TEAK TREE INVENTORY AND AUDIT REPORT

CONDUCTED FOR

ASIA TEAK GROUP

AT

Batticolao Teak Plantation

Sri Lanka

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Executive summary

Batticoloa Teak Plantation is one of the largest Teak plantation among the three estates of Teak plantations namely Batticoloa, Anamaduwa and Puttalum plantations, managed by Asia Teak Tropical Plantation. Mr.J.M.P. Jayalath, Mr.Eranda Rathnamalala and me visited on 2021.4.2 and 3 in order to inventories and audit the tree stocks of the plantation. 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. I certify that the inspected plantations are presently in reported condition.

DBH measurements of 1575 trees were taken from Batticoloa plantation and 20 sample plots which covers 2.94 ha area were used for forest inventory. It is estimated that total planted area of Batticoloa plantation is 29.5 ha. The total tree number is 15774 in Batticoloa,

Batticoloa Teak Plantation

Twenty sample plots having with total sample area of 29400 m2 have been permanently setup in different locations in Battcoloa plantation. It is found by this study that total estimated planted area is 29.5 ha and sample plots represent 9.96 % of population. In this study, 1575 trees were measured for DBH measurement and around height measurement of 200 trees were taken by hypsometer. We applied all the international standards when measuring the tree parameters such as DBH and Height. (See page 17-19). There are around 15774 trees in this plantation in which 1575 trees measured for DBH which represent 9.98% of population.

The inventory results show that there are 15774 trees (13286 good trees, 2250 small and 238 reserved tree). The average DBH and Height of trees in the estate is 11.34 cm and 8.33 m respectively. It is found that average trees per ha is 549. In 2020 tree count audit, out of 16782 total trees, there were 13349 good trees, 3180 small and poor trees, 14 thinning and 239 reserved trees. In 2021 audit it is found that there are 1008 trees less than from total tree number of 2019 audit which may be thinned out or uprooted/dyeing. Details of block wise tree information are shown in table 3.3 and (3.4).

Analyzing inventory tree data, it is found that more than 36% of trees are having DBH more than 11.34 cm for Batticoloa plantation that means, out of 15774 trees. There are 5745 trees having more than 11.34cm DBH. Block wise results are given in graphs, see page, 18 and 19. The descending order of mean DBH values of Block 1. Block 2, Block 3, Block 4 and Block 5 are given 13.57cm, 11.45cm, 11.21cm, 10.64cm, and 9.84cm respectively. These findings can be used for future planning of thinning and final mode of harvest.

After analyzing the last 9 years of growth and DBH data of 2015-2021, Mean annual increment of DBH and Height is 1.26 cm and 0.92 m respectively. This site growth parameters can be used to find the comply 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. This finding is that tree form factor is around 0.45. Total tree volume of each block was estimated based on mean DBH, Mean Height and Form factor. The Descending order of mean volume per tree of Block 1, block 2, block 3, bock 4 and block 5 were found as 0.0738 m3, 0.0385 m3, 0.0330 m3, 0,0299 m3 and 0.0535m3 respectively. Mean tree volume for Batticoloa site is around 0.045. The mean tree volume for ha is 25.2 m^3. Furthermore it is estimated that this plantation contains of 708.5m3 of timber. 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 to get as much as possible (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). In order to do that we will have to prepare the best thinning regime for this plantation .The yield table that is going to be built will solve this question.

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 and Teak 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

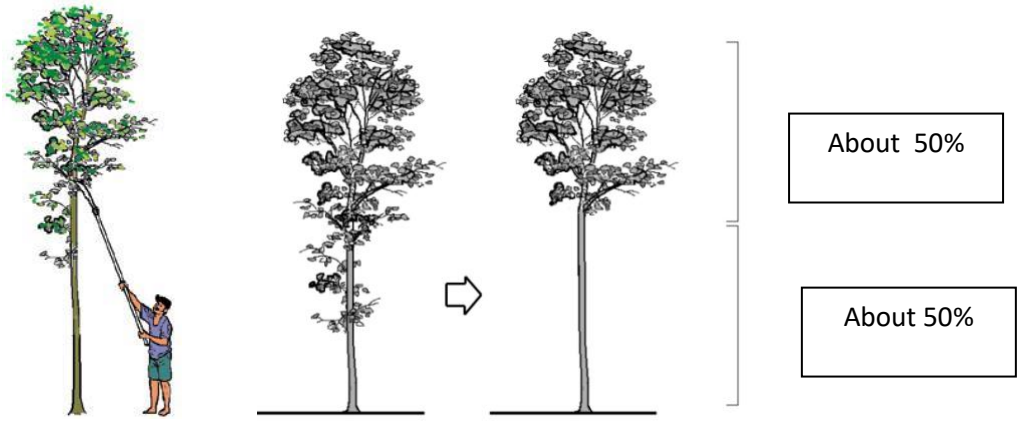
Fluting (irregular involutions and swellings) in the teak stem has been observed in a number of plantations in tropical countries. In some study, the mean heritability value of stem straightness was found to be 0.83, indicating that the character for stem straightness is strongly controlled by provenance 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

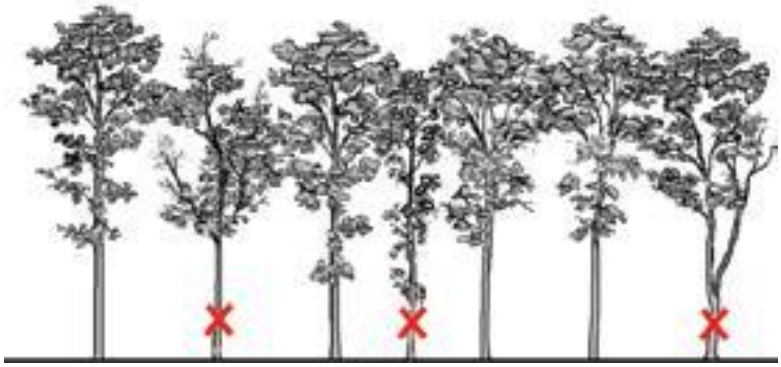
pruning is the removal of branches which increases clear bole height and reduces knots on the main stem



