TECHNICAL PROTOCOL FOR THE CULTIVATION OF TEAK (*Tectona grandis* Linn f.) PLANTATIONS

In response to requirements of TEAK HOLZ INTERNATIONAL

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THE SPECIES

The species of concern is teak. This is understood to mean *Tectona grandis* (Linn. f.) of the *Labiatae* family.

The excellent properties and versatile nature of teak (Tectona grandis L. f.) timber and its eminent suitability for an array of uses is well documented. The potential for growing and managing teak in different ecological zones and under different situations (objectives) is being increasingly recognized, leading to intensive domestication and cultivation of the species in countries/regions beyond its natural habitat. Despite the value of teak timber and its increasing demand, its full potential for providing direct revenue as well as value-added down-stream processing and for contributing to the national income has not been fully utilized.

Teak is the world's most cultivated high-grade tropical heartwood, covering approximately 6.0 million hectares worldwide. Of this net area of teak plantations, about 94% are in Tropical Asia, with India (44%) and Indonesia (31%) contributing the bulk of the resource. Other countries of the region contribute significantly with 17% in total (Thailand, Myanmar, Bangladesh, Sri Lanka). About 4.5% of the teak plantations are in Tropical Africa and the rest are in Tropical America, mostly in Costa Rica and Trinidad and Tobago. The Asian Pacific region (5.3 million hectares) have been managed under 35 to 80-year rotations , yielding annual productivities of 5 to 20 m3 ha-1 year-1, while teak plantations in Africa (310,000 hectares) are harvested at shorter rotations of 20 years, yielding between 4 and 13 m^3/ha/year. Central and South American teak plantations (205,000 ha) are being managed under similar short rotation scenarios of 20-25 years, however they have shown higher yields of up to 40 m3 ha-1 year-1 (average of 20-25 m^3/ha/year on medium and high quality sites).

Teak has been grown under plantation conditions for 150 years. In the last decade, its high value as timber of excellent appearance and mechanical resistance, and the appearance of strong markets for teak products which parallels an increasingly declining stock of natural stands, have attracted particular attention to the potential of teak plantations as a high return investment possibility.

T. grandis was introduced in Costa Rica and other countries in Central America between 1927 and 1929. Until the year 2000, approximately 223,000 ha of T. grandis plantations were established in this region. In the past 10 years, Costa Rica has steadily increased the annual plantation rate of several species to an approximate total of 11,000 hectares per year. In 2000, the total area of plantations reached 178,000 hectares, of which 30,300 ha (17.0%) corresponded to T. grandis.

GENERAL OPERATIONS TO BE CARRIED OUT ANNUALLY

The operations include:

- Carry out phytosanitary inspection according to plan;
- Check for erosion and take remedial measures where necessary;
- Carry out fire protection measures where necessary;
- Security measures to be checked and reported on;
- Ensure that infrastructure (all roads, bridges, culverts, drainage channels etc) are properly maintained.
- Damage control. If deviations occur, analysis will be done and corrective actions will be taken.
- Measurements of sample plots starting from year 2.

PARTICULAR OPERATIONS TO BE CARRIED OUT FROM YEAR ONE TO FOUR

- Carry out any other additional operation (e.g. unwanted side branches will be removed in accordance with the overall pruning strategy according to the management plan) that is required in order to ensure that the teak plantations become successfully established;
- Bending trees; tying bended trees.

REGULAR OPERATIONS TO BE CARRIED OUT THROUGH A ROTATION CYCLE

YEAR 1

Year I is understood to mean the year of planting:

ESTABLISHMENT

Area clearly identified as suitable for teak as follows:

- Ensure that areas of steep slope (> 60%) are not planted;
- Hydrology survey carried out in line with criteria and hydrological plan drawn up; a map (scale 1:50,000 or other appropriate scale) will be drawn up showing major rivers, waterways, natural and or artificial drainage. If an artificial drainage network has to be constructed, it will include primary, secondary and superficial drains. In this case, the design of the network, including drainage depths, will be drawn up by a competent professional consultant or consultant firm.

