TEAK TREE INVENTORY AND AUDIT REPORT 2023

CONDUCTED FOR

ASIA TEAK GROUP

AT

Batticaloa Teak Plantation

Sri Lanka

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Executive summary

Batticaloa Teak Plantation which was established during 2012 July to 2013 December is one of the largest Teak plantation among the three estates of Teak plantations namely Batticaloa, Anamaduwa and Puttalum plantations, managed by Asia Teak Tropical Plantation. Mr.J.M.P. Jayalath, Mr.Eranda Rathnamalala and me visited on 2023.4. 8 and9 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 1490 trees were taken from Batticaloa plantation and 20 sample plots which covers 2.94 ha area were used for forest inventory. It is estimated that total planted area of Batticaloa plantation is 29.5 ha. The total tree number is 14614 in Batticaloa,

Batticoloa Teak Plantation

Twenty sample plots having with total sample area of 29400 m2 have been permanently setup in different locations in Battcaloa 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, 1490 trees were measured for DBH measurement and height measurement of 80 trees was taken by hypsometer. We applied all the international standards when measuring the tree parameters such as DBH and Height. (See page 7-9). There are 14614 trees in this plantation in which 1490 trees measured for DBH which represent 10 % of population.

This inventory results show that there are 14614 trees (13611 good trees, 771 small and 232 reserved tree). The average DBH and Height of trees in the estate is 13.8 cm and 11.7 m respectively. It is found that average trees per ha is 514. In 2022 tree count audit, out of 15458 total trees, there were 13503 good trees, 1717 small and poor trees, and 238 reserved trees. In 2023 audit it is found that there are 844 trees less than from total tree number of 2022 audit which is mainly due to thinned out or may be uprooted/dyeing. Details of block wise tree information are shown in table 3.2 -3.10).

Analyzing inventory tree data, it is found that more than 42% of trees are having DBH more than 13.8 cm for Batticaloa plantation that means, out of 14614 trees. There are 6247 trees having more than 13.8cm DBH. Block wise results are given in graphs, see page, 10-13. The descending order of mean DBH values of Block 1. Block 3, Block 4, Block 2 and Block 5 are given 15.2cm, 14.2cm, 13.7cm, 13.4cm, and 12.8cm respectively. According to table 3.4.1-3.4.5. Current Annual Increment results show that Block 3 and 4 have better growth

compared with other blocks during the last year. These findings can be used for future planning of thinning and final mode of harvest. During the last years, Block 01 obtained the highest growth rate but now its growth has decreased compared with other blocks. We have reduced the number of trees per hectare from 619 to 551 as a remedial measure for this block.

After analyzing the last 11 years of growth and DBH data of 2015-2023, Mean annual increment for DBH and Height is 1.25 cm and 1.06 m respectively.

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 3, block 4, block 2 and block 5 were found as 0.119 m3, 0.086 m3, 0.072 m3, 0,063 m3 and 0.062m3 respectively. Mean tree volume for Batticaloa site is around 0.08. The mean tree volume for ha is 42 m^3. Furthermore it is estimated that this plantation contains of 1109 m3 of timber.

Part of teak plantation 2023

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.

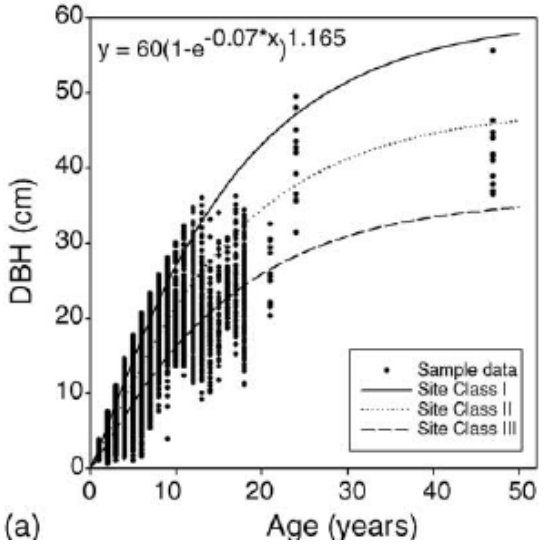
1.2. Activities of teak stand maintenance

