TEAK TREE INVENTORY AND AUDIT REPORT

CONDUCTED FOR

ASIA TEAK GROUP

AT

Puttalam Teak Plantation.
Sri Lanka

DR.NIMAL RUWANPATHIRANA
2021April

Contents

Content of Tables

Content of Figures

Content of Graphs

Executive summary

Puttalum teak plantation is one of three estates of Teak plantations namely Batticoloa, Anamaduwa and Puttalum plantations , managed by Asia Teak Tropical Plantation were inspected by Mr. J.M.P. Jayalath, Mr. Eranda Rathnamalala and me on 2020.12.5 and 2021.2.10 in order to inventories and audit the tree stocks of plantations. The annual tree audit and evaluation of tree sample data are conducted independently under globally accepted methodologies which explain in this report. All the sample data were collected throughout audit process under close supervision. We certify that the inspected plantations are presently in reported condition.

DBH measurement of 448 trees were taken from Puttalam plantations.

Puttalum Teak Plantation

Five sample plots having with total sample area of 8000 m2 have been permanently setup in different locations in Puttalum plantation. It is found by this study that total estimated planted area is 8.3ha (out of 10ha) and sample plots represent 10.6 % of population. In this study, 448 trees were measured for DBH measurement and around 50 trees for height measurement taken by hypsometer or pole. We applied all the international standards when measuring the tree parameters such as DBH and Height. (see page 17-20). There are 4608 (after thinning) trees in this plantation in which 448 trees measured for DBH, which represent 8.8% of population.

The inventory results shows that there are 5050 trees (4608 good trees and 442 trees for thinning). The average DBH and Height of trees in the estate is 17.62 cm and 12.7 m respectively. It is found that average trees per ha is 555 (after thinning). In 2020 tree count audit, out of 5093 total trees, there were 4829 good trees, 80 small and poor trees and 184 reserved trees. In 2021 audit it is found that there are 43 trees less than total tree number of 2020 audit which may be thinned out or uprooted. Details of block wise tree information are shown in table 3.2 and (3.9).

Analyzing inventory tree data, it is found that more than 33.9 % of trees are having DBH more than 16-18 cm of mean DBH value for Puttalum plantation that means, out of 4608 trees. There are 1562 trees having more than 16-18cm DBH. Plantation tree DBH distribution results are given in graphs, see page 21. Growth parameters from establishment of the plantation are summarized in table 7,8,9 and 10.These findings can be used for future planning of thinning and final mode of harvest.

After analyzing the last 10 years of growth (DBH) data of 2014-2021, mean annual increment of DBH and Height is 1.76 cm and 1.27 m respectively. This site growth parameters are useful to find the complied site quality (Yield class) or prepare the own yield table.

In order to estimate the timber volume of plantation, Mid diameter and DBH values of several trees were taken as sample to determine the form factor and actual volume of tree(see table 14 page 26). The finding is that tree form factor is around 0.45. Total tree volume of the Puttalum plantation was estimated based on mean DBH, Mean Height and Form factor. The mean volume per tree of Puttalum plantation was found as 0.139m3. The mean tree volume for ha is 77.9m3. Furthermore it is estimated that this plantation contain of 640.5m3. Growth parameters from establishment of the plantation are summarized in table 8. Our great task should be either we reduce number of trees per ha in order to produce larger trees or maintain optimum number of trees as much as possible to get maximum timber volume. We have to study what is the maximum number of trees per ha that can produce larger stem diameter and height (volume). Suitable Yield table will solve this question. The tentative yield table for Puttalum plantation is shown in table 16 and page 39 as only example.

These findings can be used for future planning of thinning and final mode of harvest. If we carefully and scientifically handle this valuable tree information, we will able to achieve highest turnover from this plantations at end of felling rotation.

Finally it can be concluded that Puttalum Teak plantations in Sri lanka are healthy and good condition. There are much more potential to get more growth increment particularly for larger tree stem diameter for next 10 years if the plantation is maintained and managed scientifically using selected prepared yield table.

Inventory team work under Corona prevention instruction.

1. Introduction

1.1 General Introduction of Teak (*Tectona grandis*) Plantation

Teak (*Tectonagrandis*L.f.) is a highly valuable timber in International trade sought by wood industries to produce good quality furniture and wood for house construction, carving, shipbuilding and many other purposes andTeak is an important timber species for tropical forestry ,Today teak is a profitable plantation crop promoted by government agencies, the private sector and farmers.Teak plantations are widely established across Indonesia,Thailand, Sri Lanka etc. in some places, they have become an inseparable part of local cultural and socioeconomic systems.

Bole form

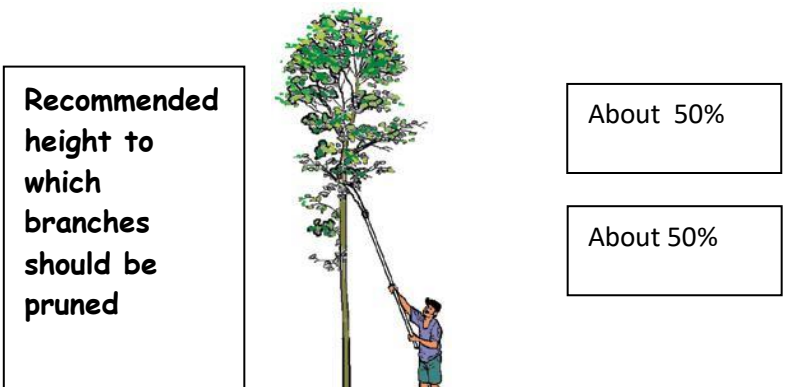
fluting (irregular involutions and swellings) in the teak stem has been observed in a number of plantations in tropical countries. In some study, the mean heritability value of stem straightness was found to be 0.83, indicating that the character for stem straightness is strongly controlled by provenance and is thus genetically inherited (Kaosa-ard, 1999). Hence, fluting can be minimized if the appropriate provenance is used in breeding trials to produce plants that exhibit straight stems. The most important form characteristic determining the value of teak logs is the length of the clear bole.