- Soil survey, in line with overall criteria. The sampling intensity will be evaluated according to soil variability and size of management units. The interpretation of the soil survey is a complex task.
- Ensure that all areas considered for trust inclusion carry no legal impediment; that there is no conflict of ownership of land or resources; that area divisions with neighbors are clear and that area and/or resource divisions between investors are clear.
- Evidence provided that best planting material available is being planted. Certified seed, certified clones or other certified material which is known to be of good genetic composition and appropriate for the areas in question must be used as the base for all planting material. Certification is also applicable for nurseries. Certification must be recognized by the reputable scientific institutions.
- Ensure that new maps are compiled where necessary according to the general criteria (legal, soil, topography, hydrology etc.); agreement must be reached by all parties on the basis for compiling maps and information to be contained and scale used. The Geographical Information System may be acceptable as a base.
- Delimit all areas that are not to be planted; ensure that the proportion of teak in the landscape conforms to national and international standards; maps will show all planted areas, biological corridors, protected areas, wetlands and forest and any other classification deemed necessary. The scale of all maps will be by mutual agreement.
- Compile a fire plan; the borders of the planted areas will be protected by roads and tilled corridors, approximately 5 m wide, that will be bare of combustible and hazardous vegetation and other material; they may also be planted with a fire retardant species. Internal roads and tilled strips of similar width will operate as fire breaks. In areas of difficult access to machinery, a corridor of 5 m bordering the plantation will be treated with herbicide and/or the vegetation removed mechanically. The purpose of this operation is to produce a bare soil belt to act as a natural barrier against fire, though this may cause erosion. Alternatively, a fire retardant species may be planted.
- Ensure that adequate security is provided each year to protect the plantations against unwanted intrusions of man and animals. Experience has shown that the presence of a worker's family in the land has been the most effective way to protect the trees and plantings. Most farms have houses in key areas of the land and this practice, or an alternative arrangement where no worker is present, must be put into operation;
- Compile a management plan for the area to be planted. A preliminary management plan is initially written for all projects and supplemented later on.
- The management plan should include a well devised pruning strategy that takes into account quality of wood produce as well as economic considerations.
- The management plan should include a phytosanitary plan. Throughout the life of the plantation, all pathogen and insect attacks will be described and the damage quantified. A lodge/record book will be kept. Arrangements will be drawn up with a relevant scientific institution so that regular inspection visits to the plantations are carried out by competent professionals, yearly in the rainy season on a statistical base. Staff will be trained to carry out regular phytosanitary inspections and report results to management. Staff will also be required to report on all problems affecting trees (wind throw, lightning, etc.). Problems must be acted upon immediately and regular reports will be produced and made available to all concerned parties.

- The management plan should include an erosion control plan. If erosion is discovered, remedial action may be taken by reducing the density of the stand and maintaining a ground cover of non-competitive species in the affected areas. Roads must be designed with appropriate slope, and water runoff must be deviated from the roads by constructing ditches as appropriate and in accordance with advice from a qualified engineer and hydrology expert.
- Prepare adequate drainage to conform with the hydrological plan; drains must be in place ahead of planting and not interfere with this operation; some secondary and superficial drains can be constructed at the same time as planting. Drainage after planting may only be carried out if no damage to the trees results (e.g. where superficial drains are developed and/or where planting distances are sufficiently wide to allow machinery to move easily and work without harming the planted trees).
- Prepare ground, including removal of existing bush and other unwanted vegetation.
- Control weeds (especially grass) before planting, either by mechanical means or through herbicides that are considered acceptable by internationally recognized certifying bodies and will not affect the teak itself.
- Ensure that an adequate road network (including culverts, bridges and other necessary constructions) are in place to facilitate all planting operations. Principal and secondary access roads must be planned for in the initial layout of the compartment or field system. Their construction must be designed to coincide with and support the planting and management of the forest blocks. The goal is to divide the land into operating units of approximate size for future management and harvesting of the stands.
- Protect against grazing animals by ensuring an adequate fencing system is established around all new proposed plantations. Protection of teak against grazing animals should be ensured as young shoots, although not often browsed are readily broken or trampled. Adequate fencing or other protection systems must be established in good time in order to protect all planted areas.
- Apply fertilizer where deemed necessary according to the soil analysis (However, fertilization should never be applied before removal of competing weeds because it can exacerbate the problem. There are three major constraints to the use of fertilizers: environmental pressure, high costs, and lack of knowledge about effectiveness. There is a general preference for little or no fertilizer in certification systems unless essential. It is necessary, therefore, to justify the use of fertilizers.
- Carry out planting at recommended plant spacing.
- Ensure that teak is planted sufficiently early in the growing season to enable the plants to reach their full growing potential in the first year. Early planting is essential in terms of the growth of the trees and in relation to the reduction of maintenance costs during the planting and following years. Planting should start at the beginning of the rainy season or allow at least 4 months of rains (in line with normal rainfall figures).
- Compile a detailed map of the area planted. A map must show major details of the area actually planted showing roads, bridges, biological corridors, forest, rivers and other relevant features.
- Carry out fire protection measures where and when necessary according to the fire plan (above), but no later than the official dry season starts.