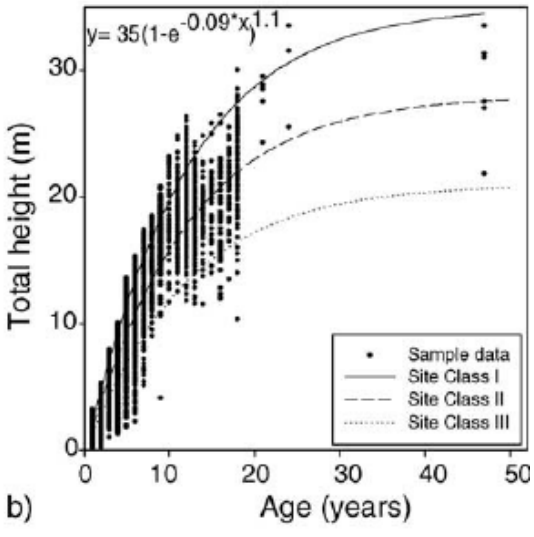
Teak grows well, grows fast, and produces high-quality timber when the land and trees are well maintained. Maintenance includes weeding, fertilizing, replanting, pruning, thinning, maintaining coppices and controlling pests and diseases.

1.2.1. 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*

1.3. 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.

1.3.1. 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.

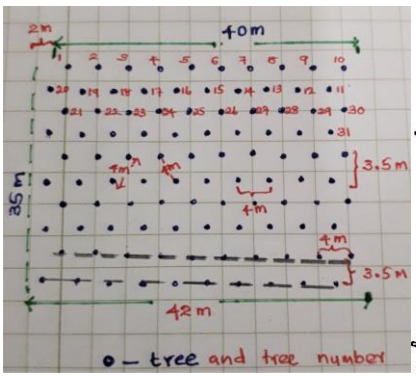
2. Methodology of Forest inventory

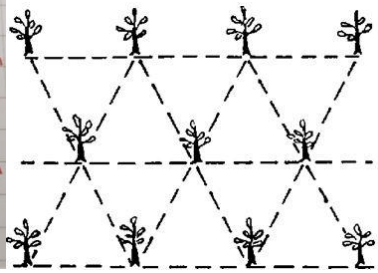
Sound forest management depends on the quantity and quality of information available on the forest. This information is obtained from forest inventories. Forest inventory is the activity of data collection that helps generating the required information base on the forest resource within an area of interest. 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.

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

2.1.1. 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 block 01, Block 3, Block 4, and Block 5 of Batticalao are 42m x 35m. (1470m^2)

2.2. 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.

2.2.1. 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

2.2.1.1. 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 2.2.. Total Tree height was measured by hypsometer and a pole, used instrument of sununto meter is shown in

