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RESEARCH ARTICLE

A Diameter Distribution Yield Prediction for Teak Stands in Taungoo District, Bago Region of Myanmar

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Abstract:

A parameter recovery procedure was applied to characterize the parameters for the Weibull distribution function based on four percentile methods and two hybrid methods which were the combination of diameter percentiles and moment methods. The procedure was used to develop a diameter distribution yield prediction for teak stands in Taungoo District of Myanmar. All the methods were evaluated by using independent observed data and calculating error indices. Among them, method 1 which involved the 31st and 63rd diameter percentiles produced the lowest error index. Therefore, method 1 was considered to predict yield based on diameter distribution and selected to construct a yield table for the study area. An example was also provided to show users how to apply this kind of yield prediction

Keywords: Parameter recovery procedure, Weibull distribution function, Teak stands, Taungoo District of Myanmar, and A diameter distribution yield prediction

Introduction

Teak (Tectona grandis L. f.) is one of the most important tropical timber species and is suitable for multiple end-uses. The potential for growing and managing teak in different ecological zones and under different situations is being increasingly recognized, leading to intensive domestication and cultivation of the species in countries/regions beyond its natural habitat [1].

Teak occurs naturally in parts of India, Myanmar, Laos and Thailand. It has been naturalized in Java, where it was introduced some 400–600 years ago[2,3]. Early introductions of teak outside Asia were made in Nigeria in 1902, with the first provenances being of Indian origin and subsequently of Burmese origin [4]. The first pure teak plantation in Tropical America was established in Trinidad in 1913. Teak planting in Honduras, Panama, and Costa Rica started between 1927 and 1929[5]. Teak is the world's most cultivated high-grade tropical hardwood, covering approximately 6.0 million hectares worldwide [6].

Of these, about (94%) are in Tropical Asia, with India (44%) and Indonesia (31%) contributing the bulk of the resource. Other countries i.e., Thailand, Myanmar, Bangladesh and Sri Lanka contribute significantly with (17%) in total. About (4.5%) of the teak plantations are in Tropical Africa and the rest are in Tropical America, mostly in Costa Rica and Trinidad and Tobago [7].

Between 2005 and 2014, the global annual trade of teak roundwood was more than one million cubic meters on average; the imports were valued at US $ 487 million per year, which is about 3 per cent of the value of the global timber trade (US $ 15.5 billion). One increasingly important consideration influencing trade in plantation-grown teak are forest management certification and legality issues [8].

In Myanmar, large-scale plantation forestry began in 1980s due to rapid deforestation that developed by that time although small-scale forest plantations started as early as late 1850s [9]. About 30,000 ha of forest plantations have annually been established since 1984. In addition to the normal teak plantation scheme, Forest Department (FD) of Myanmar has launched a Special Teak Plantation Programme since 1998 to maintain and increase teak production. It is designed to annually establish about 8100 hectares of new plantations. Moreover, FD has encouraged the private sector to establish teak plantations at a large scale since 2005. Until March 2010, 13,127 ha of private teak plantations have been established. Across the country, total area of plantations is 967,477 ha, among which that of pure teak is 424,743 ha (43.9 % of total planted area) [10].

All these teak stands are mainly concentrated in the Bago Yoma Range, a well-known place of high quality natural teak forests. These stands have been established for commercial purpose and as sustained yield basis. In order to achieve this, careful and continuous monitoring of the teak crop is very essential. However, in Myanmar, there is no scientific research related to diameter distribution yield prediction for teak stands in a specific area although it plays significant role in teak stand management for yield estimation and for important silvicultural decision making. Therefore, this study focused on the application of the methods and models to the diameter distribution yield prediction for teak stands in the Taungoo District, which is the eastern part of Bago Yoma Range.

Materials and Methods

Study Site Description

Ten teak stands for the present study are located in Taungoo District, Bago Region, Myanmar. Figure 1 shows the location of study site.

