TEAK TREE INVENTORY AND AUDIT REPORT-2024

CONDUCTED FOR

ASIA TEAK GROUP

AT

Anamaduwa Teak Plantation

Sri Lanka

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Contents

Content of Tables

Content of Figures

Content of graphs

(1)   Executive summary

Anamaduwa Teak plantations is one of three teak plantations ,namely Batticoloa, Anamaduwa and Puttalum plantations , managed by Asia Teak Tropical Plantation was inspected by Mr.J.M.P. Jayalath and me on 2024.3.8 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 measurements of 262 trees were taken from Anamaduwa plantation by mean of four sample plots.

i. Anamaduwa Teak Plantation

Four sample plots having with total sample area of 3600 m2 have been permanently setup in different locations in Anamaduwa plantation. It is found by this study that total estimated planted area is 4.18ha (out of 4.8ha) and sample plots represent 8.6 % of population. In this study, 262 trees were measured for DBH measurement and around 1 8 trees for height measurement taken by hypsometer and pole. We applied all the international standards when measuring the tree parameters such as DBH and Height. There are 2977 trees in this plantation in which 262 trees measured for DBH, which represent 8.7% of population. However we marked 330 trees to be thinned out in this inspection.

The inventory results show that there are 2977 trees (2647 good trees and 330 were identified for thinning. The average DBH and Height of trees in the estate is 17.1 cm and 16.1 m respectively. It is found that average trees per ha is 712.   In 2024 audit it is found that 21 trees are less than 2023 audit figures which may be mainly due to die or rarely uprooted. Details of block wise tree information are shown in table 3-9.

 Analyzing inventory tree data, it is found that more than 36 % of trees are having DBH more than 16-18 cm of mean DBH value for Anamaduwa plantation that means, out of 2977 trees. There are 1079 trees having more than 16-18cm DBH. Plantation results are given in graphs, see page 9. Growth parameters from establishment of the plantation are summarized in table 3-4.These findings can be used for future planning of thinning and final mode of harvest.

After analyzing the last 14 years of growth and DBH data of 2013-2024, mean annual increment for DBH and Height is 1.22 cm and 1.15 m respectively. This site growth parameters are useful to find out suitable or complying 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 some time ago as sample to determine the form factor and actual volume of tree(see table 8). The 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 mean volume per tree of Anamaduwa was found as 0.166m^3. The mean tree volume for ha is 118.2 m^3. Furthermore it is estimated that this plantation contain of 494m^3. Growth parameters from establishment of the plantation are summarized in table 3-4. 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). The yield table intended to prepare, will solve this question.

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 plantation at end of felling rotation.

Finally it can be concluded that this teak plantation are healthy and good condition. There are much more potential to get more growth increment particularly for tree stem diameter for next 6 years if the plantation is maintained and managed scientifically according to thinning planned. High density trees or more trees per ha cannot produce the trees with larger log. In year 2024, we selected 330 inferior trees to be thinned out as light second thinning and next thinning, we propose to remove another 155 trees from the plantation.

(2)   Introduction

i.   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.

ii.   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.

Table 1: Thinning regime developed for Anamaduwa plantation based on planted area 4.18ha.
(This thinning regime is prepared for already decided, remained tree number for final felling)

Age/ Year	Main crop before thinning					Crop removed				
	Tree No.	Trees / ha	Mean DBH (cm)	Mean Height (m)	Tree Vol. (m³) or Tree Vol. / ha	Tree No.	Trees / ha	Mean DBH (cm)	Mean Height (m)	Tree Vol. (m³) or Tree Vol. / (ha)
10/ 2020	3683	881	14.3	13.3	0.094/844					
11/ 2021	3683	881	15.67	14.6		673	161	First Thinning		
12/ 2022	3010	720	16	15						
13/ 2023	2998	717	16.6	16						
14/ 2024	2977	712	17.1	16.1		330	78	Light second thinning		
15/ 2025	2647	633								
16/ 2026	2647	633				155	37	Second Thinning		
17/ 2027	2492	596								
18/ 2028	2492	596								
19/ 2029	2492	596								
20/ 2030	2492	607						Final felling		