Recommended height to which branches should be pruned

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 A: Trees left after thinning based on tree height

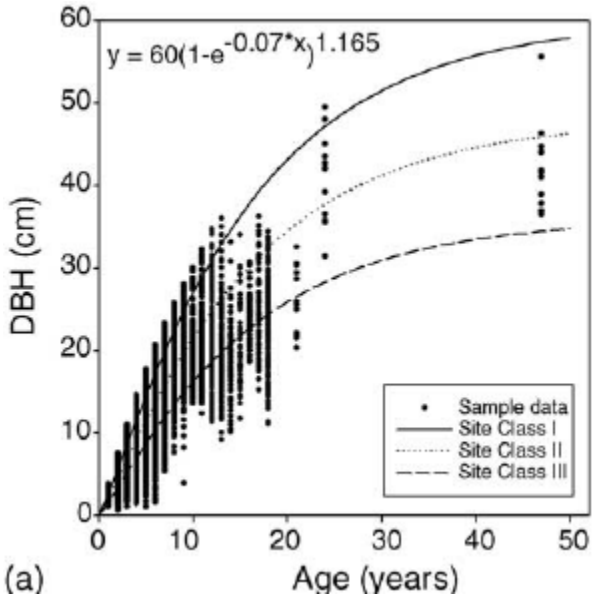
Tree height / (m)	Trees remaining / (trees/ha)	Age (yr) / (range based on soil fertility)	Spacing / (m)
11.0–13.0	1300–1500	5–11	2.5–3.0
13.5–15.5	1000–1100	7–17	3.0
15.5–17.0	800–850	10–21	3.5
17.5–21.0	500–550	15–34	4.0–4.5

1.3.1. Teak growth parameters

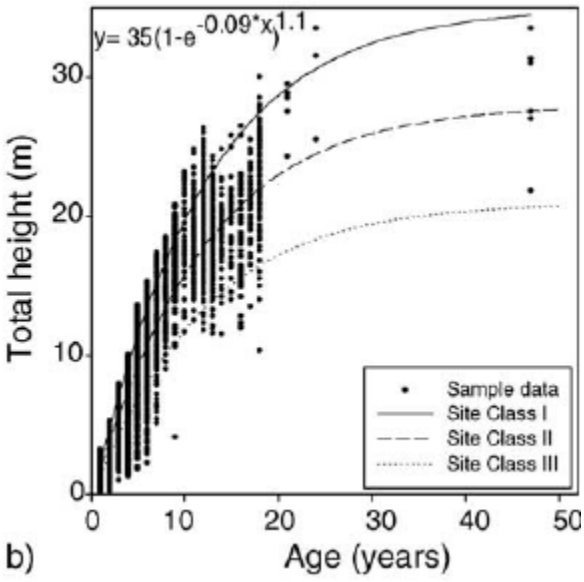
Height (H) and diameter at breast height (dbh) are the most important measures of tree growth and their relationship is useful in determining site-index, calculating tree volume, evaluating site –quality and predicting future growth of the stand (Jayaraman and Zakrzewski,2001).

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 1. 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 1.1. 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.

1.4.2. Objectives of present forest inventory and Audit of Teak Plantation in Batticoloa, in Sri Lanka

I. To inventory the teak plantation to get Teak tree stock and tree growth parameters.
II. 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.
III. To predict future tree growth, timber production and estimated timbervalue . This forecasting will help to take the remedial measures to manage the plantation efficiently to achieve the maximum benefit from the plantation.
IV. 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;

I. Should be conform to the objectives

II. Should provide adequate precision

III. Methodologically sound & follow statistical sampling criteria

IV. Have comprehensive transparent reporting & documentation

V. Overall credibility

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

2.1. Items 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, Clinometers, 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

2.2. 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.

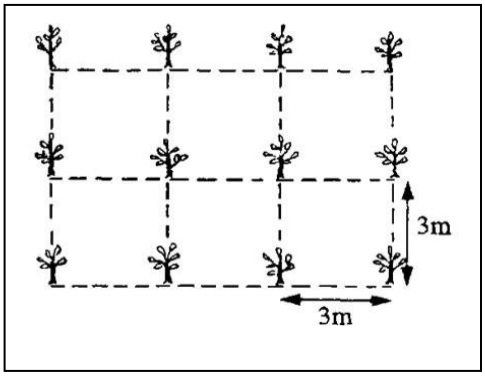
Asia Teak Group audit inventory the permanent square shape plots are used and for forest management review works, the temporary circular plots were used.

***Figure 2**. Corner boundary tree, painted with yellow color in square shape Plot and DBH measurement taken by diameter tape and height measurement of tree taken, by pole in Block 2 and plot number 3 and Block 2 and plot 1 in Batticoloa estate belong to Asia Teak.*

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

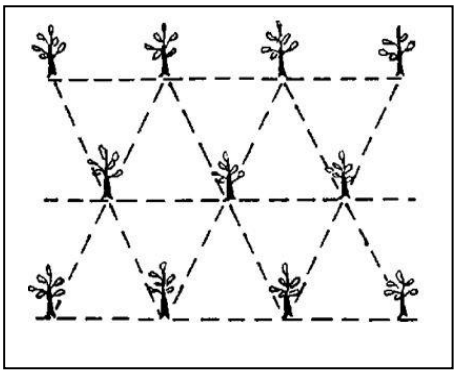
2.2.1. System of Planting

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.