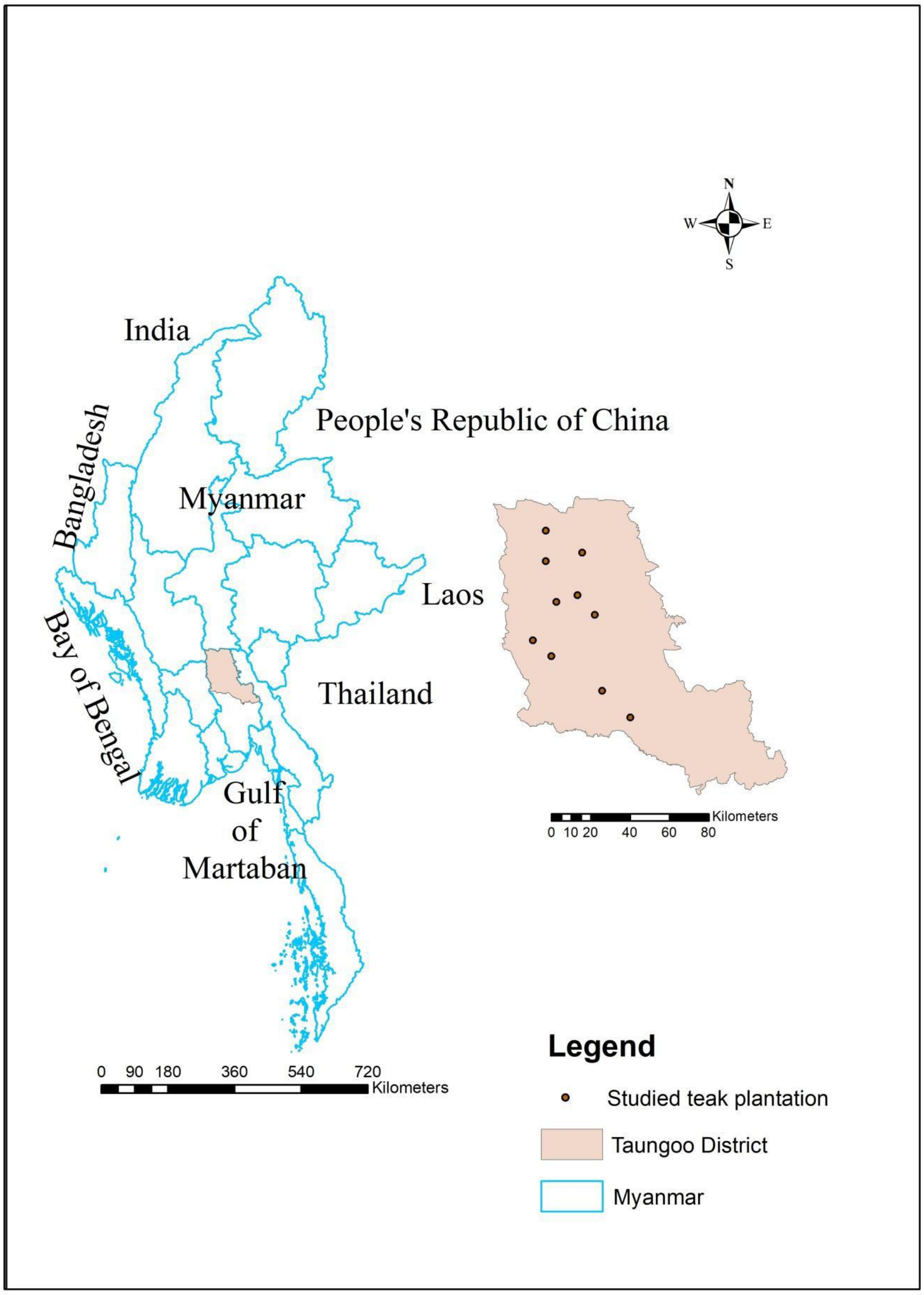

Figure 1. Location of study site

Methods

Data Collection

Data collection was carried out in 2016. There were ten teak stands for this study. Each stand for measurement was selected by the simple random sampling in order to obtain unbiased estimation of number of trees. Sampling frame (a list of the items or people forming a population from which a sample is taken), age, area, and number of sample plots measured for each stand were shown in Table 1.

Table 1. Sampling frame, age, area, and number of sample plots measured

Stand No.	Age (Year)	Total Number of Sample Plots (Sampling Frame)	Number of Sample Plots Collected	Area (ha)
1	17	379	10	19
2	15	180	10	9
3	33	187	10	9
4	13	174	10	9
5	22	533	10	27
6	52	104	10	5.3
7	42	70	10	3.5
8	40	140	10	7
9	46	252	10	12.5
10	25	586	10	25

(Spacing was 2.6m x 2.6 m for all stands)

Sample size for estimation of number of trees was calculated by using the following equation [11].

$$q = \left(\frac{ts}{E}\right)^2 \tag{1}$$

where,

q = number of sample plots estimated

t = value for student t distribution (for 95% confidence interval, t =2)

s = standard deviation

E = the desired half width of confidence interval

In order to get standard deviation, three sample plots from stand 1 were randomly selected. Sample plot size was 20m x 25 m (0.05 ha). In each sample plot, total number of trees was recorded. Total number of trees in each sample plot, and mean and standard deviation (number of trees) of three plots were shown in Table 2.

