TEAK TREE INVENTORY AND AUDIT REPORT

Conducted For

ASIA TEAK GROUP

at

CHON DAEN 1 AND CHON DAEN 224 ESTATES

PHETCHABUN PROVINCE

THAILAND

DR.NIMAL RUWANPATHIRANA

2020 FEBRUARY.

CONTENT **PAGE**

Content of Tables

Content of figure

Content of graph

Executive summary

AsiaTeak Group appointed me, Dr. Nimal Ruwanpathirana, as an Independent Forestry Consultant in November 2019. I inspected two teak plantations owned by AsiaTeak Group, namely Chon Daen 1 and Chon Daen 224, with Mr. J.M.P.H Jayalath, Mr. Eranda Rathnamalala on 3rd to 6th February 2020 in order to conduct the annual inventory and audit the tree stocks of the plantations. The annual tree audit and evaluation of tree sample data are conducted independently under globally accepted methodologies, which are explained in this report. All the sample data were collected throughout the audit process under close supervision. I hereby certify that the inspected plantations are presently in reported condition.

Chon Daen 01 estate

Twenty sample plots with a total sample area of 30,048 m2 have been permanently setup in different locations in Chon Daen 01 estate. It is found by this study that total estimated planted area is 27.92 ha and sample plots represent 10.7% of the tree population. In this study, 988 trees were measured for DBH (Diameter at Breast Height 1.3m) and around 100 trees for height measurement taken by hypsometer. We applied the correct international standards when measuring the tree parameters such as DBH and Height.(see page 12-15).

The inventory results shows that there are 9136 trees (8815 good trees, 166 marked for thinning and 155 reserved trees). The average DBH and Height of trees in the estate is 24.7 cm and 21.2 m respectively. It is found that average trees per ha is 338. In 2019 the tree count was 9,209 total trees, of which 8,894 were good trees, 151 marked for thinning and 164 reserved trees. In 2020 audit it is found that there are 73 trees less than 2019 audit, which may be due to thinning out, or uprooting. Details of tree information per block are shown in table (3.4).

After analyzing the last 8 years of DBH data (2013-2020) and other relevant factors, the age of the plantation can be estimated as approximately 20 years old and state of this plantation can be classified as site quality 19. The site growth parameters almost comply with site quality 19 (see page 8-9).

In order to estimate the timber volume of the plantation, a felled tree was taken as a sample to determine the form factor and actual volume of trees (see table 3.6 page 26). The finding is that tree form factor is 0.4. Total tree volume of each block was estimated based on mean DBH, Mean Height and Form Factor. Highest mean volume per tree was found as 0.674 m3 in block 8. Chon Daen 01 estate contains around 3654 m3 of timber volume (see table 3.7 page 27). According to quality class 19 (see page 8-9), we expect 115m3/ha of timber volume from 185 trees at 25 years old plantation. However we observed that there are 338 trees per ha in this plantation. Furthermore it is estimated that this plantation contains an average of 114m3 of timber volume/ha. Our great task should be either we reduce number of trees per ha in order to produce larger trees or maintain the optimum number of trees as much as possible to get maximum timber volume.

Analyzing inventory tree data it is found that more than 75% of trees have a DBH of more than 21 cm. (see graph 3.1-page (17-20) and table 3.2 (page 24)). The total tree number under this category is 7020 out of 9136. These findings can be used for future planning of thinning and final mode of harvest.

Chon Daen 224 estate

Nineteen sample plots with a total sample area of 2736m2 have been permanently setup in different locations in Chon Daen 224 estate. It is found by this study that total estimated planted area is 2.56 ha and sample plots represent 10.6% of the tree population. In this study, 132 trees were measured for DBH and around 90 trees for height taken by hypsometer. We applied the correct international standards when measuring the tree parameters.

The inventory (tree count data) results shows that there are 1235 trees (1077 good trees, 158 marked for thinning and 0 reserved trees). The average DBH and Height of trees in the estate 224 are 20.2 cm and 18.3 m respectively. It is found that the average trees per ha is 483. Block information is shown in table 3.3 and page 24.

After analyzing the tree growth rate and other relevant factors, the age of the plantation can be estimated as approximately 14 years old and site of this plantation can be classified as site quality 19. The site growth parameters almost comply with site quality 19 (see page 8-9). However we have DBH data only for 2018 and 2020.

In order to estimate the timber volume of the plantation, some tree data was taken to determine the form factor and actual volume of tree. The finding is that tree form factor is around 0.36. Total tree volume of each block was estimated based on mean DBH, Mean Height and Form Factor . Highest mean volume per tree was found as 0.24 m3 in block B3. Chon Daen 224 estate contains around 233.7 m3 of timber volume (see table 3.8). According to quality class 19 (see page 8-9), we expect 98.5m3/ha of timber volume from 379 trees at 12 years old plantation. However we observed that there are 483 trees per ha in this plantation. Furthermore it is estimated that this plantation contain average of 114m3 of timber volume /ha. As mentioned above our great task should be either we reduce the number of trees per ha in order to produce larger trees or maintain optimum number of trees to get maximum timber volume.

Analyzing inventory tree data it is found that more than 68% of trees have a DBH more than 17 cm. (see graph 3.2 and table 3.2). The total tree number under this diameter category is 850.

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 these two plantations at end of felling rotation.

Finally it can be concluded that both teak plantation are healthy and in good condition. There is much more potential to get more growth increment particularly for tree stem diameter over the next 5 years if the plantation is maintained and managed scientifically.

1.Introduction

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

Teak (*Tectona grandis* 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.