MAINTENANCE

Maintenance to be carried out in Year 1 includes:

- Post planting weeding. Control of competing weeds, especially grass and climbers, must be carried out as many times as necessary in Year 1. Mechanical and or herbicidal weed control may be carried out every 8 to 12 weeks during the rainy season, depending on the vegetation present and its growth. Some grasses need to be weeded every 8 weeks during the first growing season. On the other hand, chemical control may be effective for a period of 3 months. A mixture of chemical and mechanical weeding can be implemented, seeking the best balance for the trees and the environment.
- Cutting basal sprouts; carry out 1 to 3 operations to remove recurrent basal sprouts and ensure one dominant leader. Competing leaders should be removed at appropriate intervals during the first year. Some leaders may also have to be cut during the second year. This operation can be carried out during weeding.
- Carry out a survival count with respect to mortality and replanting where necessary.

YEAR 2

Operations to be carried out in Year 2 include:

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- Effective weeding of all plantations (up to an average of 3 times in year 2);
- Pruning - cut competing leaders, basal sprouts and unwanted side branches on young plants where necessary.
- Arrange a random network of growth sample plots throughout the area.
- Construct a computer data-base for the storage and analysis of plot information as per general criteria.
- Sanitary thinning will be done if necessary.
- Maintenance and repair of drainages.

YEAR 3

Operations to be carried out in Year 3 include:

- Carry out effective weeding of all plantations; (up to an average of 1 time in year 3).
- Prune unwanted side branches where necessary.
- **Carry out a sanitary thinning**.

YEAR 4

Operations to be carried out in Year 4 include:

- Pruning up to a final height of 7,0 m.

YEAR 5

Operations to be carried out in Year 5 include:

- **Carry out the pre-commercial thinning**.

YEAR 6, 7 and 8

Operations to be carried out in Years 6, 7, and 8 include:

- Regular maintenance only.

YEAR 8

- **Carry out the first commercial thinning**.

YEAR 9 to 14

Operations to be carried out in Year 11 include:

- Regular maintenance only.

YEAR 15

Operations to be carried out in Year 15 include:

- **Carry out the final harvest**.

SITE SUITABILIY

CLIMATE

Climatic type/types (macro- and micro-climates) described to ensure that it is site class 1 to 1+ for teak

Particular emphasis must be placed on total annual precipitation because teak growth rates are highly correlated with availability of an adequate supply of water throughout the growing season.

Teak grows well in a warm tropical climate in which there is a dry season of about 3-5 months, rainfall of about 1500 to 2000 mm or more per year and a mean annual temperature of around 20-30 C.

A "dry month" is defined as that in which 100 mm or less of precipitation are accumulated or when total evapo-transpiration for that month exceeds precipitation generating a soil water deficit. In recent years teak growers have been moving into areas with little or no dry season. To date many of these plantations have demonstrated rapid growth and, under good management, have not exhibited major problems. However, it is not known if problems will manifest themselves later in the rotation.

Where annual precipitation is less than 1500 mm and irrigation is required to bring the site class to 1 to 1+, a specialist advice is required.

RIVER RISK AND DRAINAGE

River risks
In case there could be a risk caused by a river regarding erosion and/or flooding for the investor plots, a hydrology survey by a qualified specialist is required to quantify this risk. Where risks are of an acceptable level, measures indicated by the survey must be executed accordingly before investor plots can be approved in the areas concerned.

Drainage
Ensure that, where necessary according to the soil specialist, a drainage survey is carried out by a professional. Where risks are of an acceptable level, measures indicated by the survey must be executed accordingly before investor plots can be approved in the areas concerned.

Soils that exhibit surface water-logging should, under no circumstances, be planted unless artificial drainage can alleviate the problem.

SLOPE

Based on the soil analysis typically carried out on any farm, the soil specialist will present a comment on site erodability.
Areas up to 40% slope can be planted; sites from 40% up to 60% have to be analyzed for suitability or take into account the erodabilty comment. All sites with more than 40 slope and under 60% that are susceptible to erosion require an erosion plan that is agreed upon by all parties before site selection. It is not allowed to plant Teak on slopes over 60% unless sound evidence can be provided and accepted by all parties. When an erosion plan is needed, the following points should be considered:

- Protect against fire.
- Encourage the understory.
- Increase initial plant espacement.
- Develop mixtures.