iii. 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 Puttalam teak plantation.
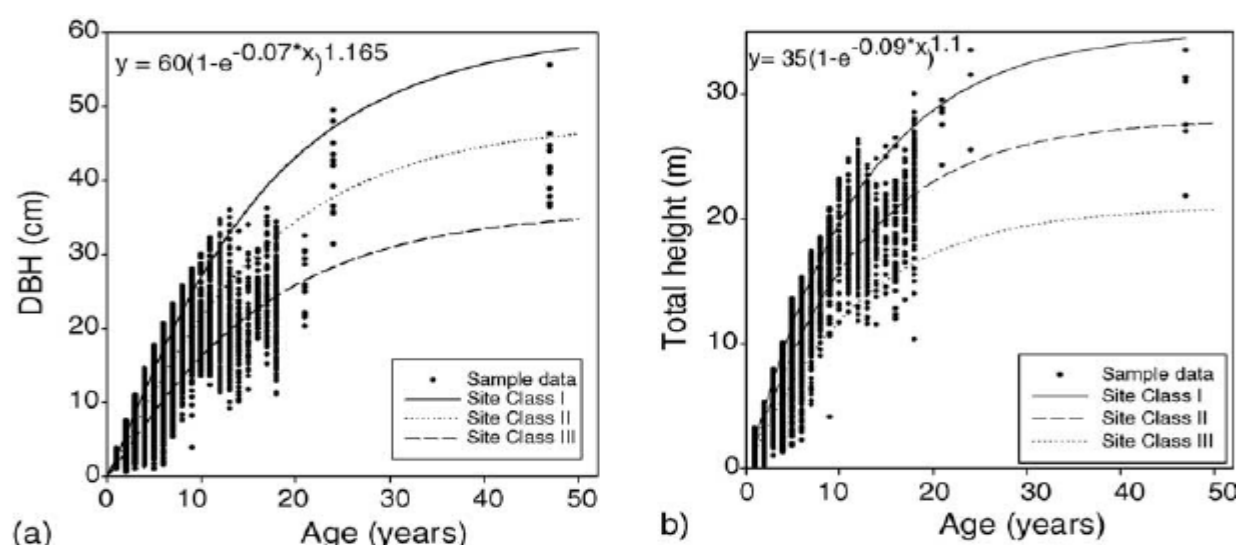
Graph 1 : (A)-Teak growth curve: DBH against age (B)-Teak growth curve: Total height against age

iv. 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.

v. 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.

(3)   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.

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

i. 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.
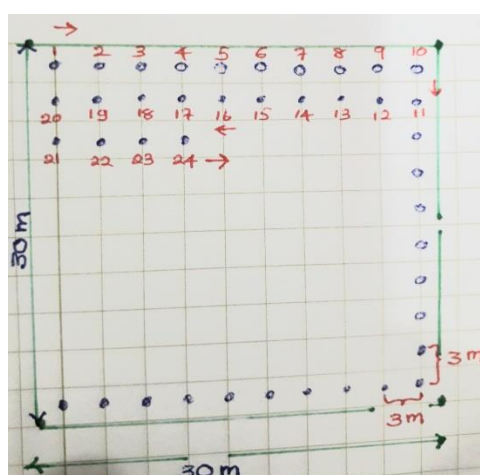
Figure 1: All the plots of Anamaduwa are 30m x 30m (900 m^2)

10 trees from vertical and horizontal rows were included to plot area. Tree spacing is 3m x 3m

ii. 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.

a. 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 tape used for the inventory

iii. 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

a. 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: instrument of sununto meter

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

Figure 4: horizontal distance between tree and height

Correct horizontal distance between tree and height observer is being positioned

(4)   Results of inventory of teak plantation-year 2024
i. Teak Plantation of Anamaduwa

Table 2 *:* Number of trees and tree mean DBH values in plots in Anamaduwa

Plot number (P)	No. of trees	Mean DBH (cm)	Mean Height (m)
1	66	19.4	16.3
2	67	16.7	16.4
3	63	16.1	13
4	66	16.3	18.5
mean	**65.5 (total 262)**	**17.1** DBH range (Max.27.8 and Mini 11.5) cm	**16.1**

Graph 2: Number of trees against to average DBH range values in Blocks in Anamaduwa