1.2 Activities of teak stand maintenance

Teak grows well, grows fast, and produces high-quality timber when the land and trees are well maintained. Maintenance includes weeding, fertilizing, replanting, pruning, thinning, maintaining coppices and controlling pests and diseases.

1.2.1 Pruning:

Pruning is the removal of branches which increases clear bole height and reduces knots on the main stem



1.2.2 Thinning

By competition for light, water and nutrients is greater in closely spaced plantations causing slower tree growth and tall, skinny stems. Thinning will encourage better growth for the good quality trees that remain.

1.3 Spacing

The spacing of trees and the number, timing and intensity of thinning strongly affect the pattern of growth and the yield of the plantation. If thinning is practiced late, growth rates decline or cease, whereas if the stand is thinned too early or too heavily, the trees have a greater tendency to produce side branches and epicormic shoots. This also reduces the potential yield of the plantation since growth is diverted from the main stem, which should be free from defects such as those caused by side branches and epicormic shoots.

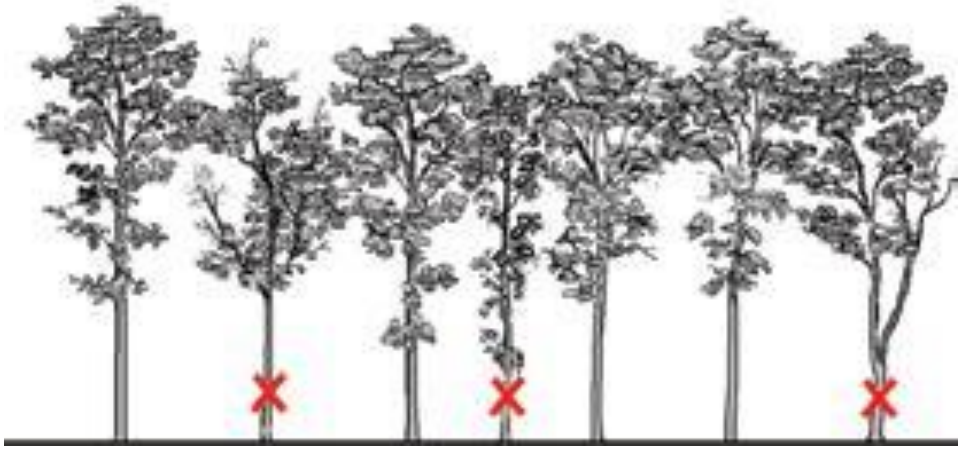


Table 1: Trees left after thinning based on tree height

Tree height (m)	Trees remaining (trees/ha)	Age (yr) (range based on soil fertility)	Spacing (m)
11.0-13.0	1300-1500	5-11	2.5-3.0
13.5-15.5	1000-1100	7-17	3.0
15.5-17.0	800-850	10-21	3.5
17.5-21.0	500-550	15-34	4.0-4.5

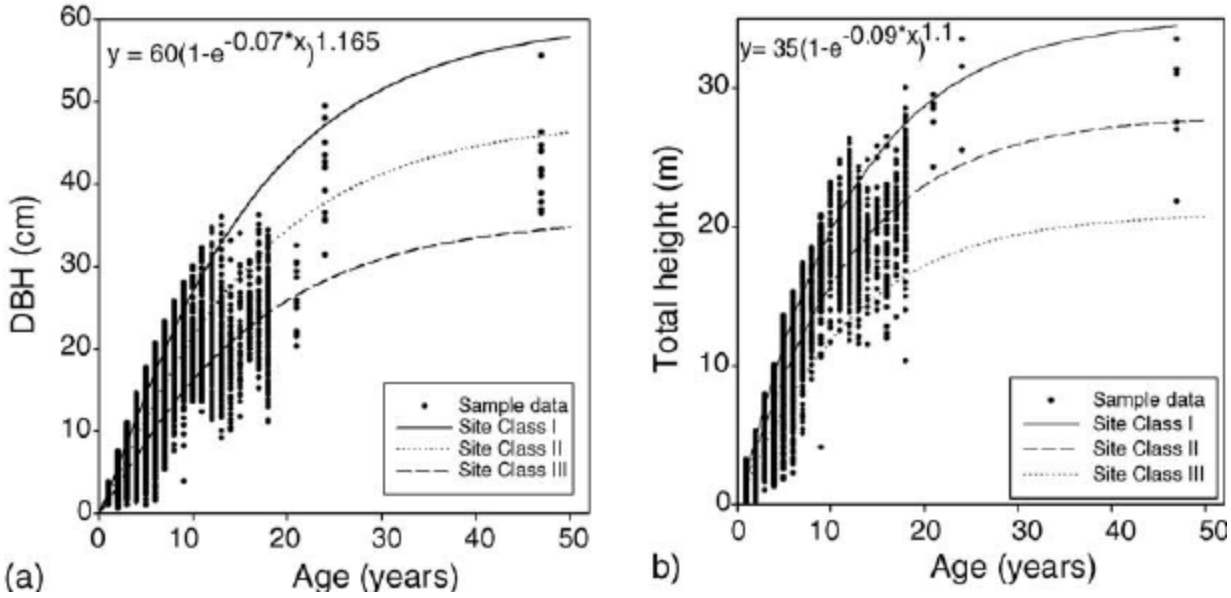
Table 2: Thinning regime developed for Puttalama plantation