Square system

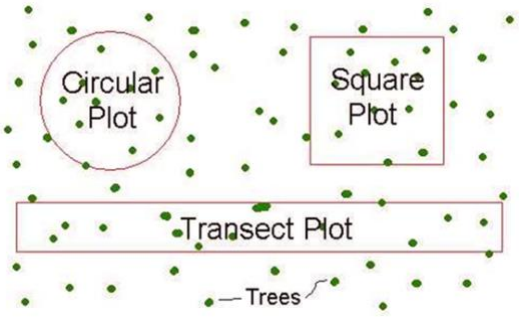
Triangular system :In this system, trees are planted as in the square system but the plants in the 2nd , 4th, 6th and such other alternate rows are planted midway between the 1st, 3rd, 5th and such other alternate rows. This system has no special advantage over the square system except providing more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



Triangular system

2.2.2. 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.

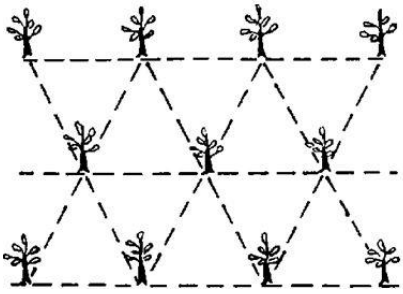


STOCKING RATE (STEMS/*HECTARE*)	PLOT SIZE (*HECTARES*)	RADIUS OF CIRCULAR PLOT (METRES)
100	0.2	25.2
200	0.1	17.8
400	0.05	12.6
500	0.04	11.3
600	0.033	10.2
800	0.025	8.9
1000 +	0.02	8.0

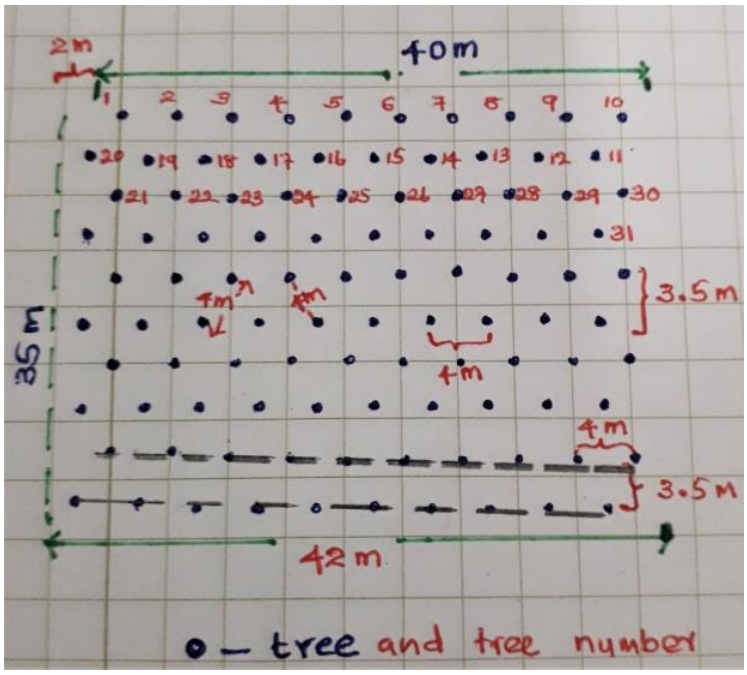
Various plot shapes

2.2.3. Plot size and planting system of Sri Lankan Asia Teak Plantation

Size of the plots is measured bypredetermined of tree spacemen (distance) and number of trees in each row.



All the plots of Puttalam are 80m x 20 m (1600 m2)



All the plots of block 01, Block 3, Block 4, and Block 5 of Batticalao are 42m x 35m. (1470m²)

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.

$C = 2\pi r = d; \quad d = C/\pi$

In this study, Diameter tape is used.

Figure 2.1: Diameter tape used for forest inventory

2.3.2. 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.

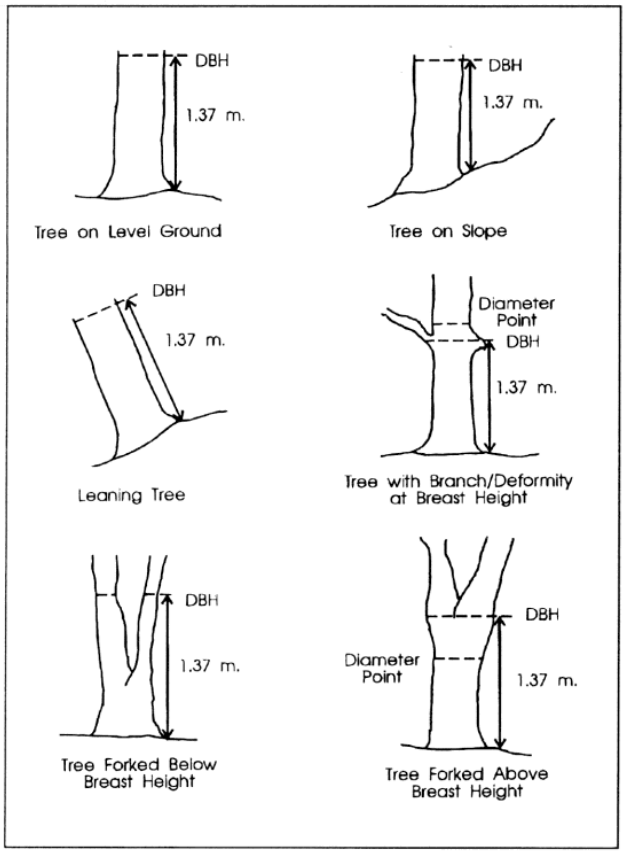


Figure 2.2: Standard rules governed to measure diameter at breast height

2.3.3. 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

2.3.3.1. 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 2.3. Total Tree height was measured by hypsometer and a pole, used instrument of sununto meter is shown in above