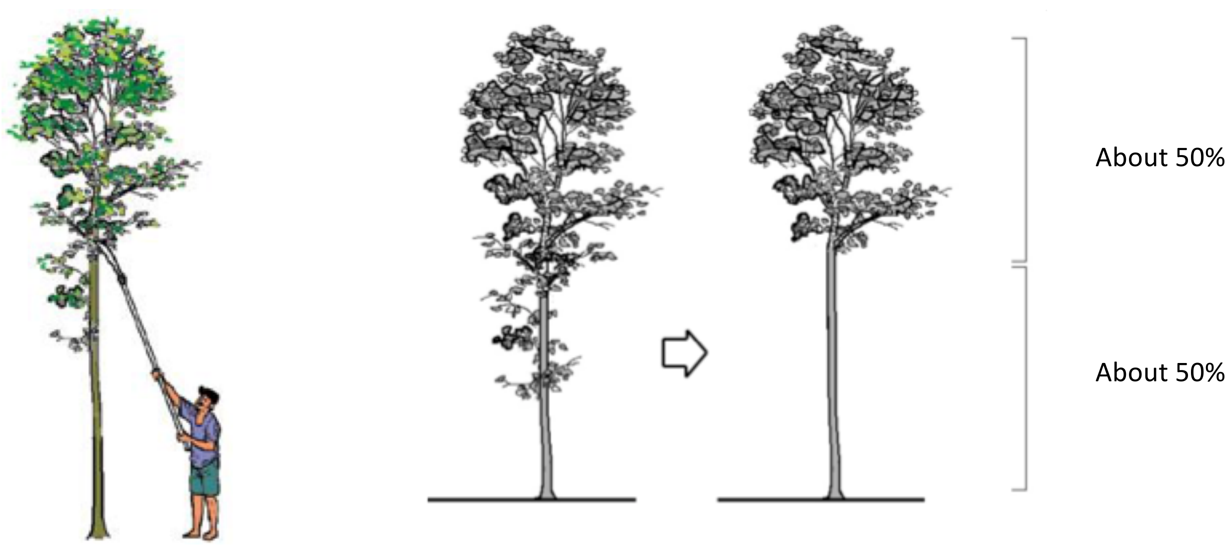
Bole form

Fluting (irregular involutions and swellings) in the teak stem has been observed in a number of plantations. In 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



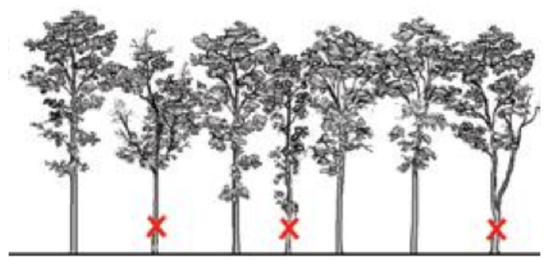
Recommended height to which branches should be pruned

1.2.2. Thinning: 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.

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

Table 1: Trees left after thinning based on tree height

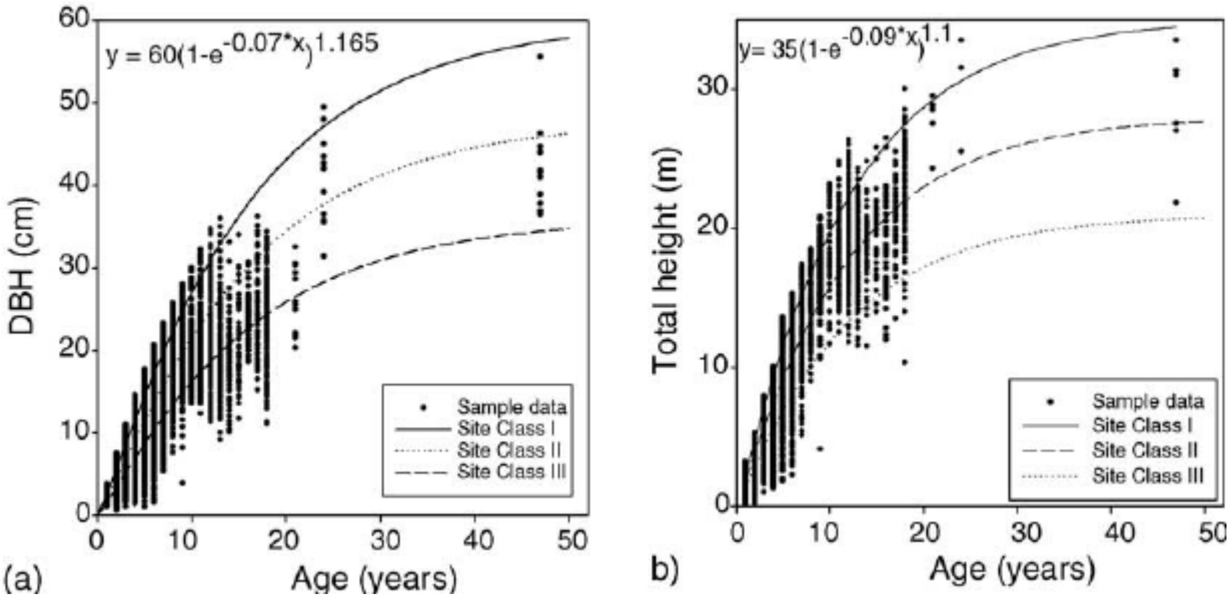
Tree height (m)	Trees remaining (trees/ha)	Age (yr) (range based on soil fertility)	Spacing (m)
11.0–13.0	1300–1500	5–11	2.5–3.0
13.5–15.5	1000–1100	7–17	3.0
15.5–17.0	800–850	10–21	3.5
17.5–21.0	500–550	15–34	4.0–4.5



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).

The following growth information published by researchers can be used to develop the yield prediction table for present teak plantation of Asia Teak group.



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

Table 2. 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 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 Audits are to assess to what extent forest management planning activities comply with the 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. Finally the audit can 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.

1. The auditor must be independent.
2. There must be sufficient and appropriate information provided by the Forestry Management team to conduct the audit.
3. There must be adequate resources and co-operation from the Forestry Management team to conduct audit process.

1.5. Objectives of present forest inventory and Audit of Teak Plantation in Chon Daen Estates

1. To audit the teak plantations to obtain the teak tree stock and tree growth parameters.
2. To decide next silvicultural treatments such as pruning, thinning and some maintenance activities of plantation like fire lines, weeding and fertilizing based on information gathered from forest inventory and field examination.
3. To predict future tree growth, timber production and estimated timber value. This forecasting will help the Forestry Management team to take the remedial measures to manage the plantation efficiently to achieve the maximum benefit from the plantation.
4. To remedy shortcomings 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 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, impotency of the above criteria is considered and followed.

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

Items needed for all field inventory or assessments field assessment datasheets (current and previous) field vest, plastic flagging (at least three different colors) mechanical pencils, sharpie permanent ink pen, compass, calculator, small ruler (metric & English), 75’ or 100’ Spencer tape w/dbh tape, clinometer, clipboard or datum

Stand map, plots mapped, small pocket sized notebook, digital camera

Numbered tree tags (check for numbers that have not been used) unmarked bearing tree tags for scribing

Rebar & plastic pipes (for replacement if missing), tree paint (spray can): orange or other bright color, first-aid kit, water, cell phone.

2.1.1.Temporary vs. Permanent Plots

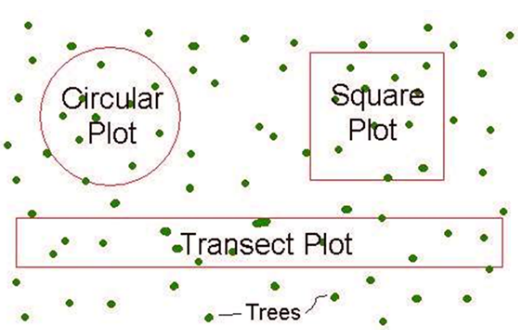
When conducting a forest inventory, most landowners install temporary plots. When the stand is re- inventoried in the future, plot locations are different. This is the simplest inventory method and is recommended for landowners who have minimal time to devote to forest inventory .**Permanent inventory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

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

Figure 2.1. Plot number and one corner post of square shape plot in Chon Daen estate.

