.0
1987	30	60.5
1988	92	300.0
1989	95	377.0
1990	50	104.0
1991	34	128.0
Total	614	1204.4

(Campos *et al*, 1993)

3.2 Teak, melina and pochote

Teak, melina and pochote are the three tree species described for the reasons explained in chapter one.

Tectona grandis

Teak (*Tectona grandis* L.f.) is a tree that originates from Birma, Thailand and from some parts in India. It was first introduced in the American continent in Trinidad and Tobago. From those places teak extended to other parts of the Americas.
In Central America the tree starts to flower and produce seeds after 5 to 8 years. Teak is a species which is very resistant to plagues.

climate

Teak requires a climate with a distinct dry season of about 3 to 5 months with a mean annual temperature between 22°C and 28°C and a precipitation range of 1250-3500 mm.
The best height to plant teak is at an altitude of less than 500 metre m.a.s.l.

soil

Teak can be planted on various soil types, but the tree prefers deep, fertile soils which are well drained with a pH that is neutral or acid. Teak does not grow well on soils that have a low magnesium and calcium content. It is better to avoid steep slopes, because of possible erosion. The species is susceptible to poor drainage.

wood

The structure of the wood is very fine and dense and it very easy to work with. The wood of teak is very resistant to fungus attack and insects and can be preserved for a very long time. This is one of the reasons why teak is considered as one of the most valuable trees in the world. The wood of teak is used for constructions like bridges, for furniture, floors etc. The final cut for teak is possible after about 20 years (Chaves&Fonseca, 1991).

Gmelina arborea

Gmelina arborea (melina) is a species which originates from southeast Asia. Optimum altitude for melina is below 700-800 m.a.s.l. and probably best below 500 m.a.s.l. The tree prefers temperatures between 24 °C- 35 °C. Optimum rainfall rates range between 2000-3000 mm, but may very from 1500-4000 mm.

soil

Just as teak, melina grows best on well drained, deep and fertile soils. However, its tolerance for shallow or less fertile soils is higher than for teak.

wood

In Costa Rica melina is mainly used to produce paperpulp, for production of packing (like pallets etc.). However it may also be used for furniture production, music instruments and construction in general because it does not show any deformations in the wood. The final cut of melina is possible after 12 years.
(Murillo&Valerio, 1991)

Bombacopsis quinatum

Pochote (*Bombacopsis quinatum*) grows in the lower and wetter areas in Central America. In contrast with melina and teak, pochote is a native species. The tree may become 30 meters high and 100 centimeters thick. Pochote has a straight form with many thorns. The optimum temperature is between 20 °C and 27°C. Pochote needs a dry period of 3-5 months. The amount of rainfall that is required varies from 800 up to 2200 mm.
The tree looses its leaves at the end of November at the start of the dry season. In May new leaves start to grow. The natural resistance against fungus is very high.

soil

The tree prefers sandy to loamy soils with a good drainage. A flat surface is preferred for an optimal growth. The soil must have a high natural fertility. For reforestation purposes, areas with a compacted topsoil (e.g. due to cattle tramping) should be avoided or mechanical land preparation prior to planting should be done.

wood

The wood of pochote is colourless or has a reddish colour. The wood is used for furniture and in constructions in general. The quality of the wood is very good, because it is very dense. When the tree is <25 years the wood is soft and has a lower density than when elder. (Anonymous, 1991 a)

4 Materials and methods

4.1 Literature investigation

Data were collected in the literature; the missing data concerning management and production were collected in the field. Many data on reforestation are already present at CATIE (Centro Agronmico Tropical de Investigacin y Ensenañza). The Nicoya and Hojancha areas are included in the investigation area of the MADELEÑA-3 project (Proyecto Diseminacin del Cultivo de Arboles de Uso Múltiple). MADELEÑA-3 is a CATIE-project. It investigates technical and socioeconomic data on trees with the purpose to get to know the potentials and the general problems of the reforested region in Central America and Panama.

4.2 Missing data

After analysing most of the data available in literature there were still some data missing that are necessary for describing a LUST. Most input data were found on management and costs of planting trees (see appendix 4), but output data or data on tree growth under different environmental conditions did not exist.

It is necessary to know whether management is different for the different tree species. When the management for the different tree species is about the same, a LUST can be made for a tree on a certain soil type and after that it will be a lot easier to repeat this for other soil types in the Guanacaste area.

4.3 Field work

4.3.1 General

Field work was done in the Guanacaste study area. Different tree plantations were visited. It was important to select tree plantations where teak and melina were managed to some extent. Plantations were selected and found with the help of MINAE personnel in Hojancha, Cañas and in Liberia. Farmers who have received subsidy are registered there. Planting date, management, size of the area etc. are known at MINAE.

Size of plantations wasn't considered important as long as the trees were not planted in a hedge, because if planted in a hedge there is less competition between trees (for light, nutrients and water) and trees will develop differently.

In the field the diameter and height of the trees was measured and slope and soil profiles were described to get an overview of the relation soil type↔tree growth.
The instruments used for measuring were:
- a tape measure for determining diameters
- an inclinometer for estimating the height of a tree
- a soil core sampler

In addition to these measurements visible damage was recorded like wind damage (bended trees) and the presence of pests and diseases. A short description of the management (when present) is given (appendix 4).

When a plantation clearly had received inadequate management, those stems which had largest diameters were measured for this study since it was assumed that these stems represent best the potential of the site.

Furthermore a sawmill in Hojancha, which buys small-diameter teak and melina trees, was visited because it was necessary to obtain information on the prices farmers get for the different wood types.

4.3.2 Pochote

After visiting the sawmill in Hojancha it was decided to leave pochote out of the investigation. The reason is that pochote is only accepted at the sawmill when it has a diameter > 35 cm. The price paid for such pochote is in between that of teak and melina (about 65 colones per pulgada tica[1] in July, 1996)

The wood quality of young pochote is too soft and not dense enough so there is no market for young pochote in the Guanacaste area. This means that wood from thinning of the plantations cannot be sold. Furthermore time needed to obtain pochote trees with a diameter > 35 cm is >25 years. So compared to teak and melina which are accepted at diameters> 15 cm, revenues will be very low. Therefore, it was decided that pochote plantations are not an economically viable option for farmers and it was decided to study only teak and melina.

4.3.3 Teak and melina

Teak and melina are accepted at diameters> 15 cm. The price that is paid for the teak is ¢85 per pulgada tica. Melina has a low price (¢22 per pulgada tica) but is included in the investigation because it is a fast growing species which can be grown on sites not suited for teak.

1 A pulgada tica is 2.54 cm wide by 2.54 cm high by 3.34 m long

5 Results

5.1 Management data of teak and melina

Plant material

Different plant material can be used to grow a tree: seedling, stumps or cutting. For teak and melina cuttings are used. Melina and teak aren't indigenous species so they are purchased in nurseries. One cutting of melina costs ¢15 (about $0.075, end July 1996) and for teak ¢20 ($0.10). Most of the teak and melina is planted as cuttings, because these are easy to handle and easy to transport. An alternative is planting trees in bags. The advantage of this method is that it is not necessary to remove sprouts and is less susceptible for dry periods shortly after planting. Plant material in bags are therefore preferred in the drier areas of Guanacaste. Planting in bags is more expensive (¢ 25 for teak) and transportation is more difficult and costly. Approximately, transport capacity of a vehicle is about 10 times higher for bags as for cuttings.