Mr.Jayalath and Mr.Eranda are taking the field data

3. Results of inventory of teak plantation-2023

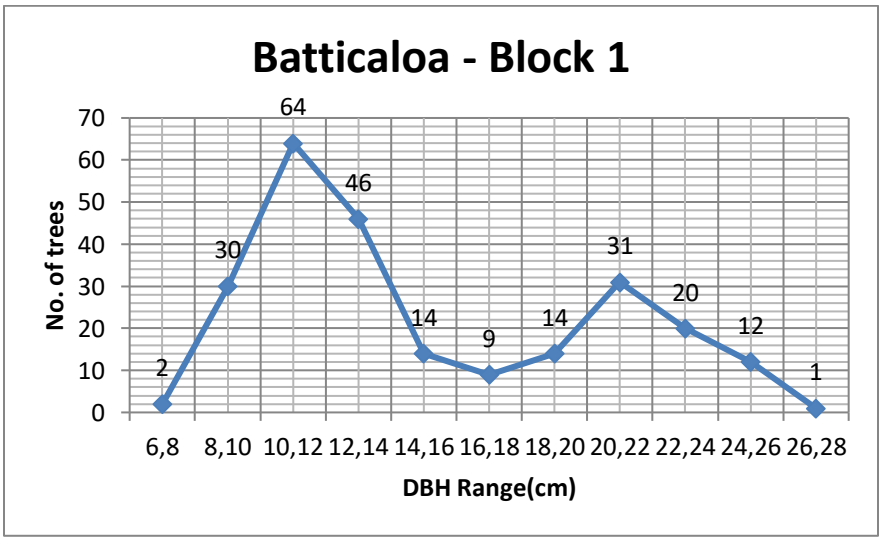
3.1. Teak Plantation of Batticaloa

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	83	12.1	11.7	91	15	13	90	14.1	13
2	81	11.7	10.5	63	11.5	8	93	15.5	13
3	79	21.9	22	81	15.4	11	82	15.3	13
4				68	11.6	8	84	11.8	10
Mean	**81**	**15.2**	**14.7**	**75**	**13.4**	**10**	**87**	**14.2**	**12.2**
Total	**243**			**303**			**349**		

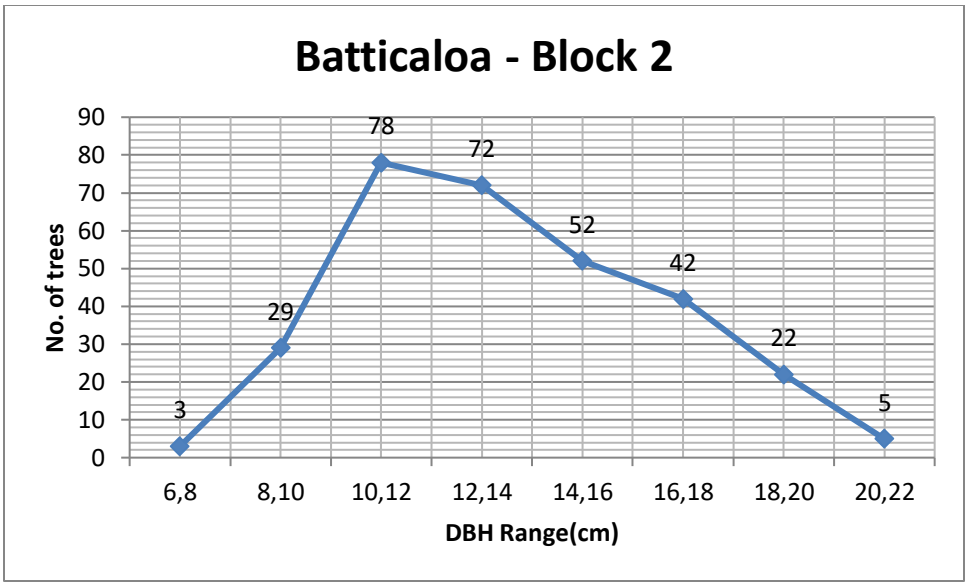
Plot number (P)	Block 04			Block 05		
	No. of trees	Mean DBH (cm)	Mean height (m)	No. of trees	Mean DBH (cm)	Mean height (m)
1	86	15.7	12	41	10	9.5
2	83	15.4	13	51	13.7	10
3	41	9.9	8	70	14	11
4				72	12	9
5				63	12.8	12
6				85	14.7	13.6
Mean	**70**	**13.7**	**11**	**63**	**12.8**	**10.8**
Total	**210**			**385**		