Age/ Year	Main crop before thinning					Crop removed				
	Tree No.	Trees / ha	Mean DBH (cm)	Mean Height (m)	Tree Vol. (m^3) or Tree Vol. / ha	Tree No.	Trees / ha	Mean DBH (cm)	Mean Height (m)	Tree Vol. (m^3) or Tree Vol. / (ha)
9/2020	5093	597	16.37	12.4	0.117/69.8					
10/2021	5093	597				442	52	First thinning		
11/2022	4651	545								
12/2023	4651	545								
13/2024	4651	545								
14/2025	4651	545								
15/2026	4651	545				740	87	Second thinning		
16/2027	3911	458								
17/2028	3911	458								
18/2029	3911	458								
19/2030	3911	458								
20/2031	3911	458	Final harvesting							

1.3.1 Teak growth parameters

Height (H) and diameter at breast height (dbh) are the most important measures of tree growth and their relationship is useful in determining site-index, calculating tree volume, evaluating site –quality and predicting future growth of the stand (Jayaraman and Zakrzewski,2001).

Following growth information published by researchers can be used to develop the yield prediction table for present teak plantation of Asia Teak group.
Three Yield tables are being prepared for Batticoloa, Anamaduwa and Puttalum teak plantation.



(a) Teak growth curve : DBH against age (b)Teak growth curve : Total height against age

Table 3. Growth parameters of Teak governed by site quality of some other countries

Site quality 19							
age	No.of stems/ha	Top height(m)	DBH(cm)	Per Tree volume (m3)	Trees volume /ha	MAI(m3/ha/year)	CIA(m3/ha/year)
3	1111	8	6.9	-	-	-	9.9
5	776	13.4	13.1	0.03	27.2	5.4	13.6
8	542	17.6	18.6	0.102	55.3	7.6	11.3
12	379	19.3	22.2	0.259	98.5	9.7	13.7
20	265	21.3	27.0	0.449	119.0	7.9	5.2
25	185	21.7	31.5	0.62	115.3	7.1	4.3

Table 4. Growth parameters of Teak governed by site quality of some other countries

Site quality 21							
age	No.of stems/ha	Top height (m)	DBH (cm)	Per Tree volume (m3)	Trees volume m3/ha	MAI (m3/ha/year)	CIA (m3/ha/year)
3	1111	8.3	7.2	0	0	0	11.3
5	754	14.4	14.2	0.04	30.2	6	15.1
8	512	19.3	20.5	0.15	76.8	10.4	17.8
12	347	22.1	25.5	0.310	107.6	11	12
20	236	23.9	30.7	0.619	146.3	9.7	7.8
25	160	24.3	36.1	0.85	136	8.7	4.5

Age (years)	H_0	Main crop before thinning					Crop removed					Main crop after thinning					Total crop		
		N	D_g	G	V	Hart	N	D_g	G	V	Vt	N	D_g	G	V	Hart	VT	MAI	CAI
Quality 23																			
3	8.6	1111	7.5	4.9	0	34.9	399	0	0	0	0	712	9.4	4.9	0	43.6	0	0	0
5	15.3	712	15.2	13.0	49.8	24.5	256	12.1	2.9	12.5	12.5	456	16.8	10.1	37.3	30.6	49.8	9.9	24.9
8	21.0	456	22.7	18.5	114.0	22.3	164	19.5	4.9	28.7	41.2	292	24.4	13.6	85.3	27.9	126.5	15.8	25.6
12	24.3	292	29.0	19.3	137.2	24.1	105	24.8	5.1	34.5	75.8	187	31.1	14.2	102.7	30.1	178.5	14.9	13.0
20	26.5	187	35.9	19.0	157.1	27.6	67	31.8	5.3	39.4	115.2	120	38.1	13.7	117.7	34.4	232.9	11.6	6.8
25	27.0	120	43.9	18.2	133.2	33.8											248.4	9.9	3.1
Quality 21																			
3	8.3	1111	7.2	4.6	0	36.1	357	0	0	0	0	754	8.8	4.6	0	43.9	0	0	11.3
5	14.4	754	14.2	11.9	30.2	25.3	242	9.4	1.7	6.78	6.78	512	16.0	10.2	23.4	30.7	30.2	6.0	15.1
8	19.3	512	20.5	16.9	76.8	22.9	165	15.7	3.2	17.3	24.1	347	22.4	13.7	59.5	27.8	83.6	10.4	17.8
12	22.1	347	25.5	17.7	107.6	24.3	111	21.1	3.9	24.1	48.2	236	27.3	13.8	83.5	29.5	131.7	11.0	12.0
20	23.9	236	30.7	17.4	146.3	27.2	76	28.7	4.9	33.0	81.2	160	31.5	12.5	113.3	33.1	194.5	9.7	7.8
25	24.3	160	36.1	16.4	136.0	32.5											217.2	8.7	4.5
Quality 19																			
3	8.0	1111	6.9	4.2	0	37.5	335	0	0	0	0	776	8.3	4.2	0	44.9	0	0	9.9
5	13.4	776	13.1	10.5	27.2	26.8	234	9.1	1.5	5.73	5.733	542	14.5	9.0	21.43	32.1	27.2	5.4	13.6
8	17.6	542	18.6	14.7	55.3	24.4	163	13.6	2.4	11.6	17.37	379	20.3	12.3	43.65	29.2	61.0	7.6	11.3
12	19.3	379	22.2	14.7	98.5	26.6	114	20.7	3.8	20.7	38.12	265	22.8	10.8	77.79	31.8	115.9	9.7	13.7
20	21.3	265	27.0	15.2	119.0	28.8	80	25.9	4.2	25.1	63.26	185	27.4	10.9	93.84	34.5	157.1	7.9	5.2
25	21.7	185	31.5	14.4	115.3	33.9											178.5	7.1	4.3

[a] H_0: top height (m); N: number of stems/ha; D_g: quadratic mean diameter at breast of height (cm); G: basal area (m^2/ha); V: commercial volume (m^3/ha); Vt: commercial volume accumulated in thinnings (m^3/ha); Hart: Hart–Becking index; VT: total commercial volume (m^3/ha); MAI: mean increment of volume (m^3/ha per year); CAI: current increment of volume (m^3/ha per year).

