

TEAK TREE INVENTORY AND AUDIT REPORT-2023

CONDUCTED FOR

ASIA TEAK GROUP

AT

Anamaduwa Teak Plantation

Sri Lanka

DR.NIMAL RUWANPATHIRANA

2023 April

Contents

(1) Executive summary	3
i. Anamaduwa Teak Plantation	3
(2) Introduction	4
i. General Introduction of Teak (<i>Tectona grandis</i>) Plantation	4
ii. Activities of teak stand maintenance.....	4
iii. Teak growth parameters.....	5
iv. Forest Plantation Audit process and Objectives	5
v. Objectives of present forest inventory and Audit of Teak Plantation in Anamaduwa in Sri Lanka.....	5
(3) Methodology of forest inventory.....	6
i. Plot size and planting system of Sri Lankan Asia Teak Plantation	6
ii. Basics of mensuration (Tree variables measurement)	6
a. Diameter tape	6
iii. Tree height measurement	7
a. Method of tree height measurement.....	7
(4) Results of inventory of teak plantation-year 2023	8
i. Teak Plantation of Anamaduwa	8
(5) Observation, Conclusions and Recommendation.....	13

Content of Tables

Table 1: Thinning regime developed for Anamaduwa plantation based on planted area 4.18ha.	4
Table 2 : Number of trees and tree mean DBH values in plots in Anamaduwa	8
Table 3: Growth parameters & growth rate of Anamaduwa teak plantation based on mean data of samples plots taken10	
Table 4: Anamaduwa block growth parameter with age.....	10
Table 5: Sri Lankan Teak Plantation tree count. Comparison Tree Audit 2022-2023 in Anamaduwa.....	11
Table 6: Sample plots information, planted area and tree inventory data and tree thinning information in year 2023 of Anamaduwa	11
Table 7: Comparison of tree parameters between year 2022 and 2023 in Anamaduwa	12
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.....	12
Table 9: Determination of site index based on growth parameters (DBH) of past years of Anamaduwa plantation.....	12

Content of Figures

Figure 1: All the plots of Anamaduwa are 30m x 30m (900 m ²).....	6
Figure 2: Diameter tape used for the inventory	7
Figure 3: instrument of sununto meter	7
Figure 4: horizontal distance between tree and height.....	8
Figure 5: Preparation for forest inventory with the hypsometer and other instruments.....	9
Figure 6: Tree height measurements is being taken by Hypsometer.....	10
Figure 7: A part of teak plantation in Anamaduwa.....	10

Content of graphs

Graph 1 : (A)-Teak growth curve: DBH against age (B)-Teak growth curve: Total height against age	5
Graph 2: Number of trees against to average DBH range values in Blocks in Anamaduwa	9

(1) Executive summary

Anamaduwa Teak plantations is one of three teak plantations ,namely Batticaloa, Anamaduwa and Puttalam plantations , managed by Asia Teak Tropical Plantation were inspected by Mr.J.M.P. Jayalath, Mr.Eranda Rathnamalala and me on 2023.4.7 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 263 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, 263 trees were measured for DBH measurement and around 16 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 2998 trees in this plantation in which 263 trees measured for DBH, which represent 8.7% of population.

The inventory results show that there are 2998 trees (2912 good trees and 86 for reserved trees). The average DBH and Height of trees in the estate is 16.6 cm and 16.5 m respectively. It is found that average trees per ha is 717. In 2022 tree count audit, out of 3010 total trees, there were 2925 good trees and 85 reserved trees. In 2023 audit it is found that 12 trees from total tree number are less than 2021 audit figures which may be mainly due to die or rarely uprooted. Details of block wise tree information are shown in table 3.1 and 3.9.

Analyzing inventory tree data, it is found that more than 53 % of trees are having DBH more than 14.-16 cm of mean DBH value for Anamaduwa plantation that means, out of 2998 trees. There are 1584 trees having more than 14-16cm DBH. Plantation results are given in graphs, see page 10. 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 13 years of growth and DBH data of 2013-2023, mean annual increment for DBH and Height is 1.27 cm and 1.26 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 0.16m³. The mean tree volume for ha is 115 m³. Furthermore it is estimated that this plantation contain of 479m³. 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 be 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 7 years if the plantation is maintained and managed scientifically according to thinning planned. High density trees or no trees per ha cannot produce the trees with larger log.

(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)