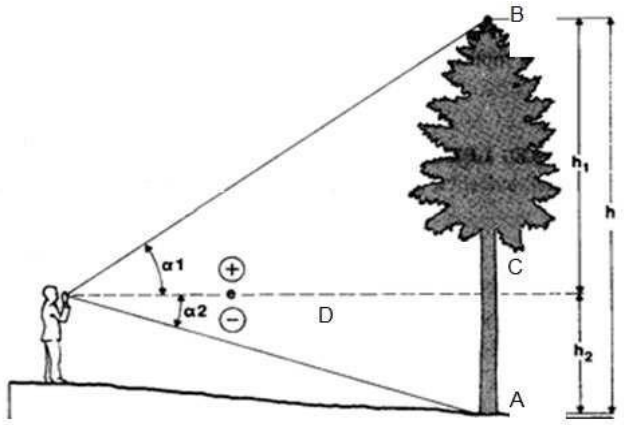
Figure 2.4. Correct horizontal distance between tree and height observer is being positioned

2.3.3.2. General steps for Hypsometer are bellow

- 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.

Figure 2.5: Tree height measurement on a flat terrain.



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)

3. Results of inventory of teak plantation

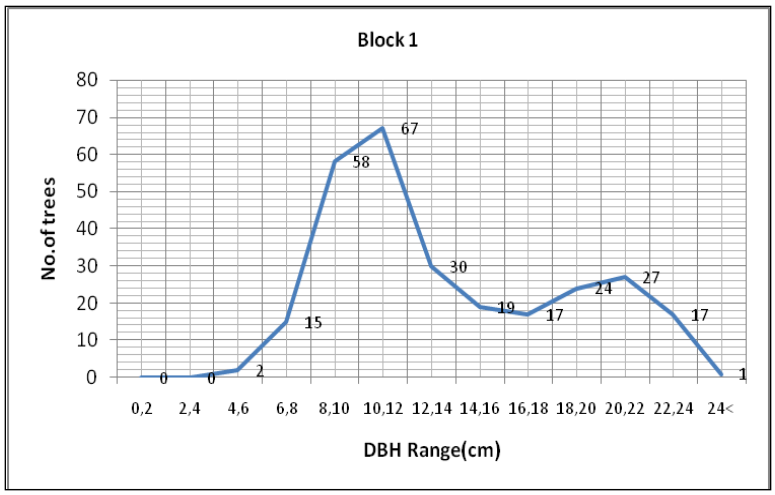
3.1. Teak Plantation of Batticaloa

Table 3.1. Number of trees and tree mean DBH values in plots in Batticaloa

Plot number (P)	Block 01			Block 02			Block 03		
	No.of trees	Mean DBH (cm)	Mean height (m)	No. of Trees	Mean DBH (cm)	Mean height (m)	No. of Trees	Mean DBH (cm)	Mean height (m)
1	91	10.69	8.5	93	12.64	9.6	93	10.98	7.65
2	90	10.37	7.1	65	9.93	8.75	96	12.56	8.2
3	96	19.65	18.5	79	13.3	8.96	89	12.23	7.75
4				65	9.96	6	91	9.06	6.2
Mean	**92**	**13.57**	**11.37**	**75.5**	**11.45**	**8.33**	**92.5**	**11.21**	**7.45**
Total	**277**			**302**			**369**		

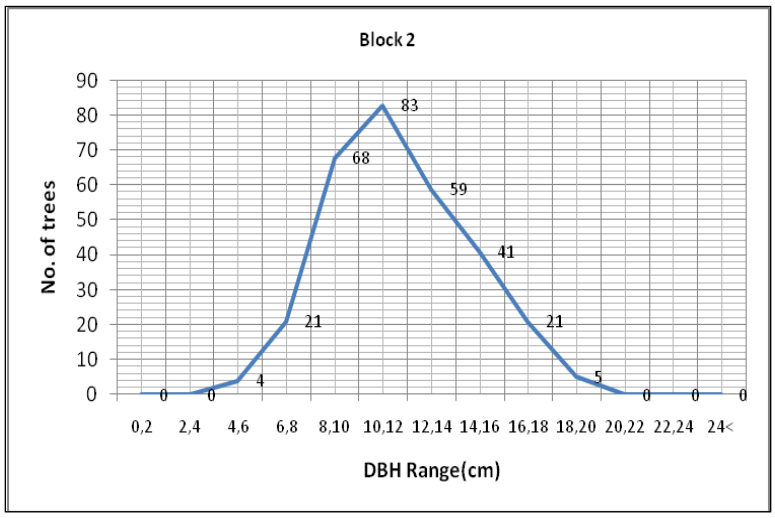
Plot number (P)	Block 04			Block 05		
	No. of trees	Mean DBH (cm)	Mean height (m)	No. of trees	Mean DBH (cm)	Mean height (m)
1	92	12.68	8.2	43	7.15	5.8
2	89	12.04	8.85	50	10.54	6.7
3	53	7.20	5.4	76	11.07	7.35
4				69	9.24	6.7
5				66	9.62	7.2
6				89	11.42	8.5
Mean	**58**	**10.64**	**7.48**	**65.5**	**9.84**	**7.04**
Total	**234**			**393**		

Graph 3.1: Number of trees against to average DBH range values in Blocks in Batticolao