Other studies have indicated that wood density and mechanical properties are independent of growth rate or that fast-grown trees of ring-porous species have higher wood density and strength (Harris, 1981; Bhat, Bhat and Dhamodaran, 1987; Rajput, Shukla and Lai, 1991). More recently, a study on the wood properties of

fast-grown plantation teak trees of different ages revealed that there were no significant differences in wood density, modulus of rupture (MOR), modulus of elasticity (MOE) or maximum crushing stress (Bhat, 1998). It was concluded that young trees (13 to 21 years of age) are not necessarily inferior in wood density and strength to older trees aged 55 and 65 years, and hence that the rotation age of fast-grown teak wood can be reduced without affecting the timber strength.

1.4 Forest Plantation Audit process and Objectives

Forest Audits generally assess and compliance with the forest management planning manual and the effectiveness of forest management activities in meeting the objectives set out in the forest management plan.

The specific objectives of forest Audit are to assess to what extent forest management planning activities comply with forest management plan and forest management principles. Another objective is to compare the planned forest management activities with actual activities undertaken and to remedy shortcoming identified in a previous audit. At finally the audit provide a conclusion stating whether or not the forest is being managed consistently with principles of sustainable forest management to achieve the set objectives of forest management plan. Present teak plantations need to be prepared the comprehensive forest management plan with set objectives.

1.4.1 Requirement for conducting the audit

There is sufficient or appropriate information to conduct the audit , in addition there are adequate resources and co-operation from the auditee to conduct audit process. The audit team must be independent.

1.5 Objectives of present forest inventory and Audit of Teak Plantation in Anamaduwa in Sri Lanka

a) To inventory the teak plantation to get Teak tree stock and tree growth parameters.
b) To decide next silvicultural treatments such as pruning, thinning and some maintenance activities of plantation like fire lines, weeding, fertilizing based on information gathered from forest inventory and field examination.

c) To predict future tree growth, timber production and estimated timber value. This forecasting will help to take the remedial measures to manage the plantation efficiently to achieve the maximum benefit from the plantation.
d) To remedy shortcoming identified in a previous audit and assess the forest management activities.

2. Methodology of Forest inventory

Sound forest management depends on the quantity and quality of information available on the forest. This information is obtained from forest inventories. Forest inventory is the activity of data collection that helps generating the required information base on the forest resource within an area of interest. There are three main factors, which influence the cost of an inventory: Type of information required; Standard of accuracy; Size of area to be surveyed and the minimum size of unit area in the forest.

A good forest inventory;

a) Should be conform to the objectives
b) Should provide adequate precision
c) Methodologically sound & follow statistical sampling criteria
d) Have comprehensive transparent reporting & documentation
e) Overall credibility

In this inventory process, important of the above criteria is considered and followed.

2.1 The following items are recommended for conducting forest inventory and monitoring exercises

Items needed for all field inventory or assessments. Field assessment datasheets (current and previous) Field vest, Plastic flagging (at least three different colors) Mechanical pencils, Sharpie permanent ink pen, Compass, Calculator, Small Ruler (metric & English), 75' or 100' Spencer tape w/dbh tape, Clinometer, Clipboard or datum, Stand map, plots mapped, Small pocket sized notebook, Digital camera, Numbered tree tags (check for numbers that have not been used) Unmarked

bearing tree tags for scribing, Rebar & plastic pipes (for replacement if missing), Tree paint (spray can): orange or other bright color, First-aid kit, Water, Cell phone

2.1.1 Temporary vs. Permanent Plots

When conducting a forest inventory, most landowners install temporary plots. When the stand is re- inventoried in the future, plot locations are different. This is the simplest inventory method and is recommended for landowners who have minimal time to devote to forest inventory. Permanent inventory plots are often used on large ownerships and are the most precise method of monitoring forest change over time. To establish "permanent" plots, plot centers or corners are marked with a stake or other marker and the variables of the forest stand within the plot are re-measured through time.

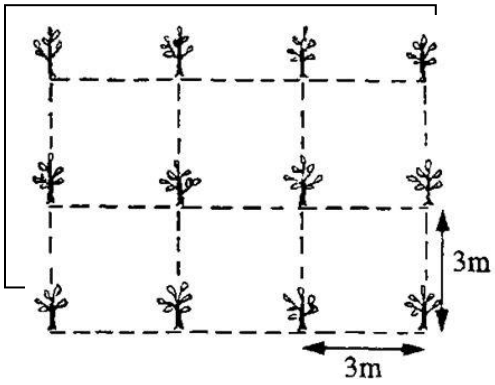
Asia Teak Group audit inventory the permanent square shape plots are used and for forest management review works, the temporary circular plots were used.

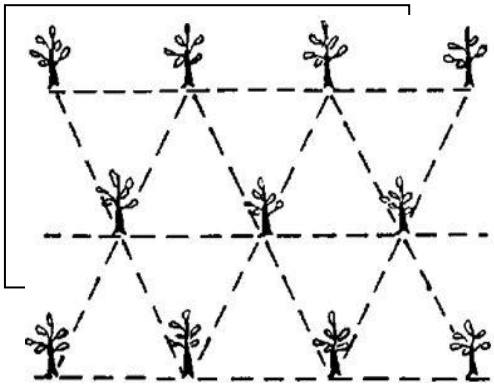
Figure 1. Plot number and one corner post of square shape plot in estate belong to Asia Teak

2.2 System of planting

Square system: This system is considered to be the simplest of all the system and is adopted widely. Under this system, intercultural operations, spraying, harvesting etc., can be done conveniently and easily and irrigation can be done in two directions.