SOIL FERTILITY

Soils should be avoided when:

1. Avoid soils with an effective soil depth of less than 60 cm. If limitations are found in the 60cm of effective soil depth then the soil cannot be classified as Class I. Some of the typical limitations are: bad drainage by endosaturation caused by a high water table or episaturation caused by a hanging water table; evidence of bad drainage are glazed profiles with more than 35% of redox mottling or evidence of redoximorphic characteristics such as Mn concretions; profiles with very fine clay textures (more than 60% of clay), that do not present structure; layers or profiles that are massive or without structure and with very low porosity; layers in form of a stone bed, compacted or impermeable gravel or sand profiles; very altered profiles or leached ones, with the presence of "plintita" and profiles with mix patterns of red, yellow and grey colors that evidence the process of plintita forming or development and B profiles with a lower CIC than 12 cmol/Kg; parental material or rock that is exposed among others. There are obvious exceptions such as when the actual bad drainage situation can be solved or corrected by doing professionally design of a drainage net or channels, and so if the drainage can be corrected then the soil can be classified as Class I.

2. Avoid soils with low fertility (sum of the bases lower than 10 cmol/Kg), and/or a CIC lower than 12 cmol/Kg, in the first 40 cm of depth. The CIC should be taken into account when the soils present or have a Bt profile or a profile taxonomically named as "argilic". The soils that present a low sum of the bases but with a CIC that is medium or high can be corrected by fertilization.

3. Avoid soils with an acidity saturation percentage higher than 30%, exchangeable acidity higher than 1.5 cmol/Kg and pH lower than 5 in the first 40 cm. In the case of soils that have a CIC higher than 12 cmol/Kg, the levels of acidity saturation and exchangeable acidity can be lowered by liming practices.

In case fertilization and/or liming is applied, an application plan must be provided. Volume and frequency should be included in the plan, as well as a monitoring system.

PROCEDURE FOR FARM SELECTION

In regions or areas where correlations were already presented and analyzed, the methodology for farm approval is the presentation of the farm selection. Following the methodology for the farm selection is presented:
Soil survey, in line with overall criteria, will be checked or undertaken by a competent and independent scientific institution that has experience with teak or can access the necessary information about the species requirements. The sampling intensity will be evaluated according to soil variability and size of management units. The interpretation of the soil survey is a complex task. Most attention should be focused on drainage, soil aeration and texture and structure.

1. A grid of 1000 m x 1000 m will be used throughout each property. The grid orientation and density should consider the topography and other characteristics of the land and should be laid down in such a way that all areas and site types are included. For this reason an initial inspection of the entire area is necessary. Intensity could be lowered when farm is homogeneous and should be increased when farm is heterogeneous.
2. First sampling point should be randomly selected for statistical independence in the process.
3. Initial sampling will be done with the soil borer to a depth of 100 cm at the intersection of grid lines. In sites that are very heterogeneous, extra borings may be necessary. In sites that are very homogeneous, not every grid intersection will have to be examined. Judgment must be made in the field by a competent technician and a clear description of any deviations from a total grid analysis must be explained. At each intersection, any soil limiting factors will be described (e.g. poor soil depth, impeded drainage, propensity to flooding, high stone contact, poor rooting, limiting texture, slope limitations, etc.). If the soil is appropriate for teak this will be noted and the soil classified. The boundary between appropriate and in-appropriate soils has to be defined.
4. The sampling grid will be drawn on a map reflecting the principal soil types of the property. General landscape marks, rivers, roads approximations need to be in this map.
5. The number of soil pits to be dug will depend on the number of soil types present in the property. All potential teak sites must contain at least one pit. Location of the pits will be at random within a particular soil type and on the grid intersections, or on extra grid points that were done out of the typical 1000 X 1000 m grid. At least one soil pit every 50 hectares is required.
6. In cases where the soil structure cannot be clearly described using the soil auger, micro soil pits must be carried out (50x50x50cm)

7. A complete profile description (taxonomy) must be carried out for the first 100 cm in each soil pit. The following soil variables will be described for each sampling unit:
    a. Soil type (including description of horizons);
    b. Depth (cm);
    c. Drainage;
    d. Porosity;
    e. Friability;
    f. Texture;
    g. Stone content;
    h. Water table depth;
    i. Rooting depth;
    j. Other soil characteristics as desired.
8. A full laboratory chemical analysis in each pit must be completed (including analysis of bases, soil texture, etc.).