Table 2. Total number of trees in each sample plot, and average and standard deviation (number of trees) of three plots

Plot	No. of Trees Per 0.05 (ha)	Mean	Standard Deviation (s)
1	12	16.33	4.51
2	16		
3	21		

By substituting the following data in Equation 1, number of sample plots to be collected were derived.

t =2

s = 4.51

E = ±3 trees / 0.05 ha

$q = \left(\frac{2*4.51}{3}\right)^2$ = 9.03 plots per plantation

Actually, 10 sample plots per stand were collected. Total number of sample plots for all stands was 100. One sample plot from each stand was reserved for model validation. Therefore, for ten stands, there were 10 sample plots (10%) from 100 sample plots.

Measurement in Each Sample Plot

In each sample plot, diameter at breast height (D in cm) of each tree and total height (m) of all trees were measured. Total height was measured by Vertex IV hypsometer. Total number of trees in each sample plot was recorded. Basic stand statistics were shown in Table 3.

Table 3. Basic stand statistics

Variable	No. of Observations	Minimum	Maximum	Mean	Standard Deviation
Model Development Dataset					
A (Year)	10	13	52	30.50	13.99
H (m)	90	10.78	38.70	25.53	8.15
D_0 (cm)	90	12.80	53.00	27.41	11.50
D_{25}(cm)	90	14.75	58.75	31.28	12.93
D_{31}(cm)	90	15.1	60.41	32.51	13.33
D_{50}(cm)	90	16.00	69.00	35.24	14.25
D_{63} (cm)	90	16.39	71.37	37.17	15.00
D_{95}(cm)	90	21.05	81.25	48.22	18.24
D_q(cm)	90	16.38	68.43	35.76	14.21
RS	90	0.16	0.50	0.27	0.09
N	90	120	640	259.40	96.84
Model Validation Dataset					
A (Year)	10	13	52	30.50	13.99
H (m)	10	14.08	34.82	25.47	8.27
D_0(cm)	10	14.00	38.00	25.23	10.82
D_{25}(cm)	10	14.75	42.00	28.39	12.44
D_{31}(cm)	10	15.00	46.32	30.36	13.05
D_{50} (cm)	10	16.80	55.00	34.27	14.08
D_{63} (cm)	10	17.49	59.24	36.65	15.27
D_{95}(cm)	10	25.06	63.00	46.19	14.73
D_q (cm)	10	17.22	55.41	34.95	14.48

Variable	No. of Observations	Minimum	Maximum	Mean	Standard Deviation
RS	10	0.18	0.45	0.27	0.09
N	10	140	500	256.00	93.71

A = stand age in years, H = average height of dominant canopy [average height of 100 tallest trees per hectare] , D_0 = minimum diameter, D_{25} = 25th diameter percentile, D_{31} = 31st diameter percentile, D_{50} = 50th diameter percentile, D_{63} = 63rd diameter percentile, D_{95} = 95th diameter percentile, D_q = quadratic mean diameter, RS = relative spacing, and N = number of trees per hectare

Diameter Distribution Model

The Weibull function was introduced by Bailey and Dell [12] to model diameter distributions in forest stands. It has since become popular because it is flexible enough to fit shapes commonly found in both uneven-aged and even-aged stands, and also because the calculation of proportions of trees in diameter classes is straightforward [13].The parameter recovery approach [14] has been found to perform better than the parameter prediction approach, in which the Weibull parameters are predicted directly. In the parameter recovery approach, the Weibull parameters are "recovered" from diameter moments (arithmetic and quadratic diameters, and diameter variance), diameter percentiles (e.g. 25th, 31st, 50th, 63rd, or 95th), or a combination of both.