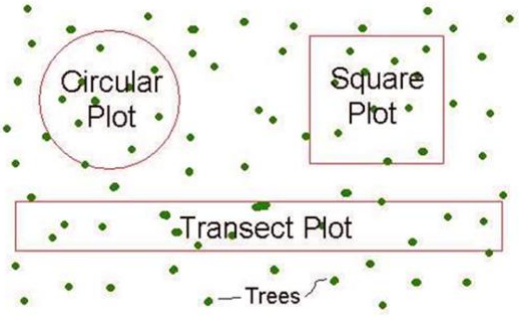
Triangular system :In this system, trees are planted as in the square system but the plants in the 2nd , 4th, 6th and such other alternate rows are planted midway between the 1st, 3rd, 5th and such other alternate rows. This system has no special advantage over the square system except providing more open space for the trees and for intercrops.





2.2.1 Plot shape

In this study, square plot are used and suggested plot size based on the stocking shown bellow. However we have used 40m x 40 m square shape plots in most of time.

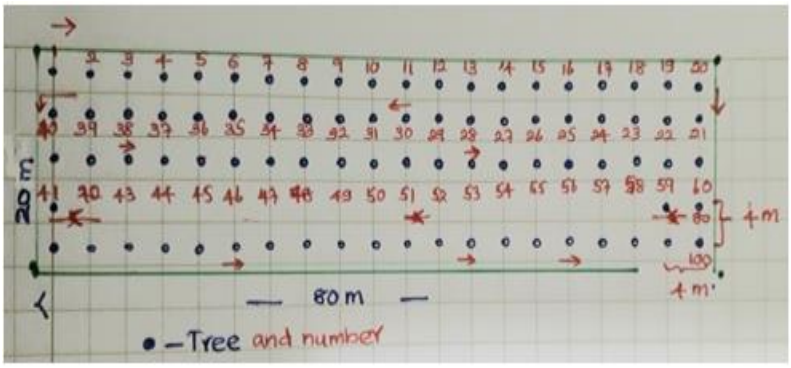


STOCKING RATE (STEMS/*HECTARE*)	PLOT SIZE (*HECTARES*)	RADIUS OF CIRCULAR PLOT (METRES)
100	0.2	25.2
200	0.1	17.8
400	0.05	12.6
500	0.04	11.3
600	0.033	10.2
800	0.025	8.9
1000 +	0.02	8.0

Various plot shapes

2.2.2 Plot size and planting system of Sri Lankan Asia Teak Plantation

Size of the plots is measured by predetermined of tree spacemen (distance) and number of trees in each row. All the plots of Puttalam are 80m x 20 m. (1600 m^2).



2.3 Basics of mensuration (Tree variables measurement)

(a) Diameter measurement of a single standing tree

(b) The diameter at breast height (dbh)

The standard position for diameter measurement at standing tree is at breast height. It is defined at 1.30 meter above ground in most countries. Calipers and diameter tape are the most commonly used instruments.

2.3.1 Diameter tape

There are diameters tapes from which the tree diameter can be directly read. Tree diameter can also be determined from circumference measurement which can be done by diameter tape or any tape since circular tree stem shape is assumed.

$C = 2\pi r = d;$

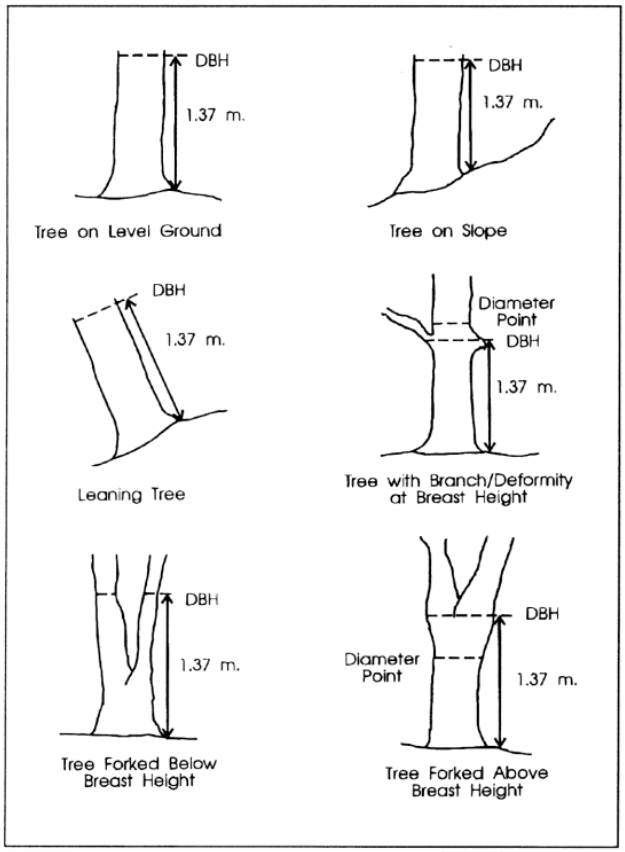
$d = C/\pi$

In this study, Diameter tape is used.

Figure 2. Diameter at breast height (1.3m) is measured by diameter tape. Inventory team follows all the standard and rules recommended in this regard

2.4 Positions of diameter measurement at different conditions

We followed following standard governing rules when take measurement of diameter at breast height of tree stem. Ex: clean the bole surface where we measure the stem diameter, diameter tape always correctly handled and read data carefully for reporting.