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

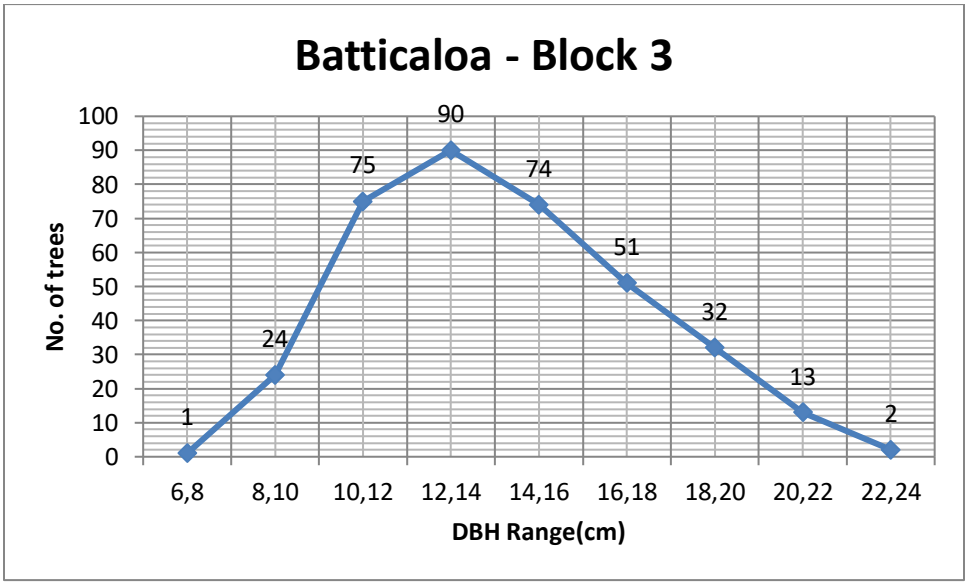


Out of 243 of trees, 101 trees are having more than site mean dbh of 13.8 cm

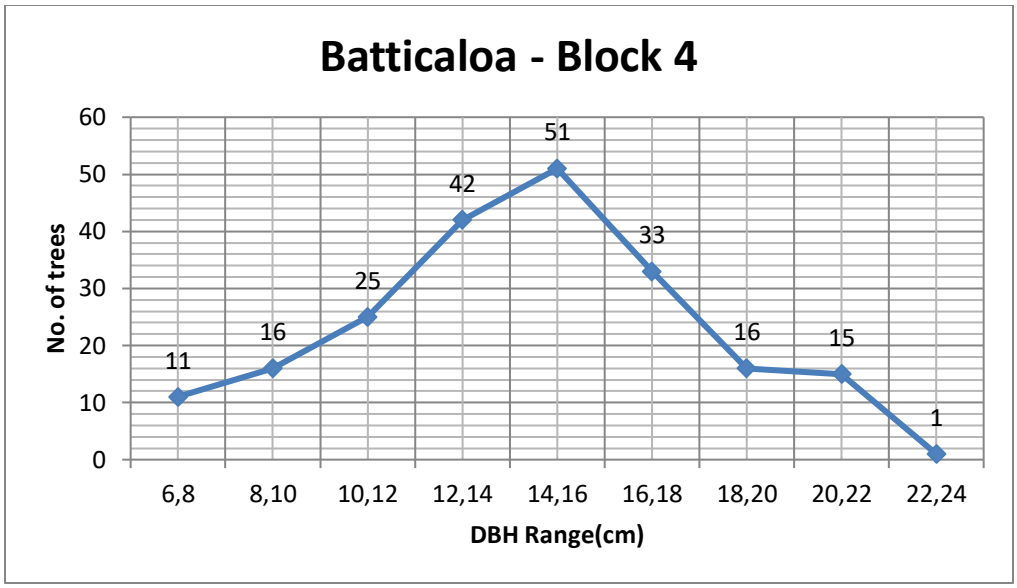
It can be assumed that in block no.1. out of 1897 trees, There are 788 trees having more than 13.8 cm DBH category(41%).