Anamaduwa Total

No. of trees vs **DBH Range**

Data points:
- 10,12: 2
- 12,14: 45
- 14,16: 55
- 16,18: 65
- 18,20: 49
- 20,22: 33
- 22,24: 10
- 24,26: 2
- 26,28: 1
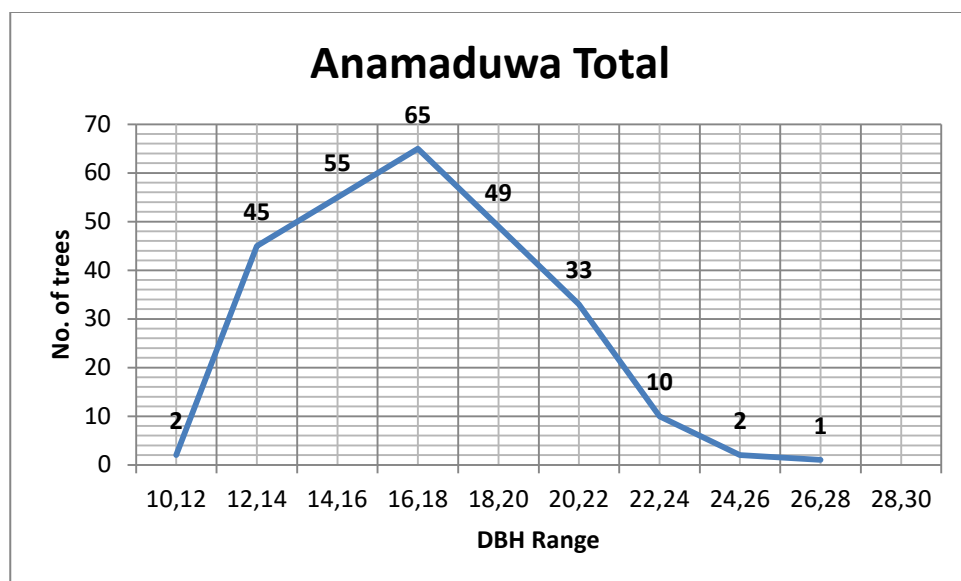
Out of 262 of trees, 95 trees are having more than 16 - 18cm dbh. (Mean value is 17.1 cm)

It can be assumed that in block no.1. Out of 2977 trees, There are 1079 trees having more than 16-18 cm DBH category.

Estate	Block no and its mean dbh value.	No. of trees more than its (16-18cm) mean DBH in Block 1 and its %
Anamaduwa	1 and 17.1 cm	1079 (36%) from 2977 trees

Figure 5: Preparation for forest inventory with the hypsometer and other instruments

Figure 7: A part of teak plantation in Anamaduwa

Figure 6: Inferior Trees are being marking for thinning

Table 3: Growth parameters & growth rate of Anamaduwa teak plantation based on mean data of samples plots taken

Age (year)	Measurement Taken year	Total no. of tree	No. of trees per ha	DBH (cm)	Height (m)
Anamaduwa (planted area app. 4.18 ha from 4.8ha) Planted year. 2009/2010
3	2013			6.6	6
4	2014	4521	1081	8.2	7.1
5	2015	4464	1068	10	7.5
6	2016	4514	1079	11.2	10.3
7	2017	4462	1067	12.1	11.3
8	2018	4264	1020	12.4	11.8
9	2019	4036	965	13.6	12.5
10	2020	3683	881	14.37	13.3
11	2021	3646(before thinning)	872	15.67	14.68
12	2022	3010	720	16	15
13	2023	2998	717	16.6	16
14	2024	2977	712	17.1	16.1

Table 4: Anamaduwa block growth parameter with age

Age (year)	Measurement taken year	DBH(cm)	Height (m)	MAI and (CAI) For DBH (cm)	MAI and (CAI) For height (m)
Anamaduwa Planted year 2009/2010
3	2013	6.6	6	2.2	2
4	2014	8.2	7.1	2.05(1.1)	1.77(1.6)
5	2015	10	7.5	2 (0.4)	1.5 (1.8)
6	2016	11.2	10.3	1.86(1.2)	1.72(2.8)
7	2017	12.1	11.3	1.73(0.9)	1.61(1)
8	2018	12.4	11.8	1.55(0.3)	1.47(0.5)
9	2019	13.6	12.5	1.51(1.2)	1.51(0.7)
10	2020	14.37	13.3	1.43(0.77)	1.44(0.8)
11	2021	15.67	14.68	1.42 (1.3)	1.33 (1.38)