2.2. Plot shape

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

2.3. 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

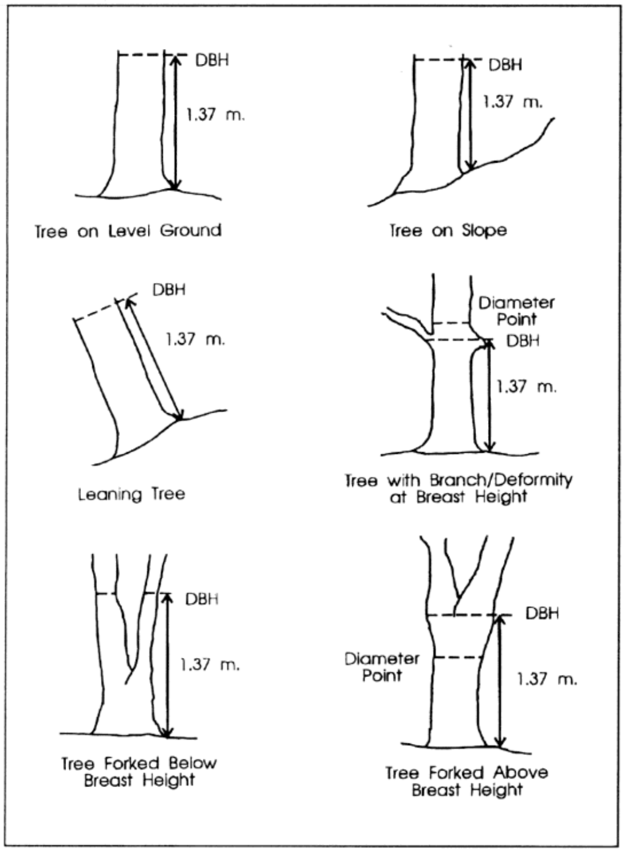
There are diameter tapes from which the tree diameter can be directly read. Tree diameter can also be determined from circumference measurement which can be done by diameter tape or any tape since circular tree stem shape is assumed.

$C = 2\pi r = d$; $d = C/\pi$ In this study, Diameter tape is used.

Figure 2.2.diameter at breast height (1.3m) is measured by diameter tape. Inventory team follows all the standard and rules recommended in this regard.

2.4. Positions of diameter measurement at different conditions.

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



Diameter tape used for the inventory

2.5. Tree height measurement

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

2.5.1. Method of tree height measurement.

There are two methods, one is direct method which involves using height measuring rods only for small trees. Other method we used is trigonometric principles. A Suunto hypsometer is used for this purpose.

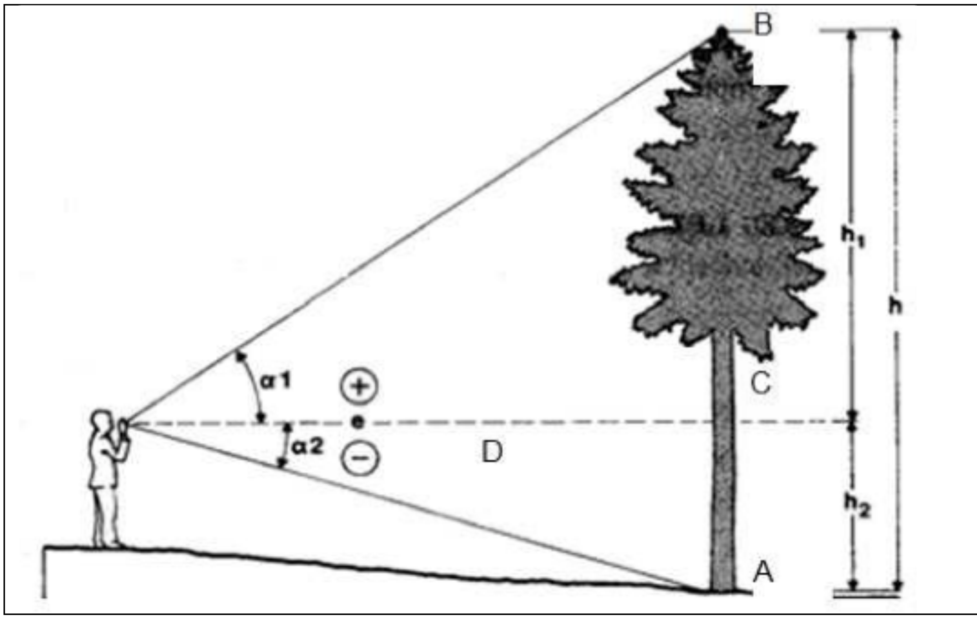
Figure 2.3. Total Tree height was measured by hypsometer, used instrument is shown in right side.

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

3.6. General steps for Hypsometer are below.

1. Stand at a fixed horizontal distance from the base of the tree (usually 10, 15, 20, 25 meters, and so on)
2. Sight at the top of the tree and read the value ‘A’ (top reading)
3. Again sight at the bottom of the tree and read the value ‘B’ (bottom reading)
4. Then the total height of the tree is top reading ‘A’ minus bottom reading ‘B’
5. Bottom reading +ve or –ve (above and below eye level)
6. Height measurement can be taken using clinometer as shown figure 2.3.

Figure 2.5: Tree height measurement on a flat terrain.



$\tan \alpha 1 = BC / D$

$BC = \tan \alpha 1 \cdot D$

$\tan \alpha 2 = AC / D$

$AC = \tan \alpha 2 \cdot D$

AB (height) = BC + AC

$AB = \tan \alpha 1 \cdot D + \tan \alpha 2 \cdot D$

$AB = D (\tan \alpha 1 + \tan \alpha 2)$

3. Results of inventory of teak plantation

3.1. Estate of Chon Daen 01.

Table 3.1. Number of trees and tree mean DBH values in plots in Chon Daen 1

Plot number (P)	Block 01		Block 02		Block 03		Block 04	
	No.of trees	Mean DBH (cm)	No.of Trees	Mean DBH (cm)	No. of Trees	Mean DBH (cm)	No.of Trees	Mean DBH (cm)
1	48	25.6	28	23.3	58	22.9	56	24.9
2	54	21.8			61	24.1	44	27
3	53	22.9					45	25.1
4	50	24.8					58	24
5	54	24.1						
mean	**51.8**	**23.8**	**28**	**23.3**	**59.5**	**23.5**	**50.75**	**25.5**

Plot number (P)	Block 05		Block 06		Block 07		Block 08	
	No.of trees	Mean DBH (cm)	No.of Trees	Mean DBH (cm)	No. of Trees	Mean DBH (cm)	No.of Trees	Mean DBH (cm)
1	30	23.4	51	25.3	60	23.5	55	27.7
2			52	23.7	44	24.7	38	30.9
3					49	25.6		
mean	**30**	**23.4**	**51.5**	**24.5**	**51**	**24.6**	**46.5**	**29.3**

Plot size : all the plots of block 01, Block 3, Block 4,Block 6, block 7 and Plot 1 of Block 8 are 40m x 40m.