Out of 303 of trees, 121 trees are having more than site mean dbh of 13.8 cm .It can be assumed that in block no.2. out of 3360 trees, There are 1341 trees having more than 13.8cm DBH category.(39%)

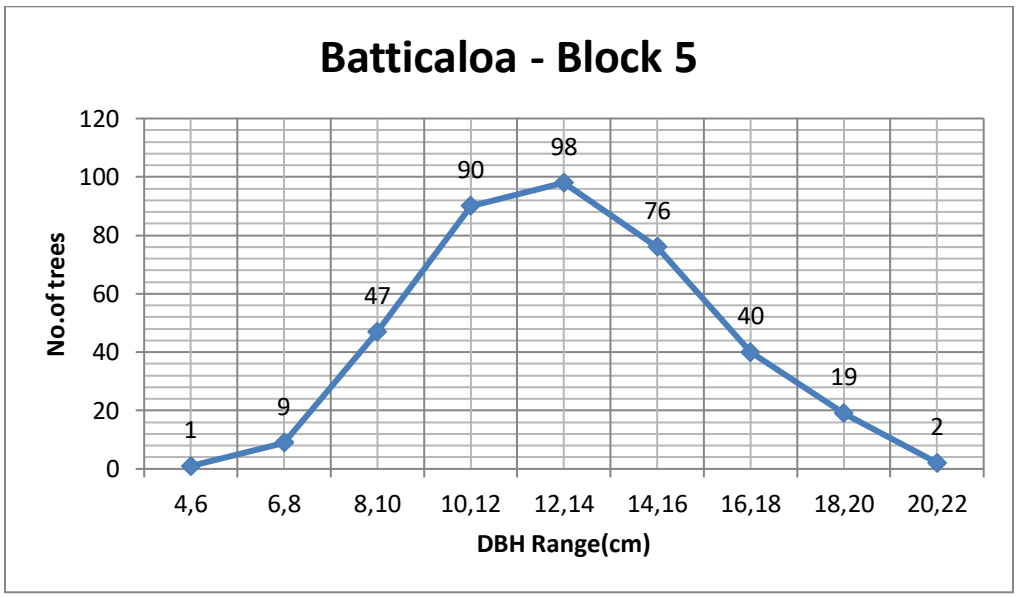


Out of 349 trees, 172 trees are having more than site mean dbh of 13.8 cm .It can be assumed that in block no.3. out of 2876 trees, There are 1417 trees having more than 13.8cm DBH category.(49%)

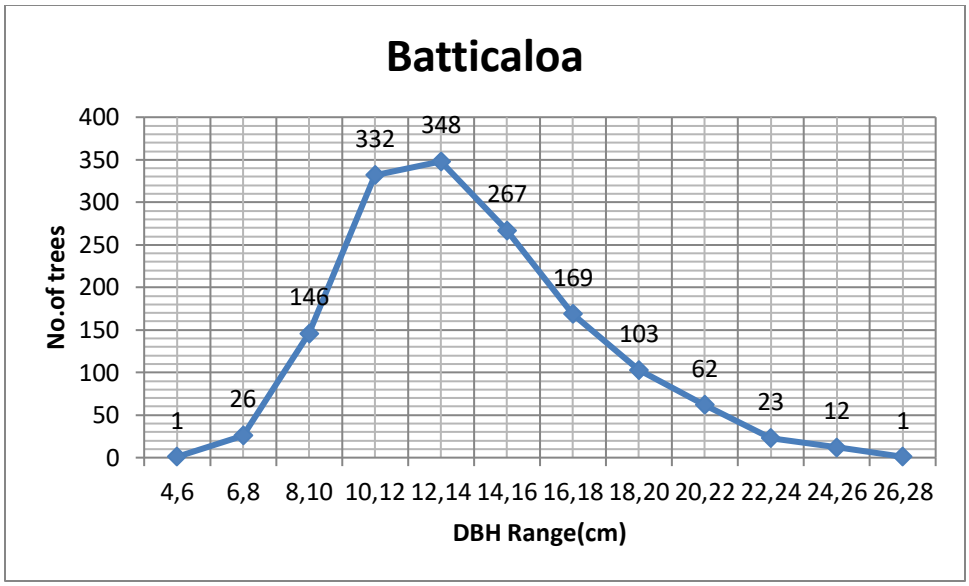


Out of 210 trees, 116 trees are having more than site mean dbh of 13.8 cm

It can be assumed that in block no.4. Out of 2320 trees, there are 1357 trees in having more than 13.8cm DBH category. (55%)