The Weibull cumulative distribution function to model diameter distributions in single-species, single-cohort stands was introduced by Bailey and Dell [12] as follow.

$$F(x) = 1 - \exp\left[-\left(\frac{x-a}{b}\right)^{c}\right] \quad (a \leq x < \alpha) \tag{2}$$

= 0, otherwise

where,

a = location parameter (minimum diameter)

b = scale parameter

c = shape parameter

Clutter et al.[15] pointed out to calculate proportion of trees in each diameter class by the following function.

$$P_i = exp\left[-\left(\frac{L_i-a}{b}\right)^{c}\right] - exp\left[-\left(\frac{U_i-a}{b}\right)^{c}\right] \tag{3}$$

where,

Pi = proportion of trees in diameter class i

Li = lower limit of diameter class i

Ui = upper limit of diameter class i

Other variables are defined as aforementioned.

This study evaluated six parameter recovery methods to predict the parameters of Weibull functions that modeled diameter distributions of teak stands. The Weibull parameters were recovered from stand attributes by use of regression.

Parameter Recovery Methods

The Weibull location parameter (a) must be smaller than the predicted minimum diameter in the stand (D_0). Parameter (a) was set as $(0.5D_0)$ since [16] found that this gave best results in terms of goodness-of-fit. The other Weibull parameters, (b) and(c), were recovered from the diameter percentiles (Percentile methods), and Hybrid methods which were the combination of diameter percentiles and the moments of the diameter distribution (Moment method). The following parameter recovery methods developed by Cao [13] were evaluated.

Percentile Methods

(i) Method 1 ($\hat{D}_{31}$ and $\hat{D}_{63}$)
(ii) Method 2 ($\hat{D}_{50}$ and $\hat{D}_{95}$)
(iii) Method 3 ($\hat{D}_{25}$,$\hat{D}_{50}$ and $\hat{D}_{95}$)
(iv) Method 4 ($\hat{D}_{31}$,$\hat{D}_{50}$ and $\hat{D}_{63}$)

Hybrid methods

(i) Method 5 ($\hat{D}_q$,$\hat{D}_{25}$ and $\hat{D}_{95}$)
(ii) Method 6 ($\hat{D}_q$,$\hat{D}_{25}$, $\hat{D}_{50}$and $\hat{D}_{95}$)

The symbols $\hat{D}_q$,$\hat{D}_{25}$,$\hat{D}_{31}$, $\hat{D}_{50}$, $\hat{D}_{63}$, and $\hat{D}_{95}$ denoted predicted values of quadratic mean diameter, and the 25th, 31st, 50th, 63rd, and 95th diameter percentiles, respectively. In method 6 [17], the parameter (a) was computed from

$$a = \frac{\hat{D}_0 n^{1/3} - \hat{D}_{50}}{n^{1/3} - 1} \qquad (4)$$

where,

n = number of trees in the plot. Other variables were already defined.

Systems of equations for the six methods developed by Cao [13] were shown in Table 4.

Table 4. Summary of six parameter recovery methods developed by Cao (2012)

Method	Equation for **a**	Equation for **b** and **c**
Percentile Methods		
1($\hat{D}_{31}$ and $\hat{D}_{63}$)	$a = 0.5\hat{D}_0$	$c = \frac{ln\left(\frac{ln(1-0.63)}{ln(1-0.31)}\right)}{ln(\hat{D}_{63}-a) - ln(\hat{D}_{31}-a)}$ $b = \frac{\hat{D}_{63}-a}{[-ln(1-0.63)]^{1/c}}$
2($\hat{D}_{50}$ and $\hat{D}_{95}$)	$a = 0.5\hat{D}_0$	$c = \frac{ln\left(\frac{ln(1-0.95)}{ln(1-0.50)}\right)}{ln(\hat{D}_{95}-a) - ln(\hat{D}_{50}-a)}$ $b = \frac{\hat{D}_{50}-a}{[-ln(1-0.50)]^{1/c}}$
3 ($\hat{D}_{25}$,$\hat{D}_{50}$ and $\hat{D}_{95}$)	$a = 0.5\hat{D}_0$	$c = \frac{ln\left(\frac{ln(1-0.95)}{ln(1-0.25)}\right)}{ln(\hat{D}_{95}-a) - ln(\hat{D}_{25}-a)}$ $b = \frac{\hat{D}_{50}-a}{[-ln(1-0.50)]^{1/c}}$
4 ($\hat{D}_{31}$,$\hat{D}_{50}$ and $\hat{D}_{63}$)	$a = 0.5\hat{D}_0$	$c = \frac{ln\left(\frac{ln(1-0.63)}{ln(1-0.31)}\right)}{ln(\hat{D}_{63}-a) - ln(\hat{D}_{31}-a)}$ $b = \frac{\hat{D}_{50}-a}{[-ln(1-0.50)]^{1/c}}$
Hybrid Methods		
5 ($\hat{D}_q$,$\hat{D}_{25}$ and $\hat{D}_{95}$)	$a = 0.5\hat{D}_0$	$c = \frac{ln\left(\frac{ln(1-0.95)}{ln(1-0.25)}\right)}{ln(\hat{D}_{95}-a) - ln(\hat{D}_{25}-a)}$ $b = -\frac{aG_1}{G_2} + \left[\left(\frac{a}{G_2}\right)^2 (G_1^2 - G_2) + \hat{D}_q^2/G_2\right]^{0.5}$
6 ($\hat{D}_q$,$\hat{D}_{25}$, $\hat{D}_{50}$and $\hat{D}_{95}$)	$a = \frac{\hat{D}_0 n^{1/3} - \hat{D}_{50}}{n^{1/3} - 1}$	$c = \frac{ln\left(\frac{ln(1-0.95)}{ln(1-0.25)}\right)}{ln(\hat{D}_{95}-a) - ln(\hat{D}_{25}-a)}$ $b = -\frac{aG_1}{G_2} + \left[\left(\frac{a}{G_2}\right)^2 (G_1^2 - G_2) + \hat{D}_q^2/G_2\right]^{0.5}$
$G_k = \Gamma\left(1 + \frac{k}{c}\right)$ Γ(-) is the gamma function.		