Standard rules governed to measure diameter at breast height

Diameter tape used for the inventory

2.5 Tree height measurement

Height is a tree variable that is used to estimate or determine the volume of a tree. The total height is the distance between the ground and top of the tree and bole height is the distance between the ground and the Crown Point.Merchantable height: the distance between the ground and the terminal position of the last useable portion of the tree stem.Tree height is defined to be the perpendicular distance between the ground level and the top of the tree. While, Tree length is the distance between the stem foot and the top along the stem

2.5.1 Method of tree height measurement

There are two methods, one is direct method which involves using height measuring rods only for small trees (see right). Other method we used is trigonometric principles. Sunto hypsometer used as instrument for this purpose

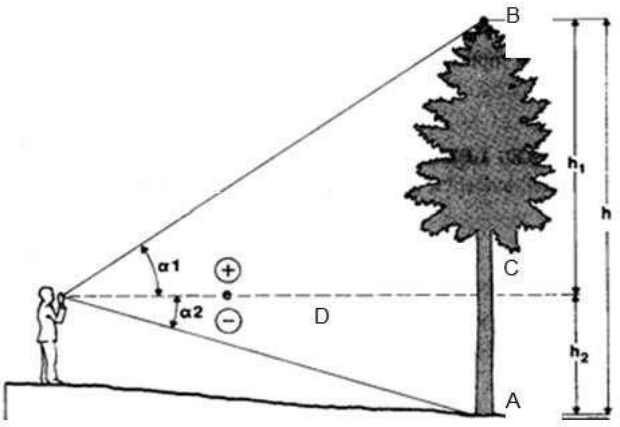
Figure 3. Total Tree height was measured by hypsometer and a pole, used instrument of sununto meter is shown in above

Figure 4. Correct horizontal distance between tree and height observer is being positioned

2.6 General steps for Hypsometer

- Stand at a fixed horizontal distance from the base of the tree (usually 10, 15, 20, 25 meters, and so on)
- Sight at the top of the tree and read the value 'A' (top reading)
- Again sight at the bottom of the tree and read the value 'B' (bottom reading)
- Then the total height of the tree is top reading 'A' minus bottom reading 'B'
- Bottom reading +ve or –ve (above and below eye level)

Height measurement can be taken using clinometer as shown figure 2.3.



tan α1 = BC / D
BC = tan α1 . D
tan α2 = AC / D
AC = tan α2 . D
AB (height) = BC + AC
AB = tan α1 . D + tan α2 . D
AB = D (tan α1 + tan α2)

Figure 5: Tree height measurement on a flat terrain

3. Results of inventory of teak plantation

3.1 Teak Plantation of Puttalam

Table 5. Number of trees and tree mean DBH values in plots in Puttalam

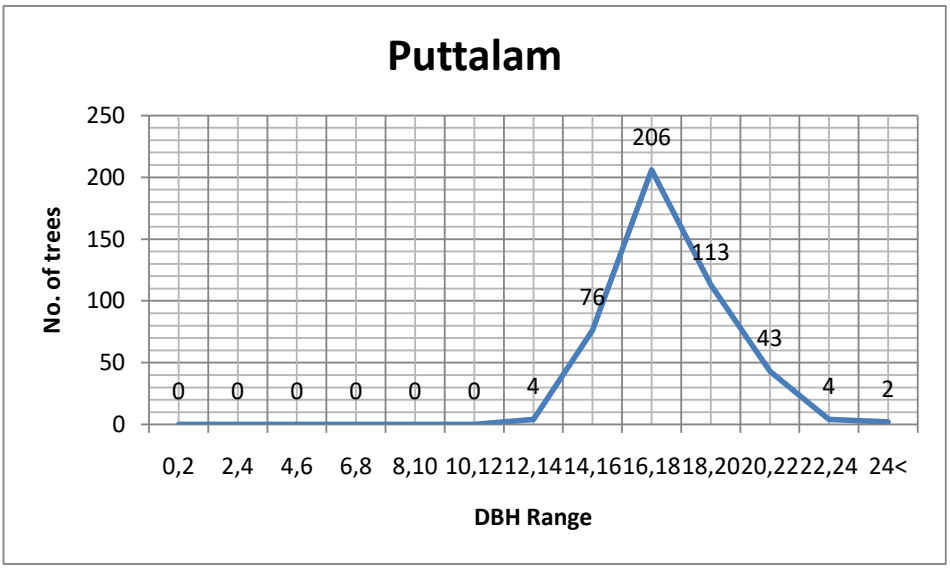
Plot number (P)	Block 01		
	No. of trees	Mean DBH (cm)	Mean height (m)
1	89	17.3	13.2
2	79	17.9	12.8
3	97	16.8	12.2
4	88	18.1	12.5
5	95	18	12.8
mean	90(448)	17.6	12.7

Table 6. Sample measurement of five trees taken from Puttalum at diameter of mid height of trees, and DBH inorder to find form factor, tree actual volume.

Parameters	Puttalum
Total Tree height (m)	13
Mean Tree DBH (cm)	17.5
Mean Tree mid diameter	11.8
Tree form factor	0.461
Actual volume (m3)	0.142
Cylindrical volume (m3)	0.308
Tree form factor	0.461

ALL PARAMETERS OF TREE IS WITH BARK

***Graph 1**: Number of trees against to average DBH range values in Blocks in Puttalam*



Out of 478 of trees, 162 trees are having more than 16-18.cm dbh. Mean dbh is 17.6cm

It can be assumed that in block no.1. out of 4608 trees, There are 1562 trees having more than 16-18cm DBH category.

Part of puttalum plantation

Figure 6. Sections of Puttalum plantation, canopy closing is apparent

Table 7. Estimated number of trees having more than its mean DBH value in Puttalumteak Plantation.