Mean block DBH is 12.8 cm. Out of 385 trees, 137 trees are more than site mean dbh of 13.8. it can be assumed that Out 4161 there are 1480 trees are more than 13.8 cm of DBH.(35%)



Mean site DBH is 13.8cm. Out of 1490 trees, 637 trees are more than mean site dbh value (13.8cm). Out of total block trees of 14614, 6247 trees are more than 13.8 cm of DBH.(42.7%)

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

Estate	Block no and its mean dbh value.	No. of trees more than its site mean (13.84 cm) DBH in Block and its %
Batticaloa	1 and 15.2 cm	788 (41%) from 1897 trees
	2 and 13.4 cm	1341 (39%) from 3360 trees
	3 and 14.2 cm	1417 (49%)from 2876 trees
	4 and 13.7 cm	1357 (55%) from 2320 trees
	5 and 12.8 cm	1480 (35%)from 4161 trees
	Estate total mean 13.8 cm	6247(42.7%) from 14614 trees

Table 3.3. Mean block growth parameter of Batticoloa plantation

Block no.	Total tree number in plots (plot size 1470 m2)	Mean tree number per ha	Mean DBH (cm)	Mean Height (m)
Block 1	**243 (plots size 4410)**	**551**	**15.2**	**14.7**
Block 2	**303(plots size 5880)**	**515**	**13.4**	**10**
Block 3	**349(plots size 5880)**	**593**	**14.2**	**12.2**
Block 4	**210(plots size 4410)**	**476**	**13.7**	**11**
Block 5	**385(plots size 8820)**	**436**	**12.8**	**10.8**
block mean	**298 (total tree 1490)**	**514**	**13.8**	**11.7**

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)	CIA of DBH(Ht)
2	2014	2474	736			
3	2015	2499	743	6.3	5.0	
4	2016	2380	708	8.1	6.0	1.8(1)
5	2017	2292	682	9.0	6.6	0.9(0.6)
6	2018	2305	686	10.6	8.2	1.6(1.6)
7	2019	2230	663	11.4	9.1	0.8(0.9)
8	2020	2129	633.6	12.65	11	11.25(1.9)
9	2021	2041	628	13.57	11.4	0.92(0.4)
10	2022	2036	619	14.3	12.6	0.7(1.2)
11	2023	1897	564(based on area)	15.2	14.7	0.9(2.1)

CIA= Current Annual Increment

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)	Height (m)	CIA of DBH(Ht)
2	2014	4532	671			
3	2015	4355	645	2.7	2.3	
4	2016	4213	624	5.0	4.0	2.3(1.7)
5	2017	4114	609	6.1	4.7	1.1(0.7)
6	2018	4159	616	8.4	6.1	2.3(1.4)
7	2019	4308	638	9.7	6.9	1.3(0.8)
8	2020	3742	554	10.27	7.4	0.57(0.5)
9	2021	3633	513	11.45	8.33	1.18(0.93)
10	2022	3487	517	12.4	10	0.95(1.6)
11	2023	3360	497	13.4	10	1(-)

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)**	**CIA of DBH(Ht)**
1	2014	4386	797			
2	2015	4248	772			
3	2016	4355	792	4.0	3.2	
4	2017	4169	758	6.1	4.9	2.1 (1.7)
5	2018	3972	722	7.3	5.3	1.2 (0.4)
6	2019	3982	724	8.7	6.4	1.4 (1.1)
7	2020	3350	629	9.64	7.7	0.94 (1.3)
8	2021	3080	627	11.21	7.45	1.57
9	2022	3055	625	12.7	10.7	1.5 (3)
10	2023	2876	522	14.2	12.2	1.5 (1.5)