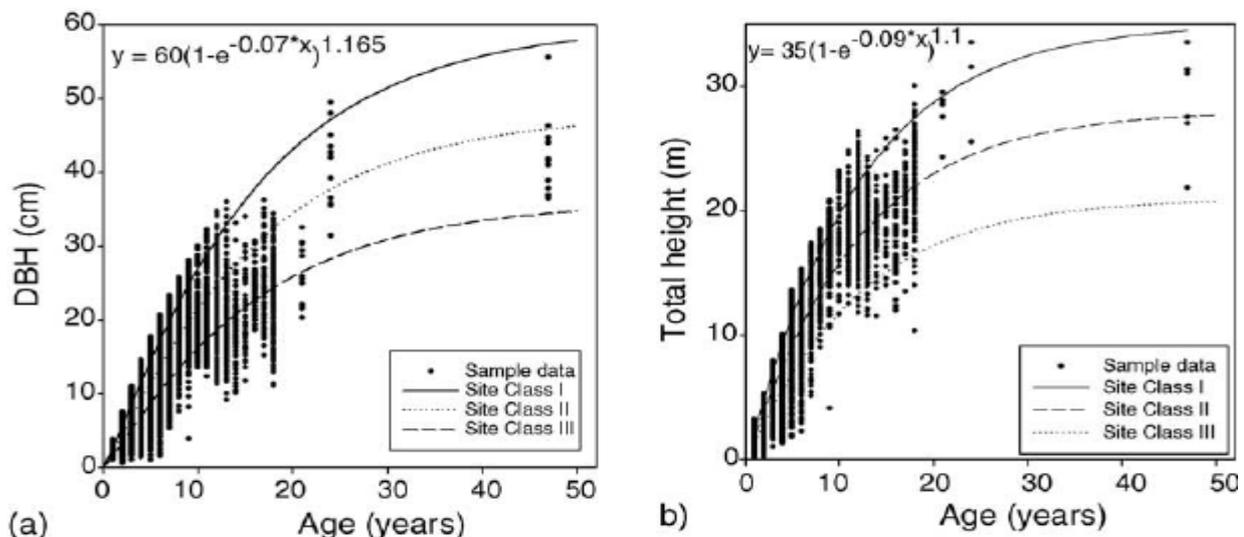
Age/ Year	Main crop before thinning					Crop removed				
	Tree No.	Trees / ha	Mean DBH (cm)	Mean Height (m)	Tree Vol. (m ³) or Tree Vol. / ha	Tree No.	Trees / ha	Mean DBH (cm)	Mean Height (m)	Tree Vol. (m ³) or Tree Vol. / (ha)
10/ 2020	3683	881	14.37	13.3	0.094/ 844					
11/ 2021	3683	881				673	161			First Thinning
12/ 2022	3010	720								
13/ 2023	3010	720								
14/ 2024	3010	720								
15/ 2025	3010	720								
16/ 2026	3010	720				518	123			Second Thinning
17/ 2027	2492	607								
18/ 2028	2492	607								
19/ 2029	2492	607								
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

- To inventory the teak plantation to get Teak tree stock and tree growth parameters.
- 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.
- 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.
- 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.

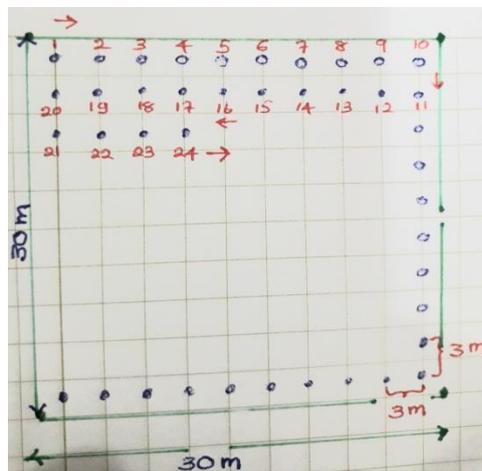


Figure 1: All the plots of Anamaduwa are 30m x 30m (900 m²)

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)

- Diameter measurement of a single standing tree
- 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