The soil survey should take account of nearby teak plantations and/or teak plantations on similar sites and in similar environments to indicate possible correlations.

FIELD OPERATIONS

SITE PREPARATION AND ESTABLISHMENT

CONTROL OF EXISTING UNWANTED VEGETATION (MANUAL, MECHANICAL AND CHEMICAL METHODS)

When using herbicides or agrochemicals, they need to comply with both the national standards and regulations and the international ones, for this last ones the FSC (Forest Stewardship Council) policies and regulations will be the ones to implement.

When heavy machinery (CAT tractors, excavators, back hoes etc) needs to be used, good selection of specific equipment and supervision will be implemented in order to minimize soil disturbance (i.e. soil erosion and/or soil compaction). Protection of the soil and natural areas (native vegetation along rivers or in forest patches) needs to be explained and instructed to the machinery operators. When working with contractors, in the contract they will accept the need to respect protection areas and to work minimizing soil disturbance or negative impacts. Among measures to implement to minimize negative impacts is to use adequate tractor "shovel" or "blades" when pushing or moving unwanted trees or other heavy debris.

PROTECTION AREAS AND PERMITS
Protection areas include the river margins and other specified in the Costarrican Forest Law (Ley Forestal 7575). All the protection areas need to be respected. These include the protection of 15 meters along the river margins in flat areas or 50 meters in the case of areas with higher slopes (40% or more). Primary and secondary forests will not be removed, and all vegetation removal needs to be in compliance with the permits and stipulations of the Forest Law and Ministry of Natural Resources and Energy (MINAE).

Physical markings in the field (i.e. flagging tape, poles etc), to show the limits or borders of the protection areas will be implemented to maintain machinery, equipment and site prep. operations out of these areas

SOIL PREPARATION
Soil preparation is implemented taking into account the physical and chemical soil characteristics of the specific site to plant according to the report of the soil specialist.

LIMITS OF EFFECTIVE PLANTING AREAS
The general rule to follow is that the teak seedlings will be planted no closer than 5 meters from the "drop line" of the bordering or neighbouring trees. Teak must be planted at least 4 meter from the border of a legal right-of-way. Permanent roads in the plantation will have 4 meters of free unplanted space that will be out of the net plot area. The extraction roads that have very little or no traffic will also have a width of 4 meters but teak seedling can be planted in the border and only 1 meter in the centre of these roads will be excluded from the net plot area.
Roads criteria, including loading bays, culverts, cul-de-sacs, etc, to be developed or adopted from existing literature.

DRAINAGE
The objective of drainage construction is to drain the superficial water or to change the water table, the following criteria apply to ensure the production of Class 1 or greater teak plantations:

Ensure that an adequate drainage is prepared before planting begins. When the Soil Specialist concludes that a specific farm, or an important portion of a farm must be drained then, a drainage plan from a drainage specialist, that includes a drainage maintenance plan is necessary. Drains must be in place ahead of planting and not interfere with this operation; some secondary and superficial drains can be constructed at the same time as planting. Drainage after planting may only be carried out if no damage to the trees results (e.g. where superficial drains are developed and/or where planting distances are sufficiently wide to allow machinery to move easily and work without harming the planted trees).

PLANTING
Density, Spacing and Design.

1. A deviation of 40 cm from the original 3m X 3m planting is allowed to enhance the quality of planting by avoiding obstacles such as rocks, holes, trash etc and to plant the seedling in the best possible micro site. This is done as exception.
2. Per hectare the density is 1111 trees/ha with a 5% deviation.

MAINTENANCE

WEEDING AND LIBERATING TEAK TREES FROM COMPETITION

Weeding purposes:

1. Avoid root competition: superficial weeding is not desirable; aggressive grass species must be eliminated totally and frequently in the screen area in order to guarantee a minimum of root competition and to eliminate these species over time.
2. Avoid light competition: any vegetation that is covering leaves of the teak tree needs to be eliminated.
3. Water competition: during the dry season the screen area of trees which have not yet reached full potential must be totally free of weeds
4. Periodical general weeding or weed management in the non-competition area has to be carried out in investor plots.
5. If fertilizer is applied screening needs to be executed upfront;
6. Weeding must continue until canopy closure.