Soil preparation

Soil preparation means clearing the whole surface by removing grass or shrubs with a machete or with herbicides. In most cases a machete is used. Before planting the trees, the individual area where plants are going to be planted is cleared with the machete. Best time in the year for soil preparation is April-May. These two months are the end of the dry season in Guanacaste. Soil preparation takes the farmers 6 man-days/ha (man-day ≈ 6 hours).

Mechanical land preparation may be necessary in areas which formerly were used for grazing. However, such land preparation is only possible in less steep terrain without stones.

Planting of trees

Trees can be planted at different densities. Most melina and teak is grown at densities of 2½ *2½m, 3*3m or 3½*3½m. A subsidy can be provided for farmers (see 3.1) who are planting trees, on the condition that the spacing between the trees is 3*3m (1111 trees/hectare) or wider. For this reason most plantations found in Guanacaste were planted with a density of 1111 trees/hectare.

Planting of trees should take place at the beginning of the rainy season so enough time is available for the young tree to establish before the next dry season sets in. In Guanacaste the best time to plant trees is at the end of May till the end of June. A spade is often used to plant trees. Replanting of trees that died is done in July (about 200 trees/ha).

Planting of trees takes the farmers about 4 man-days/ha (≈ 24 hours), replanting about 1.3 man-days/ha (≈ 8 hours).

Thinning

Thinning is a silvicultural practice which includes the elimination of trees in a plantation to promote the growing of the remaining trees (Galloway, 1993). Two or three thinnings are necessary in a plantation with an initial planting density of 1111 trees/ha (3m*3m) to obtain a final density of 180-250 trees. If no thinning is executed the diameters of the trees will remain small (see table 5.1 and 5.2).

Research was done in Hojancha, Guanacaste to compare the differences that exists between a plantation of melina with good management and an other plantation with poor management (see table 5.1 and 5.2). Plantations are located next to each other, so site conditions are about the same. Main differences in management involves thinnings. The quality of the used genetic material was the same (Valverde, 1995).

Table 5.1: Intensity and year of thinning of a well and a poorly managed melina plantation near Hojancha

thinnings	age	intensity (%) *good management*	age	intensity(%) *poor management*
1°	3.5	44	6	50
2°	5.5	54	8	50
3°	6.5	22	9.5	44

(Valverde, 1995)

Table 5.2: Differences in growth between a well and a poorly managed melina plantation near Hojancha

	good management	*poor management*
age of plantation	7	10
actual density (trees/ha)	224	224
original density (trees/ha)	1111	1111
dbh (cm)	28	25
total height (m)	22	22

(Valverde, 1995)

From these two tables it can be concluded that there has been much competition between the trees in the 10 year old tree plantation as expressed in the diameters, and to no (as in this case) or a lesser extend in the height of the trees. Thinnings were executed too late and therefore the competition for light, water and nutrients was very high. Height of a tree is less affected by delayed thinnings.

Trees which should be selected for thinning show a reduced growth, sub-optimal stem form, are dead or are infected by pests and diseases. Trees that have a large diameter should not be thinned.

Plantations with a planting density of 3*3m need to be thinned for the first time when trees reach a height of 7-9 metre. This is the same for both teak and melina but these heights are reached at a different age because of differences in growth rate. The intensity of the first thinning is about 50% (550 trees/ha). It is better to execute the first thinning as soon as possible for various reasons:

- Thinning creates better conditions for optimal tree growth. Trees can reach there commercial diameter (6 pulgades ≈ 15 cm) at an earlier age.
- Trees are less susceptible to wind because of the larger diameters.

First thinnings are not commercial so it is better to keep the costs as low as possible. Second thinnings are done at a height of 14-15 meter with an intensity of about 180 trees per hectare for teak and for melina (Galloway, 1993). Teak is thinned four times during its 20 years growth period and melina is thinned three times (see appendix 4).
Thinning is done with a chain saw; when diameters are small also a machete can be used.

Each thinning takes about 3.2 man-days (≈ 19 hours) / ha.

Pruning
Pruning involves taking away branches to obtain straight logs without knots. Melina trees have to be pruned for the first time up to a height of 3 metre when they reach a total height of about 6 m. For teak this is up to a height of 4 metre. Pruning half the height of the tree gives the best result, because when too many living branches are taken away the amount of leaves is reduced too much, causing growth reduction. Best is to execute the first pruning at the end of the dry season, because then drying of the cutted pieces will go faster and the chance for infections is lower. Second pruning have to be executed immediately after the first thinning. It is important to prune before the inferior branches start to die, because this will cause black spots in the wood (Galloway, 1993).
Pruning can be done with a machete or with a saw.

First pruning takes about 16 hours/ha, second pruning takes more time (about 30 hours/ ha), because stairs have to be used.

Logging
A farmer has to realize different activities before he can deliver plantation products at the sawmill:
- cutting
- loading
- transportation

For the cutting of the trees a price of ¢2 per pulgada tica has to be paid (prices include costs of labour and the costs of material needed, sawmill Hojancha July 1996). For loading about 3-4 colones per pulgada tica have to be paid.
Hojancha is the only sawmill at this moment in Guanacaste where trees of a small diameter are accepted (diameter > 15 cm). Transportation costs can form a great part of the logging costs when wood has to be transported from e.g. Liberia to Hojancha.

The price that has to be paid for transportation was not investigated in detail but some indications were obtained:
Transport from the Santa Maria area (about 15 km south of the Hojancha area over gravel roads): ¢10 per pulgada tica.
Plantations near Hojancha: ¢5 per pulgada tica

Unknown is how the costs are for plantations further away from Hojancha.

Final cut
The age at which a final cut can be executed depends on soil- and environmental conditions (see appendix 2). For teak this is 20 years or more and for melina 12 years or more. The intensity of a final cut varies from 180-250 trees/ha.