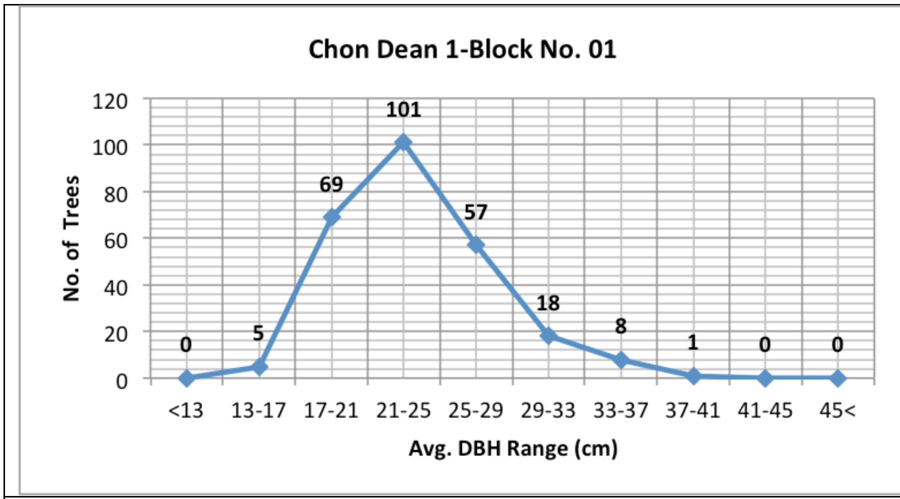
Plot 1 of Block 2 and Block 5 are 28m x 28m. Plot 2 of Block 8 is 40m x 32m.

Figure 3.1. Part view of Block 01

Figure 3.2. side view of Block 02 in Chon Daen 1

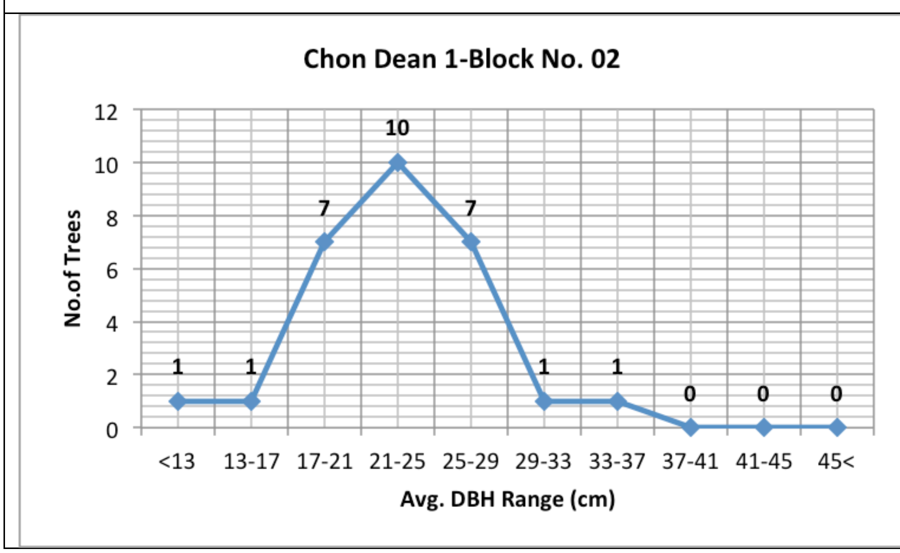
Figure 3.3. side view of Block 08 of Chon Daen 1.

Graph 3.1: Number of trees against to average DBH range values in Blocks in Chon Daen 1.



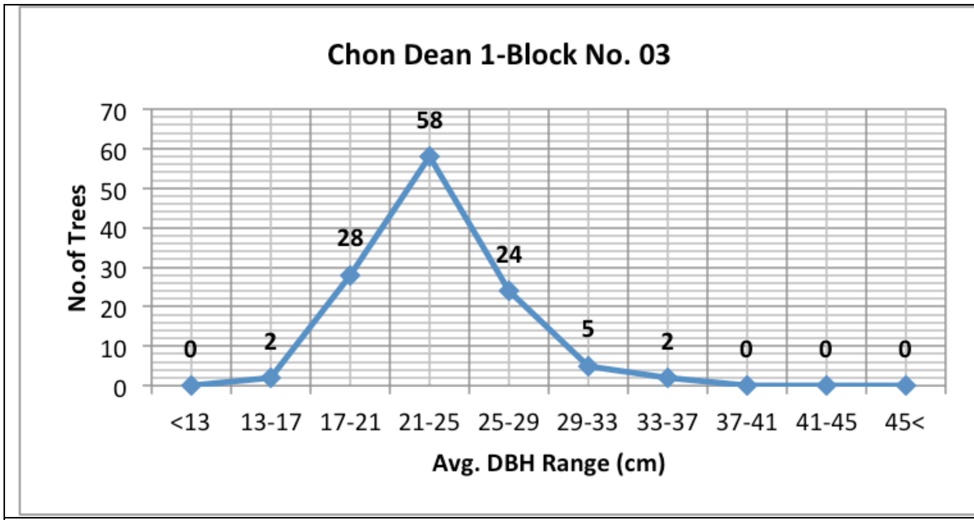
Out of 259 of trees, 185 trees have more than 21 cm DBH.

It can be assumed that in Block 1 out of 2735 trees, there are 1953 trees with more than 21 cm DBH category.