EROSION

Erosion must be monitored and when erosion decreases soil quality, appropriate measures have to be taken.

TYING OF BENDING TREES

Bent trees with potential must be tied in upright position up to four years as a corrective action to ensure straight trees without being damaged.

MANAGEMENT

GROWTH SAMPLING PLOTS

Representative Permanent Sampling Plots of appropriate size (e.g. 12.62 m radius equal to 0,05 ha) are to be established randomly once the second growing season is completed. Available statistical criteria will be used in the design of the monitoring network. An initial 1,0 % sampling intensity will be used for this purpose. However, the number of measurement plots should be based on a definition of the precision desired and the inherent variability of the plantation.

Plots should be easily identifiable on the ground and each tree clearly numbered. A map of plot distribution should be compiled. Plot positions will be determined by the Geographical Positioning System (GPS) for latitude and longitude co-ordinates.

Measurement should be taken during the dry season and should include biometric data (age, numbers of trees, individual tree diameters and heights, tree form and pruning height). Where trees exhibit unhealthy or stunted growth, phytosanitary information must be collected.

When thinning takes place in the rainy season the felled trees must be measured and recorded for accumulated volume estimation.

Biometric data should allow for the development of growth and yield tables over time; volume is the principal factor to determine, and volume definitions used must be precise (it is recommended that at least total volume over bark (OB) on main stem - from ground level - and commercial volume, i.e. under bark (UB) volume from ground level to 8 cm top diameter to be estimated in all cases in order to provide global comparisons. The volume equation must be clear.

A growth scenario should be derived as soon as possible to determine productivity by area relationships.

Each plot should be measured yearly in the dry season. If the thinning is before the measuring, these thinned trees need to be measured in order to provide a full record of the stand. A report, reflecting growth and management of plantations should be prepared and published for general use. All collected data and information must be available for all parties.

An integrated computer program has to be developed.

GROWTH PROJECTIONS

The aim of a growth projection is to provide a knowledge-based estimation of the future growth of actual plantations. As a nearly estimation that it is, a projection is not a guarantee of what will be achieved in the future, meaning that the present results should not be taken for granted (if they are over the projections) or be condemned (if they are under the projections). All these factors are pointed out in the risk description of THI Business Prospectus in addition without any promise related to the rate of return. A teak plantation can improve or get worse depending on several factors, such as plantation quality and management intensity.

Figure 1 shows a range of possible scenarios in terms of DBH growth. The dots (PSP of THI farms 2007) correspond to the data from the Permanent Sample Plots measured in September of 2007.

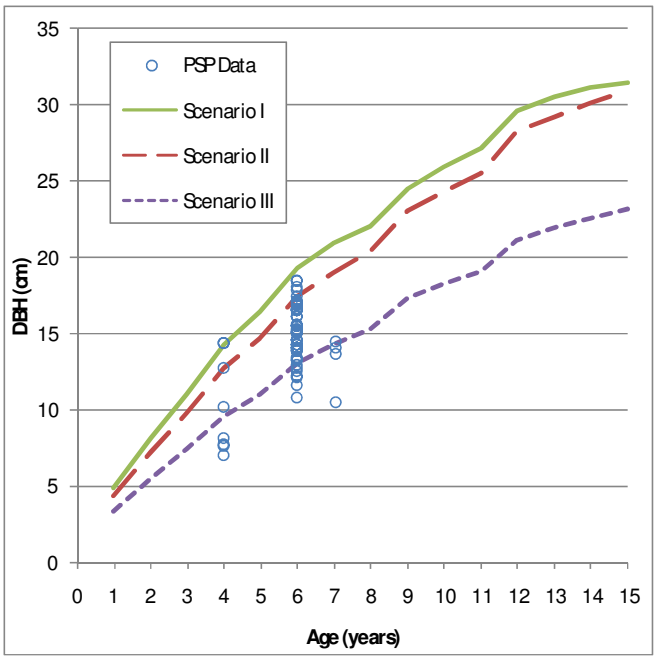

Figure 1: Set of options for DBH growth projections for THI Plantations based on actual growth reports from PSP plots.

Scenario I represents the highest expectations of the company in terms of average tree growth on DBH. At the moment there are almost no registers from consecutive measurements to determine if this curve will be achieved or if the plantations seem to already have started to follow a different trend. Consequently, a more conservative growth curve (Scenario II) has been added to prevent any eventual DBH growth decay. In addition, a third curve (Scenario III) represents a worse-case scenario, which could be a possibility if the actual growth reports show no considerable improvements but a reduction in annual growth occurs instead.