12	2022	16	15	1.33 (0.33)	1.25 (0.32)
13	2023	16.6	16.5	1.27 (0.6)	1.26 (1.5)
14	2024	17.1	16.1	1.22 (0.5)	1.15(-)

Only few height measurement taken

Table 5: Sri Lankan Teak Plantation tree count. Comparison Tree Audit 2023-2024 in Anamaduwa

Estate Name	Block number	Geophysics count trees 2023						Geophysics count trees 2024					
		Total good trees	No.of small/poor trees	Reserved trees	Marked for thinning	Total trees	Differences 2022 vs 2023	Total good trees	No.of small /poor trees	Marked for thinning	Reserved trees	Total trees	Differences 2023 vs 2024
Anamaduwa	B1	2912		86	Already removed in April 2021	2998	12	2647		330		2977	21

Table 6: Sample plots information, planted area and tree inventory data and tree thinning information in year 2024 of Anamaduwa

Estate	Block no	Total trees in block(B1)	Estimated planted area (ha)	No. of Plots	Plots area in block B1 (m²)	Year 2024				Tree Thinning information		
						No. of trees measured for DBH in Block of sub blocks	No of good trees.	Average DBH (cm)	Average height approx.(m)	No. of trees thinned	Mean DBH of thinned trees (cm)	Mean Height of thinned trees(m)
Anamaduwa	Sub Block 1	550	0.6	4	3600 (900x4)		508			42		
	Sub Block 2	636	1				566			70		
	Sub Block 3	671	1				596			75		
	Sub Block 4	723	1				625			98		
	Sub Block 5	397	0.5				352			45		
		2977	4.18	4	3600		529	17.1	16.1	330		

**** In future forest inventory, one new plot will be introduced into Block 03 which is not covered in present 4 plots

Table 7: Comparison of tree parameters between year 2023 and 2024 in Anamaduwa

Estate	Block no.	No. of Plots	Year 2023				Year 2024				
			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 approx.(m)	Variance in DBH (cm) & Height (-) 2024vs 2023
Anamaduwa	B1	4	263	717	16.6	16.	262	712	17.1	16.1	0.5 cm (0.1m)

Table 8: Tree volume and other growth parameters of plantations were estimated based on age of plantation, form factors and inventory data of Anamaduwa plantation

Tree age or inventory year 2024		AGE OF THE PLANTATION IS 14 YEARS OLD Planted year 2009/2010 AND FORM FACTORIS 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 (m^3)	MAI (m$^{3/}$ha/year)
B1	2977	712	17.1	16.1	0.166	118.2	494	8.44

Table 9: Determination of site index based on growth parameters (DBH) of past years of Anamaduwa plantation
Anamaduwa, 14 years old (Annamaduwa, planted 2009 October)

Estate	Block No	No. of Plots	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	DBH differences from Year of First Measurements to 2024 and (Mean Increment of DBH cm) and periodic increment of DBH {} from First measured year.
Anamaduwa	B1	4	6.6	8.2	10	11.2	12.1	12.4	13.6	14.37	15.67	16	16.6	17.1	10.5 ,(1.22) {0.95}

(5)   Observation, Conclusions and Recommendation

(1) The mean tree volume for ha has increased from 115.1 in 2023 to 118.2 m^3 in 2024, Furthermore it was estimated that this plantation contain of 479m^{3}in 2023 and it has increased to 494 m3 in 2024.

(2) Results section of this report shows all the necessary information from planting year of this plantation to present audit year. Mean Annual increment for DBH and height are 1.22 cm and 1.15 m respectively.

(3) Number of trees having more than 14-16 cm DBH values have increased from 1407 in 2022 to 1818 in 2024.

(4) Number of trees per ha has reduced from 1081 ha to 712 tree per ha during the period of 14 years growing of trees. After thinning of 330 trees in 2024, this number become to 633 per hectare. According to thinning regime, this number can be reduced upto 607 per ha which have been decided with establishment of plantation. However this high tree number may negatively affect for diameter growth of trees.

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