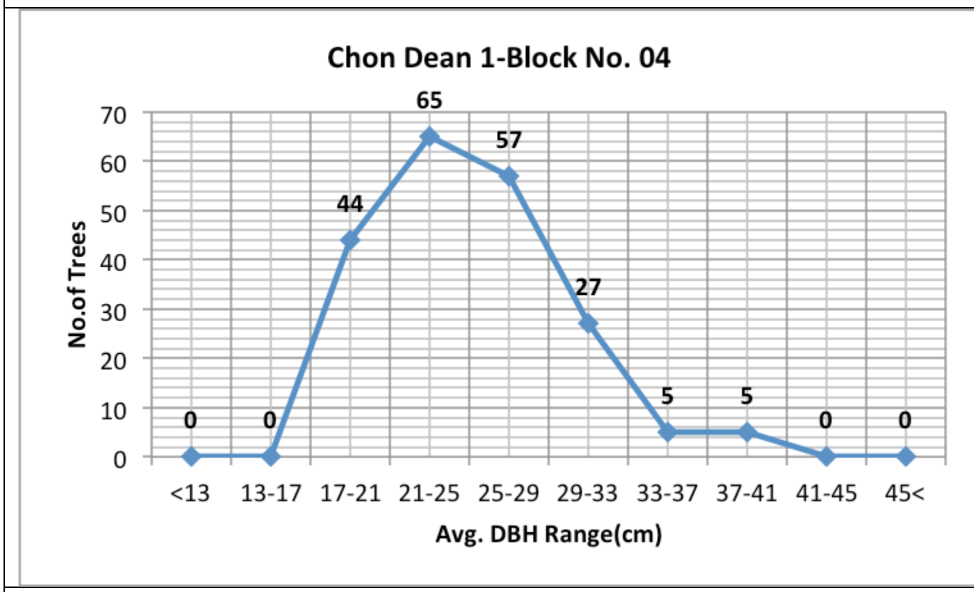
Out of 28 of trees, 19 trees have more than 21 cm DBH.

It can be assumed that in Block 2 out of 209 trees, there are 141 trees having more than 21 cm DBH category.



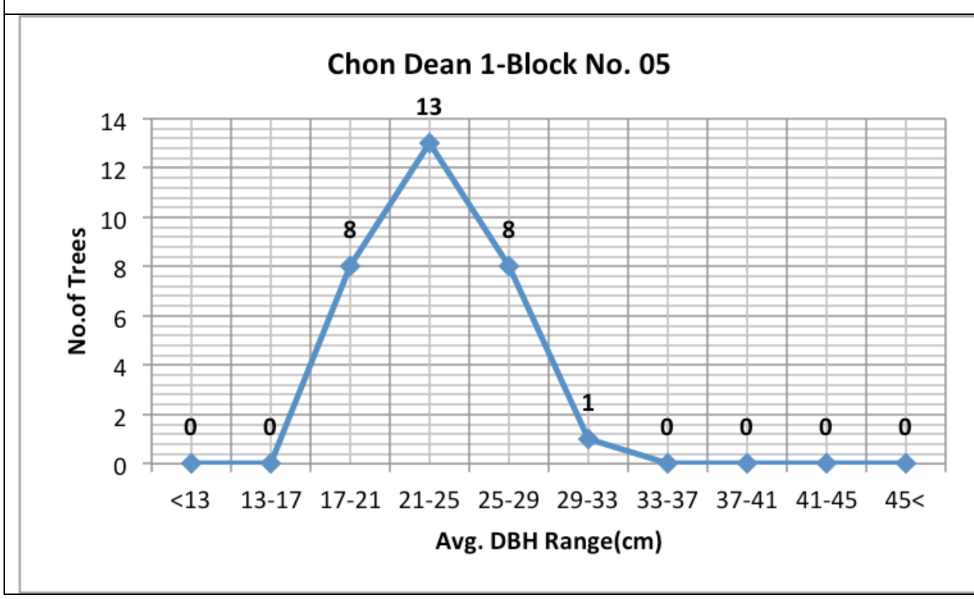
Out of 119 of trees, 89 trees have more than 21 cm DBH.

It can be assumed that in Block 3 out of 982 trees, there are 734 trees having more than 21 cm DBH category.



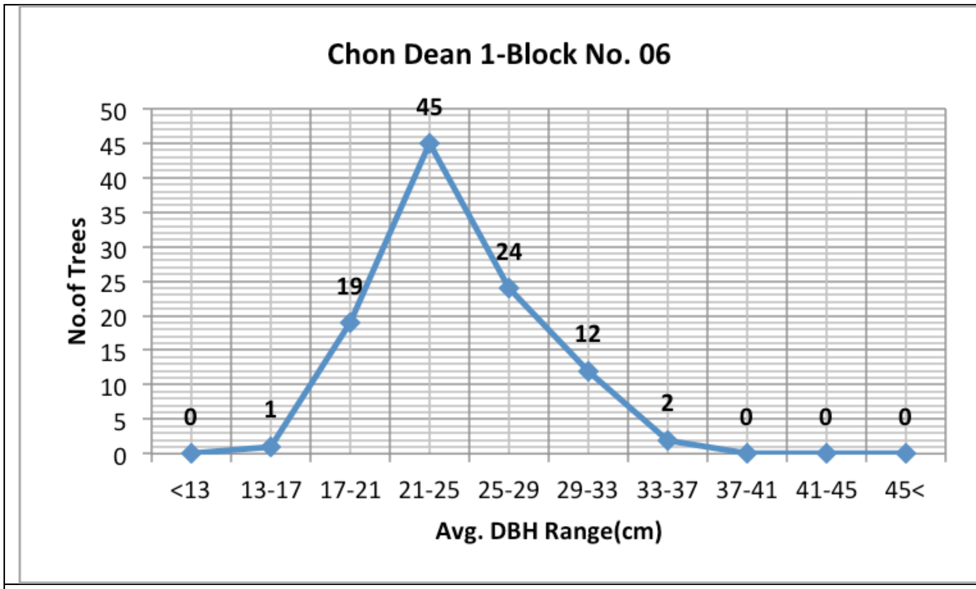
Out of 203 of trees, 159 trees have more than 21 cm DBH.

It can be assumed that in Block 4 out of 2026 trees, there are 1586 trees having more than 21cm DBH category.



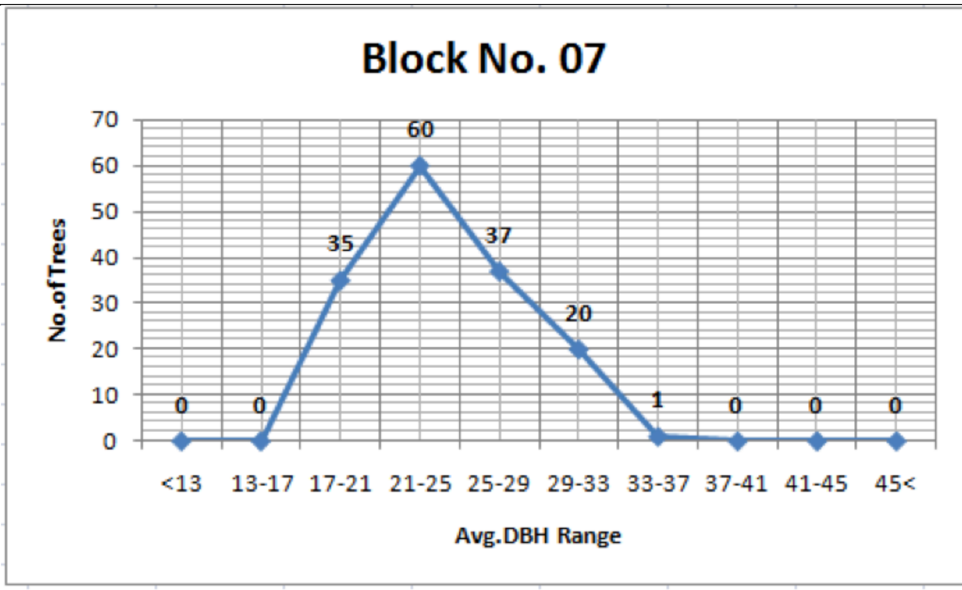
Out of 30 of trees, 22 trees have more than 21cm DBH.