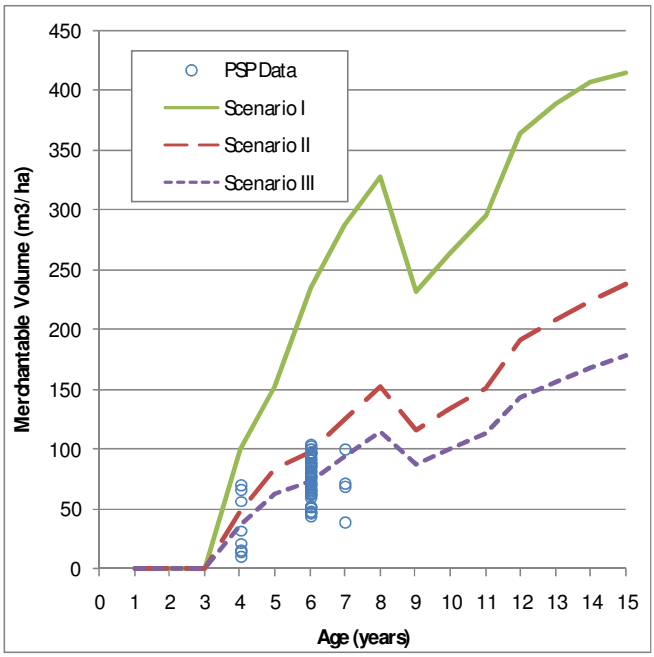

Figure 2: Set of options for volume growth projections for THI Plantations based on actual growth reports from PSP plots.

THI considers appropriate to have different scenarios for the volume production of the teak plantations. The Scenario I corresponds to the high yield projection expected on THI farms. Scenario II corresponds to a more conservative scenario, which could become the maximum production value for THI farms if the actual growth shows no substantial improvement and remains following this trend. A third curve or Scenario III correspond to the worse-case scenario which could occur if the actual volume growth rates begin to decay. The Scenario II or higher (towards the Scenario I) is the goal of THI, however, at this stage it cannot be defined which trend will be followed by all or part of the teak plantations. In the coming years the periodical monitoring of the growth status of THI plantations will be the basis for carrying out further detailed evaluations (growth classification by sectors within each farm). THI expects that the merchantable volume per hectare and for the time period until final harvest will be between Scenario I and Scenario III. This range of possible growth scenarios has been included in the financial planning of THI.

For achieving volume productions within the growth range, a integrated management scenario is required as guidance for achieving a certain goal. Table 1 shows a management option developed by THI for managing the stands according to present conditions, meaning that as stand dynamics dictate, a new or updated model may be required.

Table 1. Stand growth scenario proposal of Teak Holz International for the development of teak plantations in Costa Rica.

Age (years)	DBH (cm)	DBH thinning	H (m)	N	N thinned	Intensity (%)	BA (m2/ha)	VOL (m3/ha)	Vol. Ext. (m3/ha)	Acc. Vol. (m3/ha)	MAI VOL (m3/ha/year)
1	4,4		5,1	1100			1,7	---	---	---	---
2	7,3		9,4	1100			4,6	---	---	---	---
3	9,8		12,9	1100			8,3	---	---	---	---
Sanitary pre-thinning					**Sanitary pre-thinning**				**Sanitary pre-thinning**		
3	**10,7**	**8,9**	**12,9**	**990**	**110**	**10**	**8,8**	**0,0**	**0,0**	**0,0**	
4	12,8		15,8	990			12,8	48,6		49,7	12,4
5	14,7		18,2	990			16,9	83,7		84,7	16,9
Pre-thinning					**Pre-thinning**				**Pre-thinning**		
5	**15,6**	**13,8**	**18,2**	**663**	**327**	**33**	**12,7**	**69,1**	**20,9**	**91,1**	
6	17,4		20,1	663			15,8	97,0		119,0	19,8
7	19,0		21,7	663			18,8	125,2		147,2	21,0
8	20,4		23,0	663			21,6	152,5		174,5	21,8
First thinning					**First thinning**				**First thinning**		
8	**21,6**	**19,0**	**23,0**	**365**	**298**	**45**	**13,4**	**98,7**	**60,7**	**181,4**	
9	23,1		24,1	365			15,2	116,3		199,0	22,1
10	24,3		24,9	365			17,0	133,6		216,4	21,6
11	25,5		25,6	365			18,7	150,6		233,3	21,2
12	28,2		26,2	365			22,7	191,3		274,1	22,8
13	29,2		26,6	365			24,4	208,0		290,7	22,4
14	30,1		27,0	365			25,9	223,6		306,3	21,9
Final harvest					**Final harvest**				**Final harvest**		
15	**30,9**		**27,3**	**365**			**27,3**	**238,0**		**320,7**	**21,4**