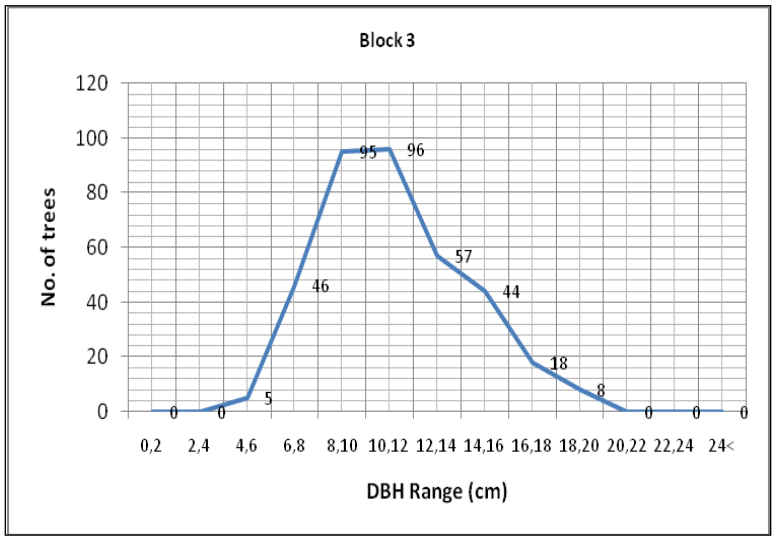
Out of 277 of trees, 105 trees are having more than 14 cm dbh. Mean dbh is 13.57cm

It can be assumed that in block no.1. out of 2041 trees, There are 773 trees having more than 14 cm DBH category.



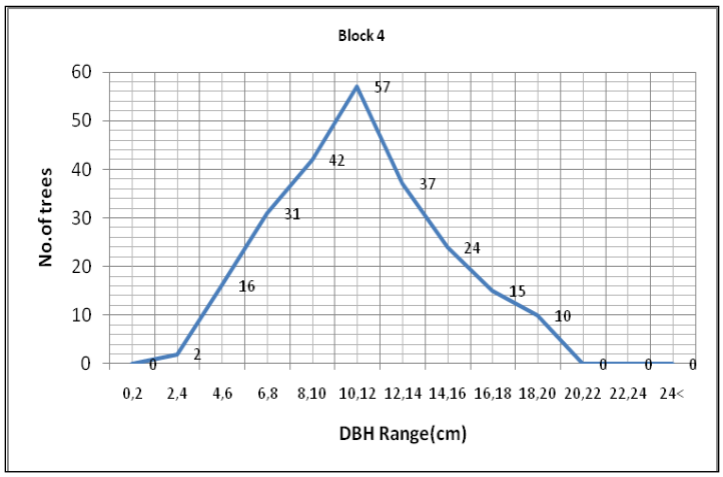
Out of 302 of trees, 126 trees are having more than 12 cm dbh. Mean dbh is 11.45

It can be assumed that in block no.2. out of 3633 trees, There are 1515 trees having more than 12cm DBH category.



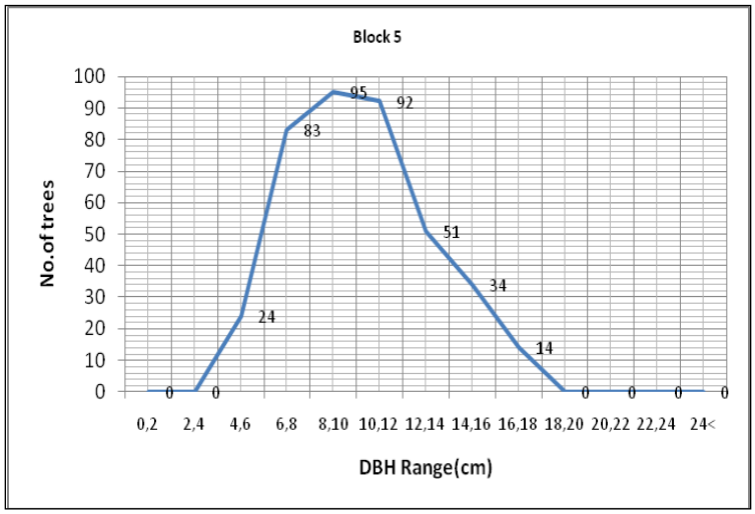
Out of 369 trees, trees are 127 having more than 11cm dbh. Mean dbh is 11.2cm

It can be assumed that in block no.3. out of 3082 trees, There are 1060 trees having more than 11cm DBH category.



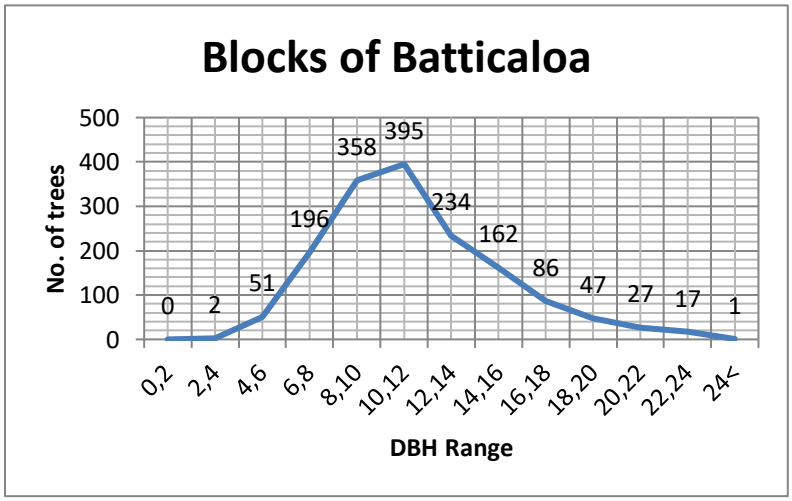
Out of 234 of trees, 86 trees are having more than 11 cm dbh. Mean dbh is 10.64cm

It can be assumed that in block no.4. out of 2499 trees , There are 918 trees having more than 11cm DBH category.