It can be assumed that in Block 5 out of 258 trees, there are 189 trees having more than 21cm DBH category.



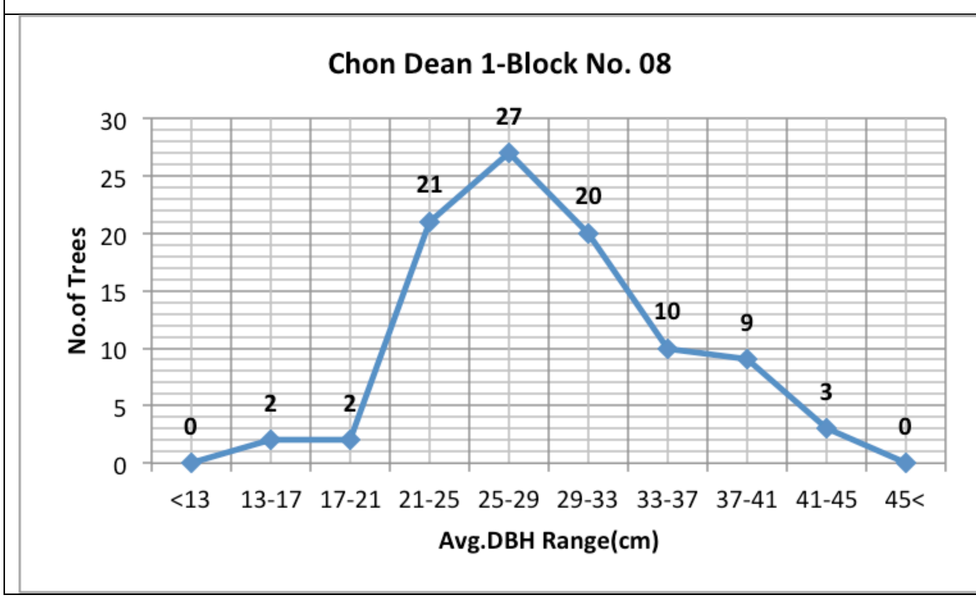
Out of 103 of trees, 83 trees have more than 21 cm DBH.

It can be assumed that in Block 6 out of 939 trees, there are 756 trees having more than 21cm DBH category.



Out of 153 of trees, 118 trees have more than 21cm DBH.

It can be assumed that in Block 7 out of 1289 trees, there are 994 trees in having more than 21cm DBH category.



Out of 93 of trees, 89 trees have more than 21cm DBH.

It can be assumed that in Block 8 out of 698 trees, there are 667 trees having more than 21 cm DBH category.

These bigger trees represent 95% of trees in Block 08.

3.1. Inventory results of Chon Daen 224.

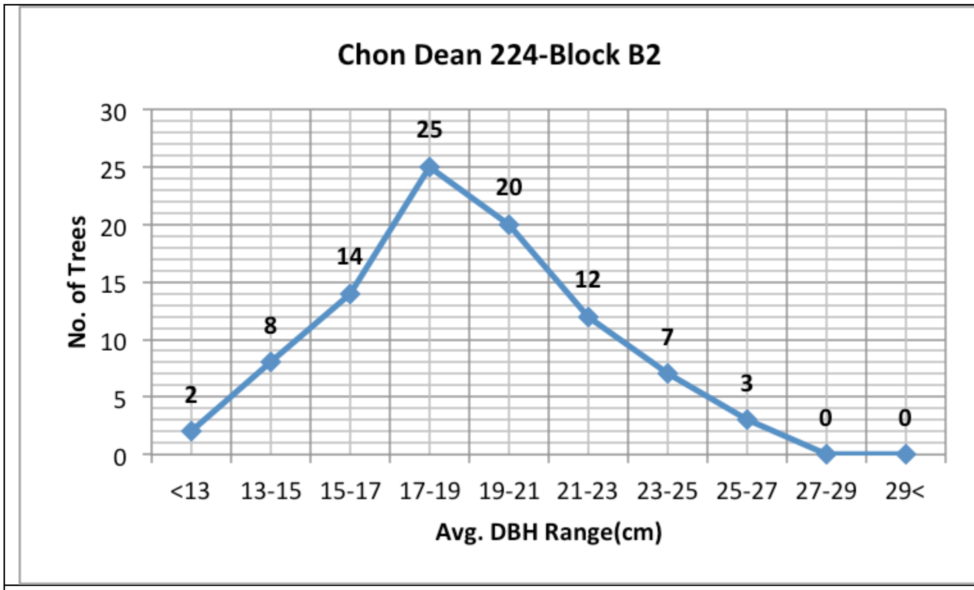
Plantation name: Chon Daen 224, Block No. B2 and Block No. B3

Figure 3.2.1 . Side view of Chon Daen 224, Block no.B2

Table 3.1.1. Number of trees and its mean DBH values in Chon Daen 224.