Source for developing the growth curves and management scenario:

- Pérez, D. 2005. Stand growth scenarios for *Tectona grandis* plantations in Costa Rica. Dissertationes Forestales 1. 77p. Doctoral Thesis, University of Helsinki, Finland. Available at http://ethesis.helsinki.fi/julkaisut/maa/mekol/vk/perez/ or www.metla.fi/dissertationes (thesis #1).

- Perez, D. 2007. Provisional yield model for the Central & South Pacific Region of Costa Rica. Document available at www.ambientetierra.com.

THINNINGS
The trees selected for thinning shall be selected to maximize the volume and value of the teakwood trees left for later thinnings or fellings, when larger piece size prices will be higher.

A density of 1111 trees (allowing 5,0 % deviation) per ha is employed. A sanitary thinning will be executed followed by a pre-thinning where 33 % of the original trees are removed. Non-commercial trees will be left on the ground for nutrient release to the soil.

The silvicultural criteria to be used for thinning interventions are:

1. Canopy closure (normally carried out after closure except where erosion is a problem);
2. Major changes in underground vegetation (caution if soils are bare)
3. Stand basal area (after first and second thinning are completed, the standing basal area is allowed to build up to 22 m^2/ha, when a removal of around 5 to 7 m^2/ha).

PRUNING
Early pruning is advisable in teak in order to improve the quality of the wood and increase the merchantable height on the best trees.

The aim of pruning is to produce as long a knot free bole as possible, especially on best formed trees. Consideration must be made of the health of the live crown. It is recommended that at least 35-40% of the total height of the live crown should be left in order to prevent hindrance to growth, especially in the early years of the rotation.

Pruning is to be achieved in several 'lifts' beginning with the removal of unwanted side branches in young trees in the first six years. Certain flexibility should be allowed for pruning with the objective of leaving at least the first 7,0 m of the bole free of branches and knotty wood on best commercial trees. It is wasteful to prune trees with no commercial potential. The goal is to have as little 'knotty' wood as possible in lower logs.

Lifts of up to 8, 10 or 15 m on best trees must be examined from the practical and economic perspectives. Pruning to 8 m or more may be uneconomical in widely spaced trees that have large branches.

MANAGEMENT (OPERATIONAL) PLAN
All guidelines and requirements provided in these criteria must be incorporated into an overall management plan with an additional operational plan for each farm, acting as a guide to the work of the plantations.

In case the plantation auditor determines during a field audit of a plantation that special requirements need to be met (in addition to the criteria described in this document) due to its local deviating characteristics, an amendment to above appendix needs to be made.

The management plan has to include the following information:

- Objectives of the enterprise
- History of land use, and land use capacity
- Climate
- Legal aspects:
    - Legal base of enterprise; (Board of directors with specifications of their freedom and limitations)
    - Ownership of land and resources;
    - Rights of way and other rights;
- Ecological aspects:
    - Environmental characteristics of the area;
    - Planting policy (e.g. areas to be planted with native species; areas to be left under natural vegetation etc - to be identified)
- Hydrology:
    - Hydrological plan;
- Soils and geomorphology:
    - Soil analysis;
    - Important practical aspects to consider (fertilization, aeration etc);
- Social aspects:
    - Social policy, safety and health issues outlined;
- Management guidelines and monitoring system:
    - Infrastructure and drainage plan;
    - Guidelines on procurement of quality of planting stock;
    - Plant spacing,
    - Damage control plan
- Maintenance,
    - weed control;
    - Pruning strategy,
- Thinning and final harvesting guidelines;
- Growth and yield data base system including measurement plots (volume definition; system for analysing growth and yield outlined, statistical validity);
- Protection:
    - Phytosanitary plan;
    - Fire protection plan;
    - Erosion control plan;
- Supervision of operations (necessary buildings, equipment etc determined);
- Training (identification of all training needs - including technical, safety)
- Managerial; plan to satisfy identified needs; implementation of plan; assessment of training);
- Economic factors:
    - Costs and prices;
    - Markets and marketing;
- Budget