Out of 393 trees, 99 trees are having more than 10cm dbh. Mean dbh is 9.84 cm

It can be assumed that in block no.5. out of 4519 trees, There are 1138 trees in having more than 10cm DBH category.



Mean block DBH is 11.34 cm. Out of 1576 trees, 574 trees are more than mean dbh value (10-12 cm). Out of total block trees of 15774 there are 5745 trees are more than 10-12 cm of DBH.

Figure 3.1. View of different blocks in Batticoloa plantation

Block 01-plot 03- Mean DBH is 19.65cm and height is 18.5m. Selective thinning is recommended due to canopy competition.

Block 2-plot 03.-Mean DBH is 13.3cm and height is 8.96m

Block 3 plot 01-Mean DBH is 10.98cm and height is 7.65m

Block 4-plot 01-Mean DBH is 12.68cm and height is 8.2m

Block 5-plot 03. Mean DBH is 11.07cm and height is 7.35m. Mechanical weeding done

Table 3.2. Estimated number of trees having more than its mean DBH value in Batticaloa teak Plantation

Estate	Block no and its mean dbh value.	No. of trees more than its mean DBH in Block and its %
Batticaloa	1 and 13.57 cm	773 (37%) from 2041 trees
	2 and 11.45 cm	1515 (41.7%) from 3633 trees
	3 and 11.2 cm	1060 (34%)from 3082 trees
	4 and 10.64cm	918 (36.7%) from 2499 trees
	5 and 9.84cm	1138 (25%)from 4519 trees
	Estate total mean 11.34 cm	5745(36%) from 15774 trees

Table 3.3. Mean block growth parameter of Batticoloa plantation

Block no.	Total tree number in plots	Mean tree number per ha	Mean DBH (cm)	Mean Height (m)
Block 1	**277**	**628**	**13.57**	**11.37**
Block 2	**302**	**513**	**11.45**	**8.33**
Block 3	**369**	**627**	**11.21**	**7.45**
Block 4	**234**	**530**	**10.64**	**7.48**
Block 5	**393**	**445**	**9.84**	**7.04**
block mean	**315 (total 1575)**	**549**	**11.34**	**8.33**

Table 3.4 Growth parameters and growth rate of Batticaloa teak plantation based on mean data of samples plots taken. Size of plot is 42mx35m (1470m2)

Table 3.4.1.		Batticaloa Block 1 (planted area appro. 3.36 ha) Planted year 2012.july to 2013 December.			
Age (year)	**Measurement taken year**	**Total no. of tree**	**No. of trees per ha**	**DBH (cm)**	**Height (m)**
2	2014	2474	736		
3	2015	2499	743	6.3	5.0
4	2016	2380	708	8.1	6.0
5	2017	2292	682	9.0	6.6
6	2018	2305	686	10.6	8.2
7	2019	2230	663	11.4	9.1
8	2020	2129	633.6	12.65	11
9	2021	2041	628	13.57	11.37

Table 3.4.2.		Batticaloa Block 2 (planted area app. 6.75 ha) Planted year 2012.july to 2013 December.			
Age (year)	**Measurement taken year**	**Total no. of tree**	**No. of trees per ha**	**DBH (cm)**	
2	2014	4532	671		
3	2015	4355	645	2.7	2.3
4	2016	4213	624	5.0	4.0
5	2017	4114	609	6.1	4.7
6	2018	4159	616	8.4	6.1
7	2019	4308	638	9.7	6.9
8	2020	3742	554	10.27	7.4
9	2021	3633	513	11.45	8.33

Table 3.4.3		Batticaloa Block 3(planted area app. 5.5 ha ?) Planted year 2012.july to 2013 December.			
Age (year)	**Measurement taken year**	**Total no. of tree**	**No. of trees per ha**	**DBH (cm)**	**Height (m)**
1	2014	4386	797		
2	2015	4248	772		
3	2016	4355	792	4.0	3.2
4	2017	4169	758	6.1	4.9
5	2018	3972	722	7.3	5.3
6	2019	3982	724	8.7	6.4
7	2020	3350	629	9.64	7.7
8	2021	3080	627	11.21	7.45

Table 3.4.4		Batticaloa Block 4 (planted area app. 4.73 ha) Planted year 2012.july to 2013 December.			
Age (year)	Measurement taken year	Total no. of tree	No. of trees per ha	DBH (cm)	Height (m)
1	2014	3338	705		
2	2015	3102	655		
3	2016	3322	702	4.2	3.5
4	2017	3240	685	5.3	4.1
5	2018	3162	668	7.5	5.6
6	2019	3282	694	8.3	6.3
7	2020	2729	577	9	6.6
8	2021	2499	530	10.64	7.48

Table 3.4.5		Batticaloa Block 5(planted area app. 9.2 ha ?) Planted year 2012.july to 2013 December.			
Age (year)	Measurement taken year	Total no. of tree	No. of trees per ha	DBH (cm)	Height (m)
0	2014	6625	720		
1	2015	5926	644		
2	2016	6760	734		
3	2017	6061	658	4.0	3.3
4	2018	6320	686	6.6	5.2
5	2019	6343	689	7.2	6.0
6	2020	4832	493	8.35	6.6
7	2021	4519	445	9.84	7.04

Table 3.5. Batticaloa block growth parameter with age

Batticaloa all Blocks Planted year 2012.july to 2013 December				MAI and (CAI)	MAI and (CAI)
Age (year)	Measurement taken year	DBH (cm)	Height (m)	For DBH (cm)	For Height (m)
3	2015	4.24	3.46	1.41	1.15
4	2016	6.22	4.84	1.55 (1.98)	1.21 (1.38)
5	2017	7.42	5.64	1.48 (1.2)	1.13 (0.8)
6	2018	8.87	6.72	1.48(1.45)	1.12 (1.08)
7	2019	9.93	7.57	1.42 (1.06)	1.08 (0.85)
8	2020	10	7.86	1.25 (0.07)	0.98 (0.29)
9	2021	11.34	8.3	1.26 (1.34)	0.92 (0.44)

Table 3.6. Sri Lankan Teak Plantation tree count.