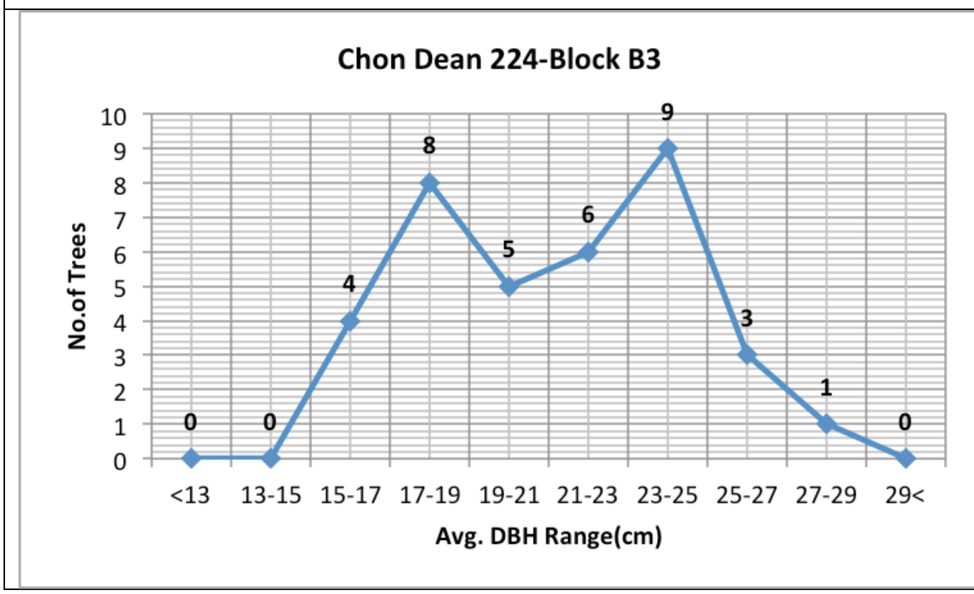
Plot number (P)	Block B2		Block B3	
	No.of trees	Mean DBH (cm)	No.of Trees	Mean DBH (cm)
1	8	18.6	8	18.3
2			7	23.5
3	8	17.8	7	20.3
4	7	19.4	6	22.1
5	7	19.4	7	21.2
6	**9**	**19.8**		
7	**7**	**21.5**		
8	**9**	**19.8**		
9	**6**	**18.4**		
10	**8**	**19.5**		
11	**7**	**19.3**		
12	**6**	**20.2**		
13	**8**	**17.4**		
14	**7**	**18.5**		
mean	**7.5**	**19.2**	**7**	**21.1**

Graph 3.2: Number of trees against mean ranged DBH values in Blocks in Chon Daen 224.



Out of 97 of trees, 67 trees have more than 17 cm DBH.

It can be assumed that in Block B2 out of 922 trees, there are 636 trees in 17cm category.



Out of 35 of trees, 24 trees have more than 17cm DBH.

It can be assumed that in Block B3 out of 313 trees, there are 214 trees having more than 17 cm DBH category.

Table 3.2. Estimated number of trees having more than 21cm DBH and 17cm DBH in Chon Daen 01 and Chon Daen 224 teak Plantation.

Estate	Block no.	Larger no. of trees in Block and its %
Chon Daen 1	1	1953 (71%)
	2	141 (67%)
	3	734 (74%)
	4	1586 (78%)
	5	189 (73%)
	6	756 (80.7%)
	7	994 (77%)
	8	667 (95%)
	Estate total	7020 (77%)
Chon Daen 224	B2	636 (68.9 %)
	B3	214 (68%)
	Estate total	850 (68%)

Table 3.3. Comparison of tree parameters between year 2019 and 2020 in Chon Daen 1 and Chon Daen 224 estate.

Estate	Block	No. of Plots	Year 2019			Year 2020			
			No. of trees measured for DBH	No of trees for ha.	Average DBH (cm)	No. of trees measured for DBH	No of trees for ha.	Average DBH (cm)	Average height approx. (m)
Chon Daen 01	1	5	261	325	23.9	259	323	23.8	20.2
	2	1	28	357	23.4	28	357	23.3	19.2
	3	2	120	374	23.4	119	371	23.5	20.5
	4	4	205	320	25.3	203	317	25.5	20.3
	5	1	30	382	23.7	30	382	23.4	17.5
	6	2	103	321	24.6	103	321	24.5	22
	7	3	154	320	24.3	153	318	24.6	19.6
	8	2	93	322	29.2	93	322	29.3	25
	Estate average				24.7			Average 24.7	Average 21.2
Chon Daean 224	B2	14	Year 2018			97		19.2	16.6
			106	17.2					
	B3	5	37	19.9		35		21.1	20
	Estate average			18.5				average 20.2	Average 18.3

Table 3.4. Sample plots information, planted area and tree inventory data in year 2020 of Chon Daen 1 and Chon Daen 224.

Estate	Block no.	Total trees in block	Estimated planted area (ha)	No. of Plots	Plots area in block (m2)	No. of trees measured for DBH in Block	No of trees for ha.	Average DBH (cm)	Average height appro.(m)
Chon Daen 01	1	2735	8.47	5	8000	259	323	23.8	20.2
	2	209	0.59	1	784	28	357	23.3	19.2
	3	982	2.65	2	3200	119	371	23.5	20.5
	4	2026	6.39	4	6400	203	317	25.5	20.3
	5	258	0.68	1	784	30	382	23.4	17.5
	6	939	2.93	2	3200	103	321	24.5	22
	7	1289	4.05	3	4800	153	318	24.6	19.6
	8	698	2.17	2	2880	93	322	29.3	25
	total	**9136**	**27.93**	**20**	**30048**	**988**	**Average 338**	**Average 24.7**	**Average 21.2**
Chon Daean 224	B2	922	1.92	14	2016	97	481	19.2	16.6
	B3	313	0.64	5	720	35	486	21.1	20
	total	**1235**	**2.56**	**19**	**2736**	**132**	**Average 483**	**Average 20.2**	**Average 18.3**

Table 3.5. Thailand Teak Plantation tree count. Comparison Tree Audit 2019-2020

Estate Name	Block number	Geophysics count trees 2019				Geophysics count trees 2020				Differences
		Total good trees	Marked for thinning	Reserved trees	Total trees	Total good trees	Marked for thinning	Reserved trees	Total trees	
Chon Daen 1	B1	2,607	42	103	2,752	2595	39	101	2735	-17
	B2	208	1	-	209	209	0	0	209	0
	B3	954	16	21	991	946	15	21	982	-9
	B4	2,038	16	12	2,066	2013	8	5	2026	-40
	B5	246	14	-	260	240	18	0	258	-2
	B6	935	9	-	944	915	24	0	939	-5
	B7	1,245	30	5	1,280	1244	40	5	1289	-9
	B8	661	23	23	707	653	22	23	698	-9
	Total all blocks	**8,894**	**151**	**164**	**9,209**	**8815**	**166**	**155**	**9136**	**-73**
Chon Daen 224		**Geophysics count trees 2018**				787	135	0	922	
	B2	843	105		948					
	B3	279	53		332	290	23	0	313	
	Total all blocks	**1122**	**158**		**1280**	**1077**	**158**	**0**	**1235**	
Total	**All plantation**					**9892**	**324**		**10371**	

Table 3.6. Form factor calculation with average size-felled trees.

1	Tree Total height with branches	22m	8	Stem volume up to 11m with bark	0.38 m3
2	Clean Tree stem height upto Diameter 16.5cm	11 m	9	Stem volume up to 11m without bark	0.312 m3
3	Diameter at breast height (ob)	26 cm	10	Tree volume based on total height and Stem mid diameter (16.5 cm at 11m) (ob)	0.470 m3
4	Mid diameter of 11m stem (ob)	5.5m	11	Form factor based on (10) and its cylindrical volume(ob)(7) 0.47/1.167	0.40
5	Small end diameter of 11 m stem(ob)	16.5 cm	12	Form factor based on stem volume upto 11m (8) and cylindrical volume of (7) height. 0.38/1.167	0.32
6	Bark thickness at one point	13mm	13	% of Clean stem timber volume from total volume (upto 16.5 cm diameter of 11m length)	80%
7	Cylindrical volume of total height of tree(22m)(Ob)	1.167m3			

Table 3.7. Tree volume and other growth parameters of plantations were estimated based on assumed age of plantation, form factors and inventory data of Chon Daen 1.