5.2 Formulas used for estimating tree production

Data collected in Guanacaste (see appendix 3 and of literature) were used to estimate volumes for teak and melina removed with the final thinning and at the final cut. Since only few plantations were managed adequately (especially thinnings were far less than necessary), actual measured growth rates were sometimes raised to obtain such estimates
With the help of formulas and tables an estimation of the volume of trees was made:

Melina

Volume of individual melina trees can be calculated using a formula determined in Siquirres (Atlantic Zone) for trees from a height of 0.3 m until a diameter in the top of the tree of at least 10 cm (Murillo and Valerio, 1991):

$$Ln(Vsc)=a+b*Ln(D)+c*Ln(h)$$

with:

Ln =natural logarithm
Vsc =volume of the tree without bark (m^3/tree)
a = -9.63
b = 1.785
D = diameter of the tree at 1.3 metre [1]
c = 0.8189
h = total height (m)
The formula can be used for 20 cm < D < 50 cm

For the *site index* the following equation is used (Murillo and Valerio, 1991):

$$Ln(IS)=a+(Ln(hd)-a)*(E/Eb)^k$$

with:

Ln = natural logarithm
IS = site index
a = 4.4277
hd = dominant height of the trees
E = age of plantation (in years)
Eb = 10 years (year of measuring IS)
k = 0.3277

1 1.3 metre is breast high

Teak

For estimating the individual *volumes* of teak trees the following equation established for Costa Rica was used (Chaves and Fonseca, 1991):

$V=0.0359+0.000022(D^2h)$

with:

V = volume without bark (m^3) from 30 cm height until a minimum diameter in the top of the tree of 8 cm
D = diameter at breast high with a bark in cm
h = total height of the tree in metres
The formula can be used for 18 cm$<$D$<$53 cm

For diameters$<$20 cm the equation established for El Salvador was used (Chaves and Fonseca, 1991):

$V=-0.0111+0.000025(D^2h)$

Site index is given by Chaves and Fonseca (1991). This formula was determined for teak growing in Colombia:

log h=log IS-b*(1/Eb-1/E)

with:

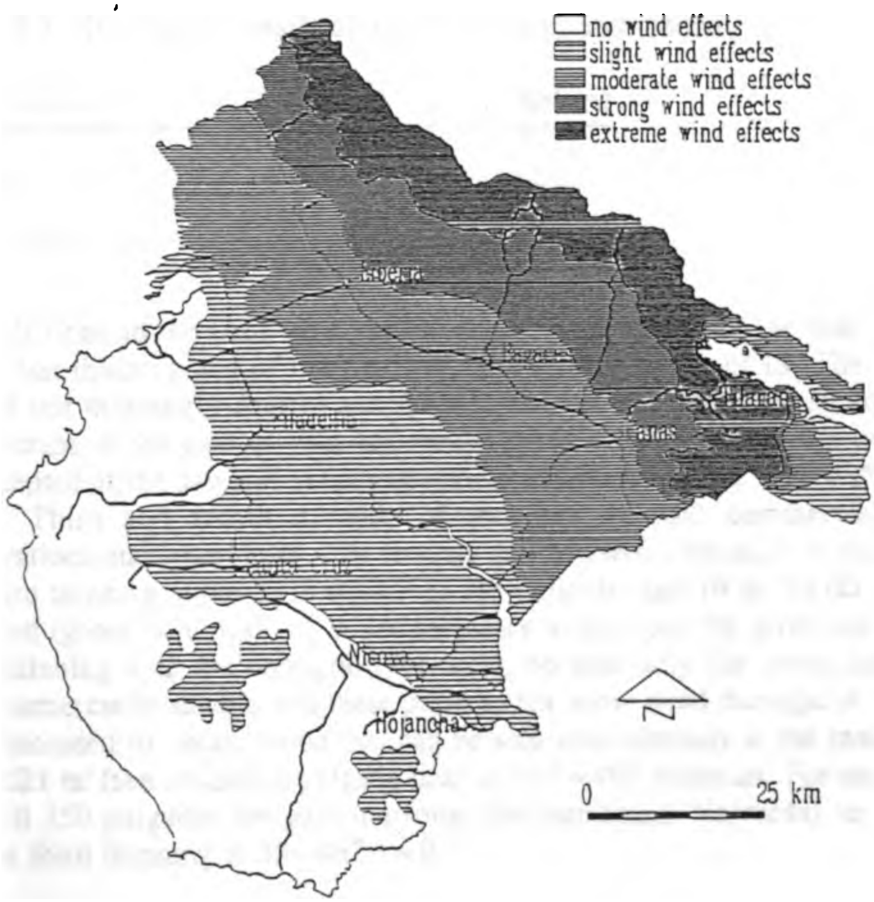
Log = logarithm
h = mean height (m)
IS = site index (m)
b = 1.4
Eb = 10 years
E = age (in years) of the plantation

5.3 Volume correction factors

It has to be taken into account that the formulas used in 5.2 are to"optimistic" to estimate the final price a farmer receives for his wood. Wood must have a diameter of at least 12.5cm without a bark (instead of 8 in the case of teak or 10 cm in the case of melina) and a length of 3 varas ≈2.50 m or 4 varas ≈3.34 m before it is accepted at the sawmill so a correction for volume had to be made. For teak the formula described in Chaves and Fonseca (1991) was reduced with a volume of $0.02m^3$ /tree. For melina this was $0.01m^3$/tree (see appendix 2 for an explanation).

Teak and melina in Guanacaste are susceptible to wind damage. For example near the Arenal volcano no teak and melina was found simply because wind speed is too high in this area. In the northeast of Cañas teak and melina can be found but looking at the form of the trees (bended in the direction of the wind) it can be concluded that wind speed is rather high in this area (see fig. 2). The form of the tree has a great influence on production rates so it was decided to include a different correction factor, for each plot, for different intensities of wind (see appendix 3).

Figure 5.1: Wind zonation for tree growth in Guanacaste based on field observations



Volume corrections were tentatively estimated as follows:

Table 5.3: Volume correction for wind effects

wind effect	volume reduction (%)
0=no effect	0
1=slight effects	15
2=moderate effects	25
3=strong effects	40
4=extreme effects	60

The volume obtained after including the correction for wind was multiplied by 0.85 (value set arbitrarily) to obtain a volume/tree corrected for irregularities like knots, a not perfect log form or length etc., because at the sawmill this wood will be lost.
After including all the correction factors a volume is obtained which is thought to be comparable to that which is actually paid for at the sawmill (see appendix 2).

5.4 Tree growth at different sites

For each plot the IS was calculated (see appendix 3) with the formulas described in 5.2 and assigned to different classes:

Table 5.4: Site-index classification (IS) for teak and melina

Classification	IS (teak)	IS (melina)
High	≥21.71	≥26.71
Middle	18.09-21.7	1.9-26.7
Low	≤18.08	≤1.9

(Vásquez and Ugalde, 1995)

Data obtained in the field were used to make an estimation of the year, diameter and height of the last thinning and of the final cut for different values of IS. The volume is calculated for the last thinning(=fourth) and for the final cut (see appendix 2), for different values of IS, because in the case of teak and melina most wood from the first two thinnings will not be accepted at the sawmill simply because the diameter of the logs< 15cm (12.5cm without bark). Third and fourth thinning of teak can be sold commercially. Based on field observations and interviews with farmers and MINAE personnel it was estimated that with the third thinning about 8 (IS=low), 12 (IS=middle) and 16 m^3/ha (IS=high) wood can be obtained (gross volumes). It is not necessary to multiply the gross volumes obtained at the third thinning with the correction for wind, because only the lower parts of the stems will be commercially salable and these parts do not show wind damage. A correction factor has to be included to obtain wood that can be sold commercially at the sawmill. A pulgada tica is 0.0021 m^3 (see definition pulgada tica) so $1m^3 \approx 467$ pulgadas. For each m^3 accepted at the sawmill 350 pulgadas are paid (personal communication Valverde) so the correction factor for the third thinning is 350/467 ($\approx$0.75).