Estate	Block no and its mean dbh value.	no. of trees more than its mean DBH in Block and its %
Puttalum	1 and 17.6 cm	1562(33%) from 4608 trees

Table .7A		Puttalum block growth parameter with age (planted area app. 8.53 ha from 10ha) Planted year. 2011			
Age (year)	Measurement taken year	Total no. of tree	No. of trees per ha	DBH (cm)	Height (m)
3	2014	5630	660	4.4	5.1
4	2015	5587	655	8.1	6.1
5	2016	5587	654	10.5	8.0
6	2017	5552	651	12.3	9.0
7	2018	5488	643	12.9	10.4
8	2019	5447	638	15.4	11
9	2020	5093	597	16.37	12.4
10	2021	4608 (after thinning)	540	17.62	12.7

Table 8. Puttalam block growth parameter with age

Puttalam Planted year 2011				MAI and (CAI)	MAI and (CAI)
Age (year)	Measurement taken year	DBH (cm)	Height (m)	For DBH (cm)	For height (m)
3	2014	4.4	5.1	1.46	1.7
4	2015	8.1	6.1	2.03(3.7)	1.52(1)
5	2016	10.5	8.0	2.1(2.4)	1.6(1.9)
6	2017	12.3	9.0	2.05 (1.8)	1.5(1)
7	2018	12.9	10.4	1.84(0.6)	1.48(1.4)
8	2019	15.4	11	2.5 (2.5)	1.37(1.6)
9	2020	16.37	12.4	1.82 (0.97)	1.38(1.4)
10	2021	17.62	12.7	1.76(1.25)	1.27(0.3)

Table 9. Sample plots information, planted area and tree inventory data and tree thinning information in year 2021 of Puttalum

Estate	Block no.B1	Total trees in block(B1)	Estimated planted area (ha)	No. of Plots	Plots area in block B1 (m2)	Year 2021						
						No. of trees measured for DBH in Block 1 and	No of trees for ha.	Average DBH (cm)	Average height appro.(m)	Tree information Thinning		
										No. of trees thinned	Mean DBH of thinned trees (cm)	Mean Height of thinned trees(m)
Anamaduwa	Sub block	984	1.6	5			615	16.5	13.2	106	15.1	
	Sub bloc	1035	1.7				608	17.0	12.8	101	15.3	
	Su b	909	1.5				606	17.4	12.2	77	15.5	
	Sub block	1098	1.8				610	17.6	12.5	73	15.7	
	Sub blo	1024	1.6				640	18.0	12.8	85	15.8	
		5050	**8.3**	5	8000	448	608	**17.3**	12.7	**442**	**15.48**	

Table 10. Comparison of growth parameter between Puttalum with tree age

Batticaloaall Blocks Planted year 2012.july to 2013 December			Anamaduwa Planted year 2009/2010		Puttalam Planted year 2011	
Age (year)	DBH (cm)	Height (m)	DBH (cm)	Height (cm)	DBH (cm)	Height (m)
3	4.24	3.46	6.6	6	4.4	5.1
4	6.22	4.84	8.2	7.1	8.1	6.1
5	7.42	5.64	10	7.5	10.5	8.0
6	8.87	6.72	11.2	10.3	12.3	9.0
7	9.93	7.57	12.1	11.3	12.9	10.4
8	11.46	9.2	12.4	11.8	15.4	11
9			13.6	12.5	16.37	12.4
10			14.37	13.3	17.62	12.7

Table 11. Sri Lankan Teak Plantation tree count.Comparison Tree Audit 2020-2021 in Puttalam.

Estate Name	Block number	Geophysics count trees 2020						Geophysics count trees 2021					
		Total good trees	No.of small/poor trees	Reserved trees	Marked for thinning	Total trees	Differences 2018 vs 2019	Total good trees	No.of small /poor trees	Marked for thinning	Reserved trees	Total trees	Differences 2021vs 2020
Puttalum	B1	4829	80	184	-	5093	354	4608		442		5050 (after thinning 4608)	43

Table 12. Sample plots information, planted area and tree inventory data in year 2021 of and Puttalam

Estate	Block no.	Total trees in block	Estimated planted area (ha)	No. of Plots	Plots area in block (m2)	Year 2021			
						No. of trees measured for DBH in Block	No of trees for ha.	Average DBH (cm)	Average height appro.(m)
Puttalum	B1	4608 (after thinning)	8.3	5	8000 (20x80x x5)	448	555	17.62	12.7

Table 13. Comparison of tree parameters between year 2020 and 2021 in and Puttalum

Estate	Block no.	No. of Plots	Year 2020				Year 2021				
			No. of trees measured for DBH	No of trees for ha.	Average DBH (cm)	Average height (m)	No. of trees measured for DBH	No of trees for ha.	Average DBH (cm)	Average height appro. (m)	Variance in DBH (cm)& Height (-) 2020 vs 2021
Puttalum	B1	5	478	597	16.37	12.4	448	560	17.62	12.7	1.25cm(m)

Table 14. Tree volume and other growth parameters of plantations were estimated based on age of plantation, form factors and inventory data of Puttalam plantation

Tree age or inventory year 2020	AGE OF THE PLANTATION IS 10 years old (planted 2011 April-October AND FORM FACTOR IS ASSUMED AS 0.45							
Block NO.	Total trees	No.of stems/ha	mean height (m)	DBH (cm)	Per Tree volume (m3)	Trees volume m3/ha	Total volume In block (m3)	MAI (m3/ha/ year
B1	4608	555	12.7	17.62	0.139	77.9	640.5	7.79

Table 15.Determination of site index based on growth parameters of past years of Puttalam plantation.