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)**	**CIA of DBH(Ht)**
1	2014	3338	705			
2	2015	3102	655			
3	2016	3322	702	4.2	3.5	
4	2017	3240	685	5.3	4.1	1.1(0.6)
5	2018	3162	668	7.5	5.6	2.2(1.5)
6	2019	3282	694	8.3	6.3	0.8(0.7)
7	2020	2729	577	9	6.6	0.7(0.3)
8	2021	2499	530	10.6	7.48	1.6(0.88)
9	2022	2457	523	12.2	10.5	1.6(3)
10	2023	2320	490	13.7	11	1.5 (0.5)

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)**	**CIA of DBH(Ht)**
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	2.6(1.9)
5	2019	6343	689	7.2	6.0	0.6(0.8)
6	2020	4832	493	8.35	6.6	1.15(0.6)
7	2021	4519	445	9.84	7.04	1.49(0.44)
8	2022	4423	448	11.7	9.1	1.2(2.1)
9	2023	4161	452	12.8	10.8	1.1(1.7)

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)
10	2022	12.7	10.5	1.27 (1.36)	1.08 (2.2)
11	2023	13.8	11.7	1.25(1.1)	1.06(1.2)

Table 3.6. Sri Lankan Teak Plantation tree count.

Comparison Tree Audit 2022-2023 in Batticaloa

Estate Name	Block number	Geophysics count trees 2022						Geophysics count trees 2023					
		Total good trees	No.of small/poor trees	Marked for thinning	Reserved tree	Total trees	Differences 2022 vs 2021	Total good trees	No.of small /poor trees	Marked for thinning	Reserved trees	Total trees	Differences 2023 vs 2022
Batticolao	B1	1564	234		238	2036	(5)	1492	173		232	1897	(136)
	B2	2917	570			3487	(146)	2868	492			3360	(492)
	B3	3016	39			3055	(27)	2868	8			2876	(176)
	B4	2414	43			2457	(42)	2308	12			2320	(137)
	B5	(3592)	831			4423	(96)	4075	86			4161	(262)
	Total all blocks	**13503**	**1717**		**238**	**15458**	**(316)**	**13611**	**771**		**232**	**14614**	**(844)**

Table 3.7. Sample plots information, planted area and tree inventory data in year 2023 of Batticaloa,

Estate	Block no.	Total trees in block	Estimated planted area (ha)	No. of Plots	Plots area in block (m2)	Year 2023			
						No. of trees measured for DBH in Block	No of trees for ha.	Average DBH (cm)	Average height appro.(m)
Batticolao	1	1897	3.66	3	4410 (1470x3)	243	**551**	**15.2**	**14.7**
	2	3360	7.35	4	5880 (1470x4)	303	**515**	**13.4**	**10**
	3	2876	4.8	4	5880 (1470x4)	349	**593**	**14.2**	**12.2**
	4	2320	4.69	3	4410 (1470x3)	210	**476**	**13.7**	**11**
	5	4161	9.1	6	8820 (1470x6)	385	**436**	**12.8**	**10.8**
	total	**14614**	**29.5 ha from 48 ha**	**total 20**	**Total 29400 (2.94ha)**	(mean 298) Total 1490	**514**	**13.8**	**11.7**

Table 3.8. Comparison of tree parameters between year 2022 and 2023 in Batticalao plantation.

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 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 (-) 2023 vs 2022**
Batticolao	B1	3	275	619	14.3	12.6	243	**551**	**15.2**	**14.7**	**0.9cm (2.1m)**
	B2	4	308	517	12.4	10	303	**515**	**13.4**	**10**	**1cm (- m)**
	B3	4	367	625	12.7	10.7	349	**593**	**14.2**	**12.2**	**1.5cm (1.5m)**
	B4	3	233	523	12.2	10.5	210	**476**	**13.7**	**11**	**1.5cm (3m)**
	B5	6	398	448	11.7	9.1	385	**436**	**12.8**	**10.8**	**1.1cm (1.7m)**
		Total 20	Total 1581	Ave. 546	AVE. 12.7	Ave. 10.5	(mean 298) Total 1490	**514**	**13.8 (ave)**	**11.7 (ave)**	**Ave. 1.1m (1.2m)**