Tree age or inventory year 2020		Chon Daen 01 AGE OF THE PLANTATION IS ASSUMED AS 20 YEARS OLD AND FORM FACTOR IS 0.4							
Block N0.	Total trees	No.of stems/ ha	Top height (m)	DBH (cm)	Per Tree volume (m3)	Trees volume m3/ha	Total volume In block (m3)	MAI (m3/ha/year	CIA (m3/ha/year
1	2735	323	20.2	23.8	0.359	115.9	981.9	5.8	
2	209	357	19.2	23.3	0.327	116.7	68.3	5.8	
3	982	371	20.5	23.5	0.355	131.7	348.6	6.6	
4	2026	317	20.3	25.5	0.414	131.2	838.8	6.6	
5	258	382	17.5	23.4	0.30	114.6	77.4	5.7	
6	939	321	22	24.5	0.415	133.2	389.7	6.7	
7	1289	318	19.6	24.6	0.372	118.3	479.5	5.9	
8	698	322	25	29.3	0.674	217	470.4	10.8	
	Total 9136					Mean 134.8	GRAND TOTAL 3654		

Table 3.8. Tree volume and other growth parameters of plantations were estimated based on assumed age of plantation, form factors and inventory data of Chon Daen 224.

Tree age or inventory year 2020		Chon Daen 224 AGE OF THE PLANTATION IS ASSUMED AS 14 YEARS OLD AND FORM FACTOR IS 0.36							
Block N0.	Total trees	No.of stems/ ha	Top height (m)	DBH (cm)	Per Tree volume (m3)	Trees volume m3/ha	Total volume In block (m3)	MAI (m3/ha/year	CIA (m3/ha/year
B2	922	481	16.6	19.2	0.192	92.4	177	6.6	
B3	313	486	20	21.1	0.279	135.6	87,3	9.7	
	1235						GRAND TOTAL 264.3		

Table 3.9.Determination of site index based on growth parameters of past years of Chon Daen 1 and Chon Daen 224.

Chon Daen 1 and Chon Daen 224 plantation age is assumed as 20 years and 14 years old respectively.

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 Ave DBH (cm)	DBH differences from 2013 to 2020 and (Mean Increment of DBH) (cm) and periodic increment of DBH{}
Chon Daen 01	1	5	19.4	19.8	20.6	20.7	22.2	23.5	23.9	23.8	4.4 (1.19){0.55}
	2	1	17.7	18.1	19.0	18.9	21.1	22.6	23.4	23.3	5.6 (1.165){0.7}
	3	2	18.3	19.2	19.5	19.5	21.2	22.5	23.4	23.5	5.2 (1.175){0.65}
	4	4	19.4	19.5	21.3	21.5	23.3	24.7	25.3	25.5	6.1 (1.275){0.76}
	5	1	19.9	19.8	21.2	21.5	22.7	23.3	23.7	23.4	3.5 (1.17){0.44}
	6	2	19.4	18.9	20.4	20.5	22.6	23.9	24.6	24.5	5.1 (1.225){0.63}
	7	3	18.9	18.6	20.8	21.1	22.8	23.8	24.3	24.6	5.7 (1.23){0.71}
	8	2	19.9	22.2	24.4	24.7	27.2	28.8	29.2	29.3	9.4(1.465){1.17}
	Estate average										
Chon Daean	B2	14						17.2		19.2	(1.37)
	B3	5						19.9		21.1	(1.5)
	Estate average										

4. Observation, Conclusions and Recommendation.

1. When excess trees build up, it creates canopy and root competition among the trees in plantation. Those inferior trees must be thinned out (removing whole tree) in order to give space for good trees to grow freely and produce a larger cylindrical bole. Selective thinning must be applied after careful study of tree growth parameters given in graphs 3.1 and one-to-one tree inspection. Thinning regime can be decided after estimation of exact age, number of stem/ha, canopy closure, tree inventory data and tree annual rings information.
2. Pruning of the adventitious shoots should be carried out only after required training has been given to local staff and always under close supervision.
3. Fire control policy and fire lines must be properly maintained.
4. Application of soil improvement and soil erosion prevention methods must be applied where site has steep slope. Erosion of the soil conditions due to the harrowing carried out in the past.
5. Root system of uprooted trees should be closely monitored at regular basis if termite causes or help for decaying of roots.

Important finding based on analyzing inventory data.

1. Attempt was made to identify the site classes (quality index) of these two plantations. For that, we need to know the exact age of the plantations, which is not yet known exactly. Hence with available information we assumed age of Chon Daen 1 as 20 years old and Chon Daen 224 as 14 years old. With comparison of international quality index of teak growing in similar condition, we found that these two plantations can be categorized as quality 19.

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

At Year 2013, we assumed that Chon Daen 1 plantation is 12 years old. We found that mean tree DBH and mean tree density of Chon Daen 1 plantation at 12 years old are 19.1cm and 421.3 per hectare respectively. At year 2020, Chon Daen plantation is now 20 years old. We found that mean tree DBH and mean tree density of Chon Daen 1 plantation is presently 24.7cm and 338 per hectare respectively when we compare the growth parameters of table 1 of quality 19 index, growth rate of Chon Daen 1 plantation is little below (slower) than quality 19 index but it is reachable and achievable. Trees in Block 8 of Chon Daen 1 has shown this good potentiality because its growth rate exceed the growth rate of quality 19 index (see table 3.9) by producing 0.674 m3 of tree at 20 years age. When analyzed the last 8 years of DBH growth data, Block 8 of Chon Daen showed 84% higher growth increment than rest of Blocks.

Very important thing we have to understand from this scenario is that Block 8 has produced not only larger trees but, having higher number of tree density (322 trees/ha). This positive trends and its scientific reasons must be studied when extra trees in blocks is decided to be thinned out. There may be unidentified good site potentiality that pushes keep growing more trees than mentioned in quality 19 index table.

Finally it can be concluded that both teak plantation are healthy and in good condition. These plantations have much more potential with site to get more growth increment particularly for diameter growth over next 5 years if the plantation is maintained and managed scientifically.

Dr. Nimal Ruwanpathirana (Ph.D., M.Sc (Forestry), B.Sc. (Bio. Science)
Consultant for Forest Management and Wood Science