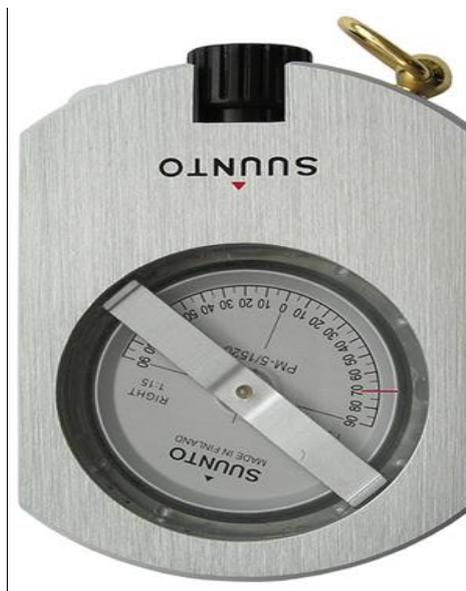


Figure 3: instrument of sununto meter

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

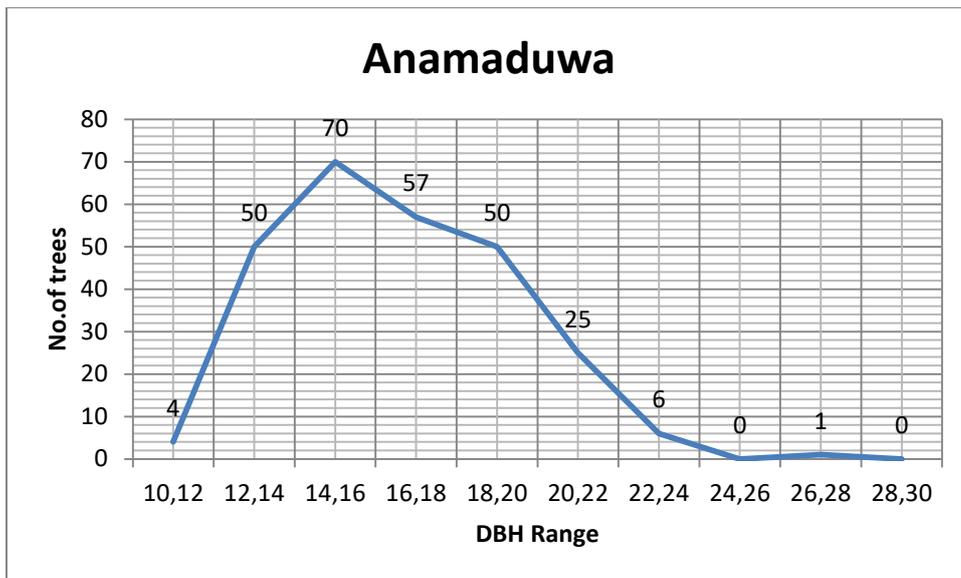
(4) Results of inventory of teak plantation-year 2023

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	18.5
2	67	16.1	17
3	63	15.8	15
4	67	15.6	15.5
mean	65 (total 263)	16.6 DBH range (Max.26.7 and Mini 11.5) cm	16.5

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



Out of 263 of trees, 139 trees are having more than 14 - 16cm dbh. (Mean value is 16.6 cm)

It can be assumed that in block no.1. Out of 2998 trees, There are 1584 trees having more than 14-16 cm DBH category.

Estate	Block no and its mean dbh value.	No. of trees more than its (14-16cm) mean DBH in Block 1 and its %
Anamaduwa	1 and 16.6 cm	1584 (53%) from 2998 trees



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



Figure 6: Tree height measurements is being taken by Hypsometer

Figure 7: A part of teak plantation in Anamaduwa

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

Anamaduwa (planted area app. 4.18 ha from 4.8ha) Planted year. 2009/2010					
Age (year)	Measurement Taken year	Total no. of tree	No. of trees per ha	DBH (cm)	Height (m)
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	16.5

Table 4: Anamaduwa block growth parameter with age

Anamaduwa Planted year 2009/2010				MAI and (CAI)	MAI and (CAI)
Age (year)	Measurement taken year	DBH(cm)	Height (m)	For DBH (cm)	For height (m)
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)

Only few height measurement taken

Table 5: Sri Lankan Teak Plantation tree count. Comparison Tree Audit 2022-2023 in Anamaduwa

Estate Name	Block number	Geophysics count trees 2022						Geophysics count trees 2023					
		Total good trees	No. of small/poor trees	Reserved trees	Marked for thinning	Total trees	Differences 2020 vs 2021	Total good trees	No. of small /poor trees	Marked for thinning	Reserved trees	Total trees	Differences 2022 vs 2023
Anamaduwa	B1	2925		85	Already removed in April 2021	3010	37	2912			86	2998	12

Table 6: Sample plots information, planted area and tree inventory data and tree thinning information in year 2023 of Anamaduwa

Estate	Block no	Total trees in block(B1)	Estimated planted area (ha)	No. of Plots	Plots area in block B1 (m ²)	Year 2023								
						No. of trees measured for DBH in Block of sub blocks	No of trees for ha.	Average DBH (cm)	Average height approx.(m)	Tree Thinning information				
										No. of trees thinned	Mean DBH of thinned trees (cm)	Mean Height of thinned trees(m)		
Anamaduwa	Sub Block 1		0.6	4	3600 (900x4)									
	Sub Block 2		1											
	Sub Block 3		1											
	Sub Block 4		1											
	Sub Block 5		0.5											
		2998	4.18	4	3600		717	16.6	16.5					

**** 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 2022 and 2023 in Anamaduwa

Estate	Block no.	No. of Plots	Year 2022				Year 2023				
			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 (-) 2023vs 2022
Anamaduwa	B1	4	261	720	16	15	263	717	16.6	16.5	0.6 cm (1.5m)

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 2022	AGE OF THE PLANTATION IS 13 YEARS OLD Planted year 2009/2010 AND FORM FACTORIS 0.45							
Block NO.	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	2998	717	16.6	16.5	0.160	115.1	479	8.85

Table 9: Determination of site index based on growth parameters (DBH) of past years of Anamaduwa plantation Anamaduwa, 13 years old (Annamaduwa, planted 2009 October)

Estate	Block No	No. of Plots	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	DBH differences from Year of First Measurements to 2023 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	10,(1.27) {1}

(5) Observation, Conclusions and Recommendation

- (1) The mean tree volume for ha has increased from 101 in 2022 to 115 m³ in 2023, Furthermore it was estimated that this plantation contain of 424m³in 2022 and it has increased to 479 m³ in 2023.
- (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 1.27 cm and 1.26 m respectively.
- (3) Number of trees having more than 14-16 cm DBH values have increased from 1407 in 2022 to 1584 in 2023.
- (4) Number of trees per ha has reduced from 1081 ha to 717 tree per ha during the period of 13 years growing of trees. 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.

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