At well-managed melina plantations the lower part of the stems, cut at the second thinning may also have the desired diameter and can be sold. Since the sold volume will probably be very low it has not been taken into account in this study (lower price for melina and a lower wood quality than teak).
After including all the correction factors etc. this resulted in a commercial volume / ha for each plot visited in Guanacaste.

5.5 Suitability of major soil types

Finally for each mayor soil type (see chapter 2.3) in Guanacaste the suitability for teak and melina was estimated according to the field observations (see table 5.5). Some soil types were characterised as not suited because tree growth is impossible on these soils :

Table 5.5: Suitability of major soil groups for teak and melina

soil group	teak IS (low, middle, high)	melina IS (low, middle, high)
1	middle-high	middle-high
2	low-middle	middle
3	high	high
4	high	high
5	middle -	high
6	not suited	not suited
7	high	high
8	middle	middle
9	low-middle	low-middle
10	not suited	not suited
11	low	low
12	not suited	not suited
13	not suited	not suited
14	middle	middle
15	low	middle

Volume predictions for each major soil type in Guanacaste can be made with the help of the data given in annex 2.

6 Discussion

6.1 Environmental factors

Environmental factors that influence the IS (Chaves and Fonseca, 1991; Murillo and Valerio, 1991; Vásquez and Ugalde, 1995, field observations) are:
- climate (rainfall, wind, temperature)
- soil type
- slope

An overview of these factors, mentioned also earlier in this report, are briefly discussed below.

climate

- rainfall

Teak grows optimally under a yearly rainfall of 2500-3000mm although it tolerates a mean annual rainfall range of 1250-3500mm (Chaves and Fonseca, 1991). For melina optimum rainfall rates range between 2000-3000 mm and may vary from 1500-4000 mm (Murillo and Valerio, 1991).

Rainfall in the Guanacaste study area varies from about 1500/1600 mm in the area of Liberia and Cañas, to slightly over 2000 mm in the Hojancha/Nicoya area. Nevertheless no clear indications for growth differences due to rainfall were obtained in the field. However personal communication with MINAE-personnel learned that in Cañas and Liberia teak and melina are planted in bags instead of cuttings, because of climatic reasons. It is better to plant trees in bags because then trees are less susceptible to dry periods which occur regularly in the areas during July and August (shortly after planting). In Cañas and Liberia costs for planting are therefore higher (see 5.1 origin of plants), because of higher transportation costs and the higher price of the plant material. On the other hand maintenance costs in the first year are slightly lower because it is not necessary to remove the sprouts when trees are planted in bags.

- temperature

According to literature teak requires a climate with a distinct dry season of about 3 to 5 months with a mean annual temperature between 22°C and 28°C (Chaves and Fonseca, 1991). This was confirmed by MINAE-personnel (personal communication Valverde) who advise not to plant teak >500 m.a.s.l. If planted at higher altitudes temperature becomes sub-optimal. Optimum height for the growing of melina is below 700-800 m.a.s.l. and probably best below 500 m.a.s.l. The tree prefers temperatures between 24 °C- 35 °C (Murillo and Valerio, 1991).

- wind

Literature states that both teak and melina are susceptible to wind without specifying wind speed or during what period of the year (Vásquez and Ugalde, 1995). However, during the field work it was observed that wind damage to melina trees was more severe than for teak. Melina branches break off far more easily than teak branches, and causes irregular tree forms which have low sawmill outputs.

soil type

-soil depth
Teak prefers deep soils with a good drainage capacity. Although growth rates are lower on shallow soils, the tolerance of melina for shallow soils is higher than for teak because even though growth is lower than on good soils, after a reasonable short time period still reasonable yields can be obtained.

Mechanical land preparation may be necessary in areas which formerly were used for grazing to stimulate tree growth and to prevent water from running off (Vásquez and Ugalde, 1995). However, such land preparation is only possible on less steep terrain without stones. No plantations were found during field work where mechanical land preparation had been executed.

-fertility
Fertile soils with a pH that is neutral or acid are preferred by teak. Teak does not grow well on soils that have a low magnesium and calcium content. Also melina grows best on well drained, deep and fertile soils. However, its tolerance for shallow or less fertile soils is higher than for teak. A calcium content> 10meq per 100 ml is optimal for teak (Vásquez and Ugalde, 1995). For melina is stated that a Ca- content> 10 meq per 100 ml and a Mg-content of 6 meq per 100 ml are good for an optimal tree growth. No further estimation on fertility were done during field work.

-stoniness
During field work it was observed that stoniness on the surface negatively influences the diameter. Diameter of melina is smaller when a lot of stones are present on the surface (with a lot of stones a diameter of 22.8 cm was measured and without stones, on the same plantation, a diameter of 26.2 cm, see appendix 3).

slope

Due to the size and the shape of the leaves teak provokes concentration of rainwater and may cause severe soil erosion. It is therefore advisable to plant teak on slopes of less than 25 %. On steeper slopes and even on less sloping areas severe erosion was observed in the Guanacaste study area. Planting teak on slopes >25% is considered unsustainable in this study; which is in accordance with Vásquez and Ugalde, 1995. No erosion was observed on soils planted with melina, not even on slopes>30%. In literature no values for optimum slope are mentioned.
Observations in the field learned that diameters of trees are smaller if planted on steep slopes due to shallowness or an eroded A horizon.

6.2 Data on management

Data used for management were obtained from: Sistema de Manejo de Informacin sobre Recursos Arboreos (MIRA) from the MADELEÑA-project, CATIE, personal communication with Valverde (MINAE-Hojancha) and during field work. Data used for the number of man-days where obtained from the MIRA-system. It is unknown how working hours were measured for this database and some data seem questionable. For instance nutrient application in the first year of planting teak and melina takes 2.2 man-days (see appendix 4). This seems to be a very long time for applying only 98 kg of fertilizer. An other remark that can be made is whether man-days for the same activity are indeed varying each year as is stated by the MADELEÑA-project.

7 Conclusions

Mainly because a governement program to plant trees had been in place teak, melina and pochote have been established in the Guanacaste area at a rate of nearly 4000 ha per year.

Teak and melina are exotic species planted mainly planted in stumps because of logistic reasons. Teak and melina are accepted at the sawmill in Hojancha at diameters > 15cm. Pochote is only accepted when it has a diameter > 35 cm. Also the quality of the young wood is often too soft and not dense enough. Pochote plantations are not an economically viable option for farmers.

Melina is thinned three times during its 12 year growth period and teak four times during 20 years of growth. If a plantation is not thinned diameters will remain smaller and to a lesser extend height of the tree is influenced. The last thinning for melina and the last two thinnings for teak can be sold commercially.

Management data (appendix 4) for teak and melina are the same only the time period during which the activities have to be executed are different for the different soil types considered.