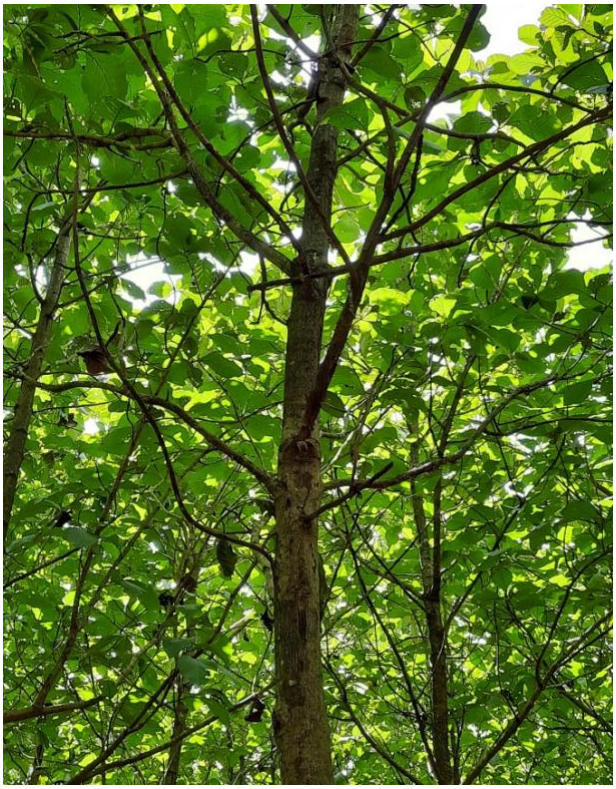
Age of Puttalam plantation is 10 years (Planted year. 2011)

Estate	Block no.	No. of Plots	2013	2014	2015	2016	2017	2018	2019	2020	2021	DBH differences from Year of first measurement to 2021 and (Mean Increment of DBH cm) and periodic increment of DBH{} from First measured year.
			Aver. DBH (cm)	Ave. DBH (cm)	Ave. DBH (cm)	Ave. DBH (cm)	Ave. DBH (cm)	Ave. DBH (cm)	Ave. DBH (cm)	Aver. DBH(cm)	Aver. DBH (cm)	
Puttalam	B1	5		4.4	8.1	10.5	12.3	12.9	15.4	16.37	17.62	13.22 (1.76) {2.2}

4. Some field activities

Tree is being marked for thinning

Selecting the most suitable tree for thinning



Tree canopy is closing to each other and lower branches are dying.

4.1 Observation, Conclusions and recommendation

When excess trees build up the canopy and root competition among the trees in plantation , those inferior trees must be thinned out (removing whole tree) in order to give space for good trees to grow freely and produce larger cylindrical bole.

After analyzing tree growth parameters , age, number of trees per ha , canopy spacing and particularly number of trees reserved as management decision , thinning schedule for plantation was prepared and shown in table 2.
In First thinning , 442 trees were identified for thinning.

Selective thinning was applied after careful study of tree growth parameters given in graphs 1 and one to one tree inspection.
Pruning of the adventitious shoots should be carried out only after required training given under close supervision.
Control fire or fire lines must be properly maintained.
Application of soil improvement method and soil erosion prevention methods must be applied.
Root system of Uprooted trees should be closely monitored at regular basis if termite causes or help for decaying of roots.]

Finally it can be concluded that both teak plantation are healthy and good condition. Plantation is much more potential to get more growth increment particularly for diameter growth for next 10 years if the plantation is maintained and managed scientifically.

DR. Nimal Ruwanpathirana (Ph.D., M.Sc (forestry), B.sc(Bio. Science)
Consultant for forest management and wood science

Table 16. Projected growth parameters of Teak governed by site quality for Puttalum Teak Plantation

Site quality 1. Projected growth parameters for Puttalum Teak Plantation **Planted area 7.8ha. Growth parameter over the bark. Tree form factor 0.48 early stage and 0.45 for after 12 years. This calculation based on ONLY mean values of tree.**										**Remarks**
Age	No.of stems/ha	Total height (m)	DBH (cm)	Per Tree volume (m3)	Tree volume m3 /ha (remained)	Tree Volume	Total volume produced m3/ha	MAI (m3/ha/year	CIA (m3/ha/year	Actual growth data 2738(53%) trees from total of 5093 trees are more than 16 cm of DBH. It means that best 350 trees per ha can be chosen to looked after till final harvesting.
3	721	5.1	4.4	0.0037	2.66		2.66	0.886		
4	716	6.1	8.1	0.015	10.74	0.018	10.75	2.68	8.09	
5	716	8	10.5	0.033	23.62	0	23.62	4.72	12.87	
6	711	9	12.3	0.051	36.26	0.165	36.42	6.07	12.8	
7	703	10.4	12.9	0.065	45.69	0.459	46.14	6.59	9.72	
8	698	11	15.4	0.098	68.40	2.99	71.39	8.92	25.25	
9	652	12.4	16.37	0.124	80.84	4.5	85.34	9.48	12.4	
12	*500*	*16*	*20*	*0.226*	*113*	18.8	*131.8*	*10.98*	*15.4*	*Forecasted growth data. 30 year old tree canopy occupy 3m radius of circle or 28 m2.this space decide the growth rate.*
15	*450*	*18*	*23*	*0.336*	*151.2*	*11.3*	*162.5*	*10.83*	*10.2*	
20	*400*	*21*	*27*	*0.427*	*170.9*	*16.8*	*187.7*	*9.38*	*5.04*	
25	*350*	*23*	*30*	*0.731*	*255.9*	*21.35*	*277.25*	*11.09*	*17.9*	
30	*350*	*24*	*33*	*0.92*	*322*	*0*	*322*	*10.7*	*8.95*	
						Total =93.7				