Comparison Tree Audit 2020-2021 in Batticolao

Estate Name	Block number	Geophysics count trees 2020						Geophysics count trees 2021					
		Total good trees	No.of small/poor trees	Marked for thinning	Reserved tree	Total trees	Differences 2019 vs 2020	Total good trees	No.of small /poor trees	Marked for thinning	Reserved trees	Total trees	Differences 2021 vs 2020
Batticolao	B1	1619	257	14	239	2129	101	1573	230		238	2041	88
	B2	2960	782			3742	566	2940	693			3633	109
	B3	2795	555			3350	632	2833	249			3082	268
	B4	2337	392			2729	553	2321	178			2499	230
	B5	3638	1194			4832	1511	3619	900			4519	313
	Total all blocks	**13349**	**3180**	**14**	**239**	**16782**	**3363**	**13286**	**2250**		**238**	**15774**	**1008**

Table 3.7. Sample plots information, planted area and tree inventory data in year 2021 of Batticolao,

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)
Batticolao	1	2041	3.66	3	4410 (1470x3)	277	628	13.57	11.37
	2	3633	7.35	4	5880 (1470x4)	302	513	11.45	8.33
	3	3082	4.8	4	5880 (1470x4)	369	627	11.2	7.45
	4	2499	4.69	3	4410 (1470x3)	234	530	10.64	7.48
	5	4519	9.1	6	8820 (1470x6)	393	445	9.84	7.04
	total	**15774**	**29.5 ha from 48 ha**	**total 20**	**Total 29400 (2.94ha)**	(mean 315) Total 1576	**Average 549**	AVERAGE 11.34	Average 8.3

Table 3.8. Comparison of tree parameters between year 2020 and 2021 in Batticolao plantation.

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 appro.(m)	No. of trees measured for DBH	No of trees for ha.	Average DBH (cm)	Average height appro.(m)	**Variance in DBH (cm)& Height (-) 2021 vs 2020**
Batticolao	B1	3	279	632	12.65	11	277	628	13.57	11.37	**0.92cm (0.37m)**
	B2	4	326	554	10.27	7.4	302	513	11.45	8.33	**1.2cm (0.93 m)**
	B3	4	370	629	9.64	7.7	369	627	11.2	7.45	**1.56cm**

										(m)
	B4	3	254	576	9	6.6	234	530	10.64	7.48	**1.64cm (0.88m)**
	B5	6	435	493	8.35	6.6	393	445	9.84	7.04	**1.49cm (0.44m)**
		Total 20	Total 1664	Ave. 577	AVE. 9.6	Ave. 7.9	Total 1575	**Ave. 549**	AVE. 11.34	Ave. 8.3	**Ave. 1.74 m (0.4m)**

Table 3.9.Tree volume and other growth parameters of plantations were estimated based on age of plantation, form factors and inventory data of Batticaloa plantation.

Tree age or inventory year 2021	**AGE OF THE PLANTATION IS 9 YEARS OLD Planted year 2012.july to 2013 December AND FORM FACTOR IS 0.45**							
Block N0.	Total trees	No.of stems/ha	DBH (cm)	Height (m)	Per Tree volume (m3)	Trees volume m3/ha	Total volume In block (m3)	MAI (m3/ha/ year
1	2041	628	13.57	11.37	0.0738	46.3	150.6	5.1
2	3633	513	11.45	8.33	0.0385	19.75	139.8	2.1
3	3082	627	11.2	7.45	0.0330	20.69	101.7	2.3
4	2499	530	10.64	7.48	0.0299	15.84	74.7	1.3
5	4519	445	9.84	7.04	0.0535	23.8	241.7	2.6
	15774 (total)	**Ave. 549**	AVE. 11.34	Ave. 8.3	Mean=0.045	Mean=25.27	GRAND TOTAL=708.5 (mean 141.7)	Grand mean=2. 6

Table 3.10. Determination of site index based on growth parameters of past years of Batticaloa

Batticaloa plantation age is 9 years (Batticoloa,**Planted year 2012.july to 2013 December**)

Estate	Block no.	No. of Plots	2013 Ave. DBH (cm)	2014 Ave. DBH (cm)	2015 Ave. DBH (cm)	2016 Ave. DBH (cm)	2017 Ave. DBH (cm)	2018 Ave. DBH (cm)	2019 Ave. DBH (cm)	2020 Aver. DBH(cm)	2021 AVER. DBH(cm)	DBH differences from Year of first measurement t (Mean Increment of DBH cm)
Batticolao	1	3				6	6.6	8.2	9.1	12.65	13.57	7.57 (mean DBH 1.55)
	2	4			2.9	5	6.1	8.4	9.7	10.27	11.45	8.55 (1.27)
	3	4				4	6.1	7.3	8.7	9.64	11.2	7.2 (1.2)
	4	3				4.2	5.3	7.5	8.3	9	10.64	6.44 (1.18)
	5	6					4	6.6	7.2	8.35	9.84	5.8 (1.09)
	Estate average				**2.9**	**4.8**	**5.62**	**7.6**	**8.6**	**9.98**	**AVE. 11.34**	**8.44 (1.26)**

4. Forest management and silvicultural activities observed

4.1. Application of fertilizer

13:15:13 NPK 400g per tree applied during the period of 2021 feb to 2021 March.

500g of Dolamite per tree applied for 1200 trees and fertilizer is available for another 3800 trees.

10kg organic fertilizer per tree applied for 2800 trees (2300 trees in block 4 and 500 trees in block (3). This was done during the period of 2020 march to 2020 may.