Suitability for teak and melina was estimated for major soil types in Gaunacaste. Most suited for both teak and melina are:
-thick loamy Andisols of a moderate soil fertility and well drained (soil 3)
-thick sandy Andisols of a high soil fertility and excessively drained (soil 4)
-well drained, deep Mollisols, loamy to light clayey; of a high soil fertility(soil 7).

Unsuited are:
-thick clay soils dominated by swelling and shrinking clays (Vertisols) of a high soil fertility (soil 6)
-swamp soils, having a high soil fertility but dominated by a poor drainage which hinders their agricultural use (soil 10)
-very shallow, loamy to clayey soils on rock of a variable soil fertility often stoney (soil 12)
-barren rock found in some small volcanic areas (soil 13)

Site index is influenced by environmental factors like climate, soil type and slope. Teak grows optimally under a yearly rainfall of 2500-3000mm. For melina this is between 2000-3000mm. Temperature requirements for teak are between 22 and 28°C and between 24-35°C for melina. Teak can best be grown at an altitude < 500 m.a.s.l. and melina at an altitude < 700-800 m.a.s.l. Melina is very susceptible to wind. Strong winds can cause irregular tree forms which can not be sold commercially. Each site index has its own specific production data.

8 Personal

My first visit to a tropical country. How would it be? What if I didn't like to be in such a country? That would mean the end of my study......

Costa Rica is a perfect country for a first experience in the tropics. It is different but not too different. It is impossible to dislike Costa Rica with its beautiful national parks, volcanos and beaches. People are very kind and they help you to make you feel at home.

During a language course in San Jose, the first three weeks, I learned to speak Spanish so I was capable to communicate with the local people. The first intention for my practical period was to do interviews. This was the main reason why I decided to follow a Spanish course. Although I didn't do any interviews I am very glad that I learned to speak Spanish.

My practical period consisted of field work and literature investigation. The first few weeks after the language course I did literature research. After that I did some field work which was necessary for creating a clear picture of the relationship soil type↔tree growth.. In the field a better overview could be obtained and furthermore a better insight in the way of thinking of a farmer. That is an aspect of the fieldwork that I like a lot. Guanacaste is also a very beautiful green place to do fieldwork.

No this visit to the tropics definitely does not mean the end of my study in fact I am more and more convinced that this study was a right choice.

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Appendixes

1. Indigenous and exotic tree species in Hojancha, Guanacaste

Indigenous tree species	
Carao	*Cassia grandis*
Cristóbal	*Platymiscium pinnatum*
Caoba	*Swietenia macrophilla*
Cedro dulce	*Cedrela odorata*
Genízaro	*Samanea saman*
Espavel	*Anacardium excelsum*
Cocobolo	*Dalbergia retusa*
Guanacaste	*Enterolobium cyclocarpum*
Pochote	*Bombacopsis quinatum*
Roble de sabana	*Tabebuia rosea*
Ceiba	*Ceiba pentandra*
Gallinazo	*Squizolobium parahybum*
Indio desnudo	*Bursera simarouba*
Jobo	*Spondias mombin*
Guácimo	*Guazuma ulmifolia*
Laurel	*Cordia alliodora*
Corozo- Palma Real	*Scheelea rostrata*
Madero negro	*Gliricidia sepium*
Guarumo	*Cecropia sp.*
Caliandra	*Calliandra calothyrsus*
Ojoche	*Brosimum costarricanum*
Gavilán	*Pentaclethra macroloba*
Guachipellin	*Diphysa robinoides*
Itabo	*Yucca elephantipes*
Targua	*Croton sp.*
Tempisque	*Mastichodendron capiriri*

Exotic tree species	
Teca	*Tectona grandis*
Melina	*Gmelina arborea*
Pino	*Pinus caribaea*
Eucalipto	*Eucalyptus deglupta*
Guayaquil	*Albizzia guachelepe*

2 Production data

Teak

The formula described in Chaves and Fonseca (1991) is used to determine a volume per tree from a height of 0.3 m above the soil until a minimum diameter of 8 cm without bark. For the determination of production data the volume per tree until a minimum diameter of 12.5 cm is needed. The formula is an overestimation of the volume.
For the correction of 0.02 m^3 /tree the formula of a cylinder was used:

$$V=\pi * r^2 * l$$

V=volume of a cylinder (m^3)
r =radius(m)
l =length(m)

The diameter of a tree diminishes about 2 cm each metre so for the length 2.25 m was taken ((12.5-8)/2) and for the radius 10.25 cm (average of 8 and 12.5).

The so-calculated volumes per tree were used to estimate the production, of a plantation on low, middle and high quality sites, as follows:

Estimation of production:
third thinning

At the third thinning lower parts of the stems can be sold. Based on field observations, interviews with farmers and MINAE-personnel the following estimations of the bruto volumes obtained at the third thinning are made:

IS	Volume (m^3/ha)
low	8
middle	12
high	16

Commercial volume at third thinning (m^3/ha):
Gross volumes*0.75

IS	vol/ha (m^3/ha)
low	6.0
middle	9.0
high	12.0

last thinning

classification	# trees	dbh (cm)	height (m)	vol / ha (m^3/ha)	# years
low	100	27.5	18	30.92	18
middle	125	30	20	38.87	15
high	150	30	22	50.67	13

Commercial volume last thinning (m^3 /ha)=
V*a*correction for wind

with:
V=volume without bark from a height of 0.3 m to a diameter (without bark) of 12.5 cm
a=0.85 (correction for imperfect tree shape) intended to include the often received "punishment" at the sawmill
correction for wind=reduction factor for different wind intensities, causing poor tree form

classification	wind=0 (0% red.)	wind=1 (15% red.)	wind=2 (25% red.)	wind=3 (40% red.)	wind=4 (60% red.)
low	26.3	22.4	19.7	15.8	10.5
middle	33.0	28.1	24.8	19.8	13.2
high	43.1	36.6	32.3	25.9	17.2

Estimation of production:
final cut

classification	# trees	dbh (cm)	height (m)	vol / ha (m^3/ha)	# years
low	180	40	22	152.80	24
middle	200	45	23.5	231.72	22
high	250	45	25	308.63	20

Commercial volume at final cut:

classification	wind=0 (0% red.)	wind=1 (15% red.)	wind=2 (25% red.)	wind=3 (40% red)	wind=4 (60% red.)
low	129.9	110.4	97.4	77.9	52.0
middle	197	167.5	147.8	118.2	78.8
high	262.3	223	196.7	157.4	104.9

Melina

The formula described in Murillo and Valerio (1991) is used to determine a volume per tree from a height of 0.3 m above the soil until a minimum diameter of 10 cm without bark. For the determination of production data the volume/tree until a minimum diameter of 12.5 cm is needed.

The correction of 0.01 m^3/tree for melina is obtained in the same way as for teak.