$\hat{D}_0$= minimum diameter, $\hat{D}_{25}$ = 25th diameter percentile, $\hat{D}_{31}$= 31st diameter percentile, $\hat{D}_{50}$= 50th diameter percentile, $\hat{D}_{63}$ = 63rd diameter percentile, $\hat{D}_{95}$= 95th diameter percentile, $\hat{D}_q$= quadratic mean diameter, and n = number of trees per plot

Model Evaluation

The error index [18] was used to evaluate how well each method performed for the validation dataset was defined as:

$$\text{EI} = \frac{1}{m}\sum_i \sum_k |n_{ik} - \hat{n}_{ik}| \tag{5}$$

where,

EI = error index

n_{ik} = observed number of trees per ha in diameter class k for the ith plot

$\hat{n}_{ik}$ = predicted number of trees per ha in diameter class k for the ith plot

m = the number of sample plots

The smaller the error index, the better the distribution fits the data.

Model Used for Parameter Recovery Methods

The model used was of the following general form according to Cao [13].

$$\text{y} = \exp[b_1 + b_2 RS + b_3 \ln(N) + b_4 \ln(H) + b_5 A^{-1}] + \epsilon \tag{6}$$

where,

ln = natural logarithm

exp = exponential function

y = minimum diameter($\widehat{D}_0$), quadratic mean breast height diameter (D_q) and diameter percentiles

ϵ = random error

RS = relative spacing

N = number of trees per hectare

H = average height of dominant canopy (meter) [in this study, average height of 100 tallest trees per hectare]

A = stand age in year

b_1,..., b_5 = regression parameters to be estimated

Relative spacing was computed by the following formula [11].

$$\text{RS} = [10{,}000/N]^{0.5}/H \tag{7}$$

All the variables are defined as aforementioned.

Clutter et al.[15] suggested to calculate the quadratic mean breast height diameter as follow.

$$D_q = \sqrt{\frac{1}{n}\sum_{i=1}^{n} D_i^2} \tag{8}$$

where,

D_q was already defined.

D_i = diameter (cm) over bark at breast height of tree i

Individual Tree Height

To calculate individual tree height, the following height-diameter model was fitted by using 213 observations from this study.

$$\ln(h) = b_1 + b_2 D^{-1} \tag{9}$$

where,

h= total height in meters of a teak tree

D=diameter (cm) at breast height

Other variables are defined as aforementioned.

Individual Tree Volume Equation

Individual tree volume equation for teak stands developed by Naing [19] was as follow.

$$V = -0.0230361338 + 0.0000485831 D^2 h - 0.00000084 D^2 h^2 \tag{10}$$

where,

V = volume in cubic meters (over bark) up to top diameter of approximately 10 cm excluding stump

Other variables were already defined. In the above volume equation 10, all the parameters and F-test were highly significant ($p < 0.01$). Coefficient of determination (R^2) was 0.94.