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 2023	**AGE OF THE PLANTATION IS 11 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(age 11)	1897	**551**	**15.2**	**14.7**	0.119	65.5	225.7	5.95
2(age 11)	3360	**515**	**13.4**	**10**	0.063	32.4	211.6	2.9
3(age 10)	2876	**593**	**14.2**	**12.2**	0.086	50.9	247.3	5.09
4(age 10)	2320	**476**	**13.7**	**11**	0.072	34.2	167	3.4
5(age 9)	4161	**436**	**12.8**	**10.8**	0.062	27	257	3
	14614	**514**	**13.8 (ave)**	**11.7 (ave)**	Mean=0.0805	Mean=42	GRAND TOTAL= (1109)	Grand mean=4

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

Batticaloa plantation age (majority) is 11 years (Batticaloa, **Planted year 2012.july to 2013 December**)

Estate	Block no.	No. of Plots	2015 Ave. DBH (cm)	2016 Ave. DBH (cm)	2017 Ave. DBH (cm)	2018 Ave. DBH (cm)	2019 Ave. DBH (cm)	2020 Ave. DBH (cm)	2021 Ave. DBH (cm)	2022 Ave. DBH (cm)	2023 Ave. DBH (cm)	DBH differences from Year of first measurement to 2023 and (Mean Increment of DBH cm)
Batticaloa	1	3		6	6.6	8.2	9.1	12.65	13.57	14.3	**15.2**	9.2 (mean DBH 1.3)
	2	4	2.9	5	6.1	8.4	9.7	10.27	11.45	12.4	**13.4**	10.5 (1.2)
	3	4		4	6.1	7.3	8.7	9.64	11.2	12.7	**14.2**	10.2 (1.4)
	4	3		4.2	5.3	7.5	8.3	9	10.64	12.2	**13.7**	9.5 (1.37)
	5	6			4	6.6	7.2	8.35	9.84	11.7	**12.8**	8.8 (1.4)
	Estate average		**2.9**	**4.8**	**5.62**	**7.6**	**8.6**	**9.98**	**AVE. 11.34**	**12.7**	**13.8 ave**	

Figure : some inferior and disturbance trees in plantation have been removed.

Figure : in near future, tree competition for light and water need to be assessed in order to decide thinning regime.

Pilila (Dendrophthoe falcata)plants have grown over the canopy, this half –parasite may kill the teak trees, Action need to remove the parasitic plants and stop the spreading in the plantation.

After applying “the Candasan” , Trunk canker is recovering.

Figure: section of slow growing trees in the plantation have” little improvement”

4. Observation, Conclusions and recommendation

1. Pilila *(Dendrophthoe falcata*) plants have grown over the canopy of Teak trees in block 1, this half – parasite may kill the teak trees, Action need to remove theparasitic plants and stop the spreading in the plantation.
2. Some inferior or disturbance excess trees have been removed in most of Blocks which resulted reduction of total tree number in the plantation from 15458 to 14614 (844) and number of trees per hectare from 546 to 514.
3. It can be assumed that Out of total block trees of 14614, 6247 trees are more than 13.8 cm of DBH.(42.7%)
4. Results section of this report shows all the necessary information from planting year of this plantation to present audit year. Mean DBH and height have increased from 2022 to 2023 as 1.1 cm and 1.2 m respectively. Number of trees per hectare has reduced from 546 ha to 514 per ha from 2022 to 2023. We need to prepare thinning regime and reduce trees number per ha until harvesting stage. The mean tree volume for ha has increased from 33.6 in 2022 to 42 m^3 in 2023, Furthermore it was estimated that this plantation contain of885m^3in 2022 and it has increased to 1109m3 in 2023.

Finally it can be concluded that Batticaloa Teak plantations are healthy and good condition. There is good potentiality to get better growth increment particularly for diameter growth for next 9 years if the plantation is maintained and managed scientifically.

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