Estimation of production:
last thinning

classification	#trees	dbh (cm)	height (m)	vol/ha (m^3/ha)	#years
low	100	28	18	25.85	10
middle	125	30	23	45.14	9
high	150	32	26	67.6	8

Commercial volume at last thinning (m^3/ha)=
V*a*correction for wind

with:
V=volume without bark from a height of 0.3 m to a diameter (without bark) of 12.5 cm
a=0.85 (correction for bad tree shape)
correction for wind=reduction factor for different wind intensities

classification	wind=0 (0% red.)	wind=1 (15% red.)	wind=2 (25% red.)	wind=3 (40% red.)	wind=4 (60% red.)
low	22.0	18.7	16.5	13.2	8.8
middle	38.4	32.6	28.8	23.0	15.4
high	57.5	48.9	43.1	34.5	23

final cut

classification	#trees	dbh (cm)	height (m)	vol/ha (m^3/ha)	#years
low	180	40	24	130.84	16
middle	200	42	27	152.32	14
high	250	45	32	248.25	12

Commercial volume at final cut:

classification	wind=0 (0% red.)	wind=1 (15% red.)	wind=2 (25% red.)	wind=3 (40% red)	wind=4 (60% red.)
low	111.2	94.5	83.4	66.7	44.5
middle	129.5	110.1	97.1	77.7	51.8
high	211.0	179.4	158.3	126.6	84.4

Commercial volumes can be used to estimate *gross income* in colones (july 1996) of the last thinning and of the final cut:
1 m3 ≈ 467 pulgadas.
For each pulgada of teak 85 colones are paid, and for each pulgada of melina 22 colones are paid, both when the logs are delivered at the sawmill.
The exchange rate is 1$ ≈ 210 colones (end of july 1996).
For the third thinning of teak the commercial volume can be obtained in the same way.

Gross income (in colones july 1996) for teak and melina at last thinning:

classification	wind=0 (0% red.)	wind=1 (15% red.)	wind=2 (25% red.)	wind=3 (40% red)	wind=4 (60% red.)
low teak	1043978 ($49.7)	889168 ($42.3)	781992 ($37.2)	627181 ($29.9)	416798 ($19.8)
melina	226028 ($1076)	192124 ($915)	169521 ($807)	135617 ($646)	90411 ($431)
middle teak	1309935 ($6237)	1115430 ($5312)	984436 ($4687)	785961 ($3743)	523974 ($2495)
melina	394521 ($1879)	335960 ($1600)	295891 ($1409)	236302 ($1125)	158220 ($753)
high teak	1710855 ($8147)	1452837 ($6918)	1282149 ($6105)	1028101 ($4896)	682754 ($3251)
melina	590755 ($2813)	502399 ($2392)	442809 ($2109)	354453 ($1688)	236302 ($1125)

Gross income at final cut:

classification	wind=0 (0% red.)	wind=1 (15% red.)	wind=2 (25% red.)	wind=3 (40% red)	wind=4 (60% red.)
low teak	5156381 ($24554)	4382328 ($20868)	3866293 ($18411)	3092241 ($14725)	2064140 ($9829)
melina	1142469 ($5440)	970893 ($4623)	856852 ($4080)	685276 ($3263)	457193 ($2177)
middle teak	7819915 ($37238)	6648913 ($31661)	5866921 ($27938)	4691949 ($22343)	3127966 ($14895)
melina	1330483 ($6336)	1131167 ($5387)	997605 ($4751)	798290 ($3081)	532193 ($2534)
high teak	10411999 ($49581)	8851985 ($42152)	7808007 ($37181)	6247993 ($29752)	4164006 ($19829)
melina	2167814 ($10323)	1843156 ($8777)	1626374 ($7745)	1300688 ($6194)	867126 ($4129)

3 Field data

Teak and melina in Guanacaste

number	specie	location	coordinates x	coordinates y	year of planting	dap (cm)	height (m)	IMA dap (cm/year)	IMA alt (m/year)
I	teak	CACH,Hojancha	382,600	226.6550	1986	22.7	15	2.3	1.5
1(003J)	teak	Hojancha	383,000	228,850	1991	10.5*	8.5*	2.7	2.2
2(219L)	teak	Hojancha	385,425	229,650	1989	15.4*	13.0*	3.5	2.6
3(001J)	teak	road Jicaral	395,450	230,700	1992	10.0*	10.2*	3.5	3.6
5	teak	road B.Honda	388,150	235,600	1989				
6	teak	Q.Honda (gringo)	393,700	241,350	1982	27.6	22-24	2.0	1.6
7	teak	San Miguel	377,500	218,600	1980	22.2	22	1.4	1.4
8	teak	Carillo	376,450	206,850	1988	27.4	22	3.4	2.8
9	teak	B.Puerto Carillo	373,850	207,700	1987	19.4	16	2.2	1.8
10 (010J)	teak	S.Maria	378,850	212,600	1989	18.3*	16.5*	3.1	2.7
15(002J)	teak	Mansion	383,850	231,700	1992	12.3*	11.3*	4.5	4.1
18	teak	H.Tenorio,Cañas	415,200	285,800	1992	6.5	6	1.6	1.5
20	teak	road to ferry Hojancha				29.8	21-22		
22a	teak	H.Guachipelin	386,000	304,400	1988	17.6	12.5	2.2	1.6
22b	teak	H.Guachipelin	386,200	304,400	1988	18.4	12.5	2.3	1.6
23	teak	H.Pelon de la Bajura	379,700	278,400	1988	17.2	14	2.2	1.8
24	teak	H.Pelon de la Bajura	379,600	278,800	1988	15.8	12	2.0	1.5
25	teak	H.Pelon de la Bajura	382,500	275,100	1988	22.7	15-17	2.8	2
26	teak	H.Pelon de la Bajura	383,500	276,700	1987	25.3	nm	2.8	nm
28	teak	Terreros,Liberia	382,200	283,400	1993	nr	nr	nr	nr
31	teak	Copaguan.,Belen	362,300	263,800		33	20		
33	teak	F.Huacas,Interam.	382,600	284,100	1985	23.9	16.5	2.2	1.5
36	teak	F.Ensayo,C.Dulces	372,800	300,550	1982	27.7	22	2.0	1.6
II	melina	Hojancha	381,200	225,700	1986	33.2	24-25	3.3	2.5
4	melina	B.Honda	387,850	236,000	1988				
11	melina	S.Maria	379,700	211,750	1988	22.3	28	2.8	3.5
12(025J)	melina	Hojancha,CACH	382,700	222,750	1985	25.4*	21.3*	2.6	2.1
13(022J)	melina	Hojancha	382,800	222,550	1988	26.3*	17.1*	3.8	2.4
14	melina	Hojancha	381,500	226,375	1991	13.0	10-11	2.6	2.1
16(027J)	melina	Matina de Mansion	385,900	229,425	1990	21.1*	17.7*	3.4	2.8
17	melina	Montezuma,Cañas	417,400	291,400	1988	30.9	17	3.4	1.8
19	melina	Hacienda la Roca	415,300	259,400	1984	38.1	25-26	3.2	2.1
21	melina	Guachipelin, Liberia	383,800	301,000	1989	25.2	16.5	3.6	2.4
27	melina	Terreros,Liberia	381,700	283,400	1993	14.8	9-10	4.9	3.2
29	melina	Finca La Flor	368,700	292,800	1986	25.3	20	2.5	2
30	melina	Playa Portrero	345,000	274,650		29.6	26		
32	melina	F.Huacas,Interam.	382,750	284,200	1986	32.7	18	3.3	1.8
34	melina	Rincon de la Vieja	386,100	301,800	1988	nm	14	nm	1.75
35a	melina	Rincon de la Vieja	385,550	303,200	1988	22.8	14	2.8	1.8
35b	melina	Rincon de la Vieja	385,350	303,300	1988	26.2	18	3.3	2.3