Results and discussion

In Equation 6, ln (H) was not significant ($p > 0.05$). and this variable was excluded from the model and analyzed again. The parameter estimates obtained from the model development dataset were presented in Table 5. All the parameters were highly significant ($p < 0.01$). Moreover, F- test also showed that the regression was highly significant ($p < 0.01$). The value of coefficient of determination (R^2) for each model was very high. Therefore, all the models were considered the best fit to data. Table 6 showed the error indices computed for each method from validation dataset. Method 1 produced the best result by scoring the lowest error index, followed by Method 4 and 6. Therefore, method 1 was selected for further calculations. Table 7 presented the predicted values for each plantation from validation dataset to calculate Weibull parameters for each method. Cao [13] suggested that the method involved $\widehat{D}_{31}$ and $\widehat{D}_{63}$ should not be used in recovering the Weibull parameters in his study for loblolly pine. However, in this study, two methods (method 1 and 4) involved $\widehat{D}_{31}$ and $\widehat{D}_{63}$ provided the lowest error indices for teak stands. These conditions may be due to differences in species and spacing although the same methodology was used. Thinning frequency can also affect these conditions. Another aspect is that this kind of situation may depend on the definition in dominant height for calculating the relative spacing. Moreover, in this study, only 90 sample plots were used for model development. For model validation, 10 plots were considered. In this case, one can assume a few sample plots were analyzed and evaluated. However, this depended on time limitation, and available materials for this study. Moreover, in Myanmar, there is no yield prediction method like this and it is the first approach for the management of teak stands.

Table 5. Estimated parameter values

Variable	b_1	b_2	b_3	b_5	R^2	P-value (for all parameters)	F-test (P-value)
$\hat{D}_q$	6.13	-1.19	-0.32	-13.80	0.92	0.01	0.01
$\hat{D}_0$	9.06	-4.03	-0.76	-22.42	0.71	0.01	0.01
$\hat{D}_{25}$	5.95	-1.26	-0.31	-13.91	0.88	0.01	0.01
$\hat{D}_{31}$	6.28	-1.53	-0.36	-12.84	0.90	0.01	0.01
$\hat{D}_{50}$	6.39	-1.38	-0.37	-13.38	0.92	0.01	0.01
$\hat{D}_{63}$	6.42	-1.38	-0.37	-13.27	0.92	0.01	0.01
$\hat{D}_{95}$	7.84	-3.48	-0.48	-8.39	0.92	0.01	0.01
ln (h)	3.62	-13.46			0.99	0.01	0.01

$\hat{D}_q$= quadratic mean diameter, $\hat{D}_0$= minimum diameter, $\hat{D}_{25}$= 25th diameter percentile, $\hat{D}_{31}$= 31st diameter percentile, $\hat{D}_{50}$= 50th diameter percentile, $\hat{D}_{63}$= 63rd diameter percentile, $\hat{D}_{95}$= 95th diameter percentile, h= total height of a teak tree

Table 6. Error index and rank for each method

Method	Error Index	Rank
1	206.43	1
4	216.78	2
6	237.18	3
5	258.32	4
3	261.23	5
2	284.35	6

Table 7. Predicted values from validation dataset to calculate Weibull parameters

Stand	Variable						
	$\widehat{D}_q$	$\widehat{D}_0$	$\widehat{D}_{25}$	$\widehat{D}_{31}$	$\widehat{D}_{50}$	$\widehat{D}_{63}$	$\widehat{D}_{95}$
	Predicted Value						
1	21.31	6.54	18.19	18.46	20.55	21.70	25.81
2	17.22	5.26	15.00	15.35	16.50	17.52	27.50
3	43.86	33.52	37.90	39.83	43.95	46.25	72.42
4	16.26	4.44	13.94	14.45	15.78	16.72	23.63
5	31.08	18.11	27.03	28.389	30.79	32.54	55.43
6	44.38	31.98	38.69	39.46	43.45	45.78	67.93
7	46.10	36.73	40.29	41.51	45.45	47.90	76.85
8	45.21	36.60	39.67	40.92	44.53	46.98	79.12
9	47.48	40.63	41.51	43.18	47.16	49.70	83.64
10	41.40	31.13	36.16	37.63	41.00	43.24	72.86

$\widehat{D}_q$ = quadratic mean diameter,$\widehat{D}_0$= minimum diameter, $\widehat{D}_{25}$= 25th diameter percentile, $\