4.2. Pruning activities

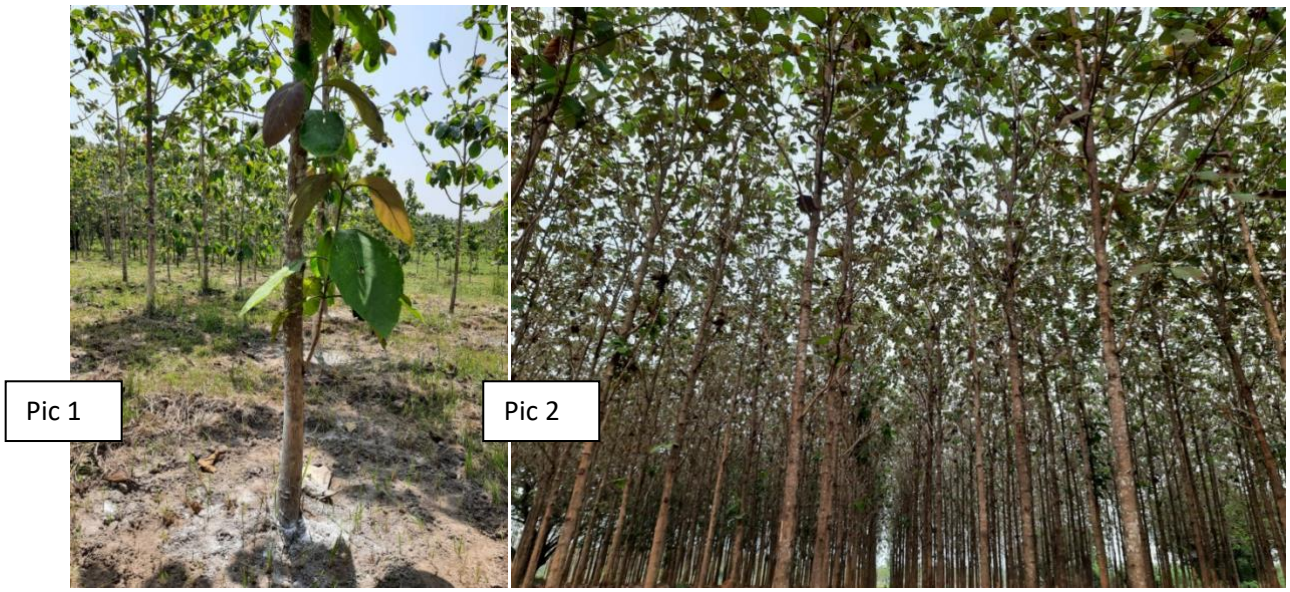
First round of pruning was completed in 2020 may to 2020 June.

Second round of pruning was started from 2021 February.

4.3. Weeding

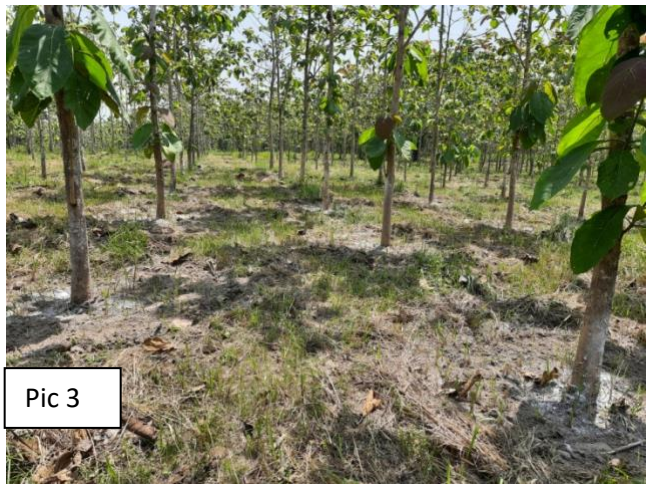
First round of weeding was completed during the period of 2020 June to 2020 December.

Second round of weeding started from 2021 February.



Pic 1: Young teak sapling having branches on stem. these branches are being cut.

Pic 2. Teak trees in Block 1 Plot3 are having canopy competition. Extra trees needs to be removed by identified thinning schedule.



Pic 3: Dolamite fertilizer with chemical fertilizer have been applied around the base of trees

Pic 4: Mechanical weeding has been carried out.

5. Observation, Conclusions and recommendation

I. Most of the recommendations given in 2020 audit report have already been implemented such as

I.1. Elephant fence maintenance and rebuild need to be reviewed and rectified to stop of elephant damage to Teak Plantation of Batticoloa.

I.2. Application of soil improvement method and soil erosion prevention methods must be applied where site has steep slope. It is observed that organic compost (cow dung) has been applied in between two row of planting tree lines. It is recommended to apply these cow dung only close proximity to tree. Otherwise most of compost quantity is utilized by weeds. Because teak trees root system has not growth enough widely to reach the compost.

I.3. In all the sites, concrete posts at corner of sample plot need to be reestablished otherwise unnecessary time is wasted to find the boundary of the plots. iv Pruning of the adventitious shoots should be carried out only after required training given under close supervision.

II. It is observed that trees in some blocks are competing for sunlight hence specific thinning schedule to be applied for particular areas. When excess trees build up the canopy and root completion 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. Selective thinning must be applied after careful study of tree growth parameters given in graphs 3.1 by one to one tree inspection. Thinning regime can be decided in relation to tree age and number of stem /ha, canopy closer, tree inventory data and tree annual rings information.

III. Control fire or fire lines must be properly maintained.

Finally it can be concluded that Batticoloa Teak plantations are healthy and good condition. There is good potentiality to get better growth increment particularly for diameter growth for next 11 years if the plantation is maintained and managed scientifically.