[a] correction wind:

0= no effect	(0%volume reduction)
1= slight effects	(15%volume reduction)
2= moderate effects	(25%volume reduction)
3= strong effects	(40%volume reduction)
4= very strong effects	(60%volume reduction)

[b] according to Vazquez and Ugalde

* data from 1995

nr=not relevant   nm=not measured

slope (%)	management, remarks	volume (m^3/tree)	wind-correction[a]	IS	classification IS[b]
15	2 thinnings	0.19	0	15	low
5	1[e] thinning(50%)	nr	0	13.8	low
12	thinning is delayed	0.05	0	16.1	low
5	1[e] thinning(50%)	nr	0	21.6	middle
8-10	2 thinnings,bad shape,needs thinning		0		
4	good wood quality,too much wind, needs pruning	0.41	1	21	middle
20-30	poor management, not enough thinnings	0.25	0	19.5	middle
4	2 thinnings, needs to be pruned again	0.37	0	23.9	high
40	poor management, no thinnings	0.12	0	16.6	low
20	2 thinnings,insects in tree	0.11	0	20.4	middle
3	teak grows good, needs thinnings	nr	0	23.9	high
4	needs cleaning	nr	3	9.7	low
1	not bad,thinnings,trees are not straight	0.44	2		
7	no optimal form of trees, no thinnings	0.07	3	13.5	low
5-10	no thinnings, better shape than 22a	0.07	3	13.5	low
6	no thinnings or pruning	0.07	2	15.2	low
10	no thinnings or pruning	0.04	2	13	low
4	no thinnings or pruning	0.20	1	17.3	low
8	no thinnings or pruning		1		
2	teak died, bad site	nr	2	nr	nr
2	no thinnings or pruning	0.49	1/2		
2	little thinning, no pruning	0.22	2	16	low
1	almost no thinnings, no pruning	0.39	2	20	middle
0-10	good management	0.45	0	24.5	middle
4	melina with a good form		0		
10-15	poor management, too little thinnings	0.25	0	30.3	high
5-20	3 thinnings, but too late	0.24	0	21.3	middle
40	4 thinnings	0.21	0	20.4	middle
20	poor management,1 thinning, needs pruning	nr	0	16.0	low
10	no management,trees aren't growing straight	0.15	0	24.2	middle
4	poor management, strong windeffect	0.29	4	17.9	low
5	sub-optimal management,problems because of wind	0.61	2	23.7	middle
1	uniform height, needs thinning and pruning	0.19	3	19.7	middle
2	no management	nr	2	19.3	low
2	no management	0.23	1	20	middle
15	thinnings much too late	0.40	0		
2	bad shape (wind effect), poor thinning and pruning	0.34	2/3	18	low
10	no management	nr	3	15.9	low
3	no thinnings or pruning	0.14	2/3	15.9	low
2	no thinnings or pruning	0.23	2/3	20	middle

site	main soil	depth A-B-CB	texture A	texture B	stoniness in %	depth to mottling	parent material
I-1	2	30-60-100	Si-CL	C	2	_	
I-2	2	15-50-70	C	C	2	_	
II	9	15-90	C	C	0	35	
1-1	1	30-80-100	CL	C	2	_	
1-2	2	5-60	CL	C	50	_	
2	2	25-60-80	CL	C	5	70	
3	1	25-75-100	C	C	15	_	
4	9	30-50-80	CL	C	20	35	
5	no data						
6	7/9	10-50-100	C	CL	0	100	
7	2	20-70-90	CL	C	20	80	
8	7	20-100	CL	CL	5	_	
9	2	15-45-80	CL	C	20	_	
10	1/2	20-80-100	CL	C	10	_	
11	1	25-80-110	CL	C	5	_	
12	1	30-75-90	CL	C	5	_	
13	1/2	30-60-?	CL	SiCL	2	_	
14a	2	15-60-80	CL	CL	30	_	
14b	2	5-70-?	CL	SL	25	_	
15	1/7	30-120	CL	CL	0	100	
16	2	25-60-85	C	C	20	50	
17	1	25-90	SiCL	SiCL	0	_	
18	2	25-50-90	SiCL	C	30	40	
19	2	20-50+	SiCL	C	30	_	
20	7/9	35-90-110	L	CL	0	60	
21 [illegible]	8	50-70-90	CL	SiCL	0	80	
22	2	30-60-110	SiCL	CL	25	_	
23	8/9	30-45-80	SiCL	CL	10	45	
24	8	20-45-60	CL	CL	5	_	
25	8	50-100-12	CL	CL	5	100	
26	8	30-70-100	CL	L	10	_	
27	8	25-70-80	Si	C	0	_	
28	9/6	30-60	SiCL	CL	0	20	
29	7/8	25-100-12	SiL	C	0	100	
30	1	25-90-100	CL	C	5	_	
31	1/2	25-60-110	CL	C	5	_	
32	8/9	20-50	CL	CL	0	30	
33	8/9	20-40-60	CL	CL	0	35	
34	2	30-40-?	CL	C	50	_	
35a	7/8	40-120	CL	CL	10	_	
35b	8	20-60-?	CL	CL	50	_	
36	7/8	30-110-12	L	L-CL	0	110	

*topsoil seems to have a poor internal drainage

4 Management activities
(Source: Sistema de Manejo de Información sobre Recursos Arboreos (MIRA) del Proyecto MADELEÑA del CATIE, november 1995 and personal communication with Valverde)

Prices, quantities and units used for management data (july 1996)

	price in ¢:	price in $:
-cutting teak	¢20/stump	$0.10
-cutting melina	¢15/stump	$0.075
-fertilizer (10-30-10)	¢3625/quintal (46 kg)	$17.3
-Gramoxone	¢3950/galon (3.78 l)	$18.8
-cutting trees	¢2 per pulgada tica(includes labour and material)	$0.010
-loading	¢3-4 per pulgada tica(includes labour and material)	$0.014-0.019
transport		
-near Hojancha	¢5 per pulgada tica (includes labour and material)	$0.024
-Santa Marta	¢10 per pulgada tica (includes labour and material)	$0.048

first year in the planting of teak and melina (for IS=high, middle, low)

activity	*man-day* (6 hours)	*materials*	*time*	*costs (¢)* (labour)
-field preparation	5.98	machete,herbicides, chainsaw	April-May	6775
-measuring planting distance	1.96		May	2221
-weeding around tree	4.92	weeding knife, sickle, machete	May-June	5574
-herbicide application	1.16	3.7 litre Gramoxone	May-June	4311
-holing	3.72	spade	June	4215
-transporting trees	1.60	pick-up	June	1813
-planting	4.26	stump teak	15 May-June	27047
		stump melina		21492
-1^e nutrient application	2.20	98 kg (10-30-10)	end of July	6511
-replanting	1.26	197 plants (teak)	July	5368
		(melina)		4383
-weeding around tree	4.94	spade,machete	Aug	5597
-cleaning plantation	7.60	machete	Sept-Okt	8635
-2^e nutrient application	2.20	98 kg(10-30-10)	end September	6511
-maintenance	1.88	machete	end September	2130

second year in the planting of melina (IS=low, IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-pruning	2.67	saw, machete	March-April (height 2-3 m)	3025
-weeding around tree	11.36	spade, machete	August	12871
-cleaning plantation	9.88	machete	Sept-Okt	11194
-maintenance	2.5	machete	end September	2833
-removing shoots	2	machete	January	2266

third year melina (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-cleaning plantation	7.87	machete	Sept-Okt	8917
-herbicide application	1.40	3.0 liter Gramoxone	end September	4016
-weeding around tree	12.40	spade, machete	July	14049
-maintenance	2.63	machete	end September	2980

fourth year melina (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-cleaning plantation	10.8	machete	Sept-Okt	12236
-maintenance	1.88	machete	end September	2130
-thinning	3	machete,saw	March	3399
-pruning	5	machete, saw	March	5665

year 5-10/ year 12-15 (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance (every year)	1.88	machete	end September	2130 (per year)
-thinning (year 7)	3.0	machete, saw, spade	March	3399
-pruning (year 8)	5.0	saw, machete	March	5665
-cleaning plantation (year 7)	10.8	machete	Sept-Okt	12236

year 11 (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
last thinning:				
-cutting				20548
-loading				41096
-transport				51370

year 16 (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
final cut:				
-cutting				103861
-loading				207722
-transport				259652

year 3 in the growth of melina (IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-cleaning plantation	7.87	machete	Sept-Okt	8917
-herbicide application	1.40	3.0 liter Gramoxone	end September	4016
-weeding around tree	12.40	spade, machete	July	14049
-maintenance	2.63	machete	end September	2980
-thinning	3	machete,saw	March	3399
-pruning	5	machete	March	5665

year 4-8/ 10-13 (IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance (every year)	1.88	machete	end September	2130 (per year)
-thinning (year 6)	3.0	machete, saw, spade	March	3399
-pruning (year 7)	5.0	saw, machete	March	5665
-cleaning plantation (year 6)	10.8	machete	Sept-Okt	12236

year 9 (IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
last thinning:				
-cutting				35866
-loading				71731
-transport				89664

year 14 (IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
final cut:				
-cutting				120953
-loading				241906
-transport				302383

year 2 in the planting of melina (IS=high)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-pruning	2.67	saw, machete	March-April (height 2-3 m)	3025
-weeding around tree	11.36	spade, machete	August	12871
-cleaning plantation	9.88	machete	Sept-Okt	11194
-maintenance	2.5	machete	end September	2833
-removing shoots	2	machete	January	2266
-thinning	3	machete,saw	March	3399

year 3-7/9-11 (IS=high)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance (every year)	1.88	machete	end September	2130 (per year)
-thinning (year 5)	3.0	machete, saw, spade	March	3399
-pruning (year 6)	5.0	saw, machete	March	5665
-cleaning plantation (year 5)	10.8	machete	Sept-Okt	12236

year 8 (IS=high)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
last thinning:				
-cutting				53705
-loading				107410
-transport				134263

year 12 (IS=high)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
final cut:				
-cutting				197074
-loading				394148
-transport				492685

year 2 in the planting of teak (IS=low, middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-pruning	2.67	saw, machete	March-April (height 2-3 m)	3025
-weeding around tree	11.36	spade, machete	August	12871
-cleaning plantation	9.88	machete	Sept-Okt	11194
-maintenance	2.5	machete	end September	2833
-removing shoots	2	machete	January	2266

year 3 (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-cleaning plantation	7.87	machete	Sept-Okt	8917
-herbicide application	1.40	3.0 liter Gramoxone	end September	4016
-weeding around tree	12.40	spade, machete	July	14049
-maintenance	2.63	machete	end September	2980

year 4 (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-cleaning plantation	10.8	machete	Sept-Okt	12236
-maintenance	1.88	machete	end September	2130
-thinning	3	machete,saw	March	3399
-pruning	5	machete	March	5665

year 5-11/ year 13-17/year 19-23 (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance (every year)	1.88	machete	end September	2130 (per year)
-thinning (year 7)	3.0	machete, saw, spade	March	3399
-pruning (year 8)	5.0	saw, machete	March	5665
-cleaning plantation (year 7)	10.8	machete	Sept-Okt	12236

year 12 (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
third thinning:				
-cutting				5604
-loading				11208
-transport				14010

year 18 (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
last thinning:				
-cutting				24564
-loading				49128
-transport				61411

year 24 (IS=low)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
final cut:				
-cutting				121327
-loading				242653
-transport				303317

year 3 (IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-cleaning plantation	7.87	machete	Sept-Okt	8917
-herbicide application	1.40	3.0 liter Gramoxone	end September	4016
-weeding around tree	12.40	spade, machete	July	14049
-maintenance	2.63	machete	end September	2980
-thinning	3	machete.saw	March	3399
-pruning	5	machete	March	5665

year 4-9/11-14/16-21 (IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance (every year)	1.88	machete	end September	2130 (per year)
-thinning (year 6)	3.0	machete, saw, spade	March	3399
-pruning (year 7)	5.0	saw, machete	March	5665
-cleaning plantation (year 6)	10.8	machete	Sept-Okt	12236

year 10 (IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
third thinning:				
-cutting				8406
-loading				16812
-transport				21015

year 15 (IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
last thinning:				
-cutting				30822
-loading				61644
-transport				77055

year 22 (IS=middle)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
final cut:				
-cutting				183998
-loading				367996
-transport				459995

year 2 (IS=high)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-pruning	2.67	saw, machete	March-April (height 2-3 m)	3025
-weeding around tree	11.36	spade, machete	August	12871
-cleaning plantation	9.88	machete	Sept-Okt	11194
-maintenance	2.5	machete	end September	2833
-removing shoots	2	machete	January	2266
-thinning	3	machete,saw	March	3399

year 3-7/9-12/14-19 (IS=high)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance (every year)	1.88	machete	end September	2130 (per year)
-thinning (year 5)	3.0	machete, saw, spade	March	3399
-pruning (year 6)	5.0	saw, machete	March	5665
-cleaning plantation (year 5)	10.8	machete	Sept-Okt	12236

year 8 (IS=high)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
third thinning:				
-cutting				11208
-loading				22416
-transport				28020

year 12 (IS=high)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
last thinning:				
-cutting				40255
-loading				80511
-transport				100638

year 20 (IS=high)

activity	*man-day*	*materials*	*time*	*costs (¢)*
-maintenance	1.88	machete	end September	2130
final cut:				
-cutting				244988
-loading				489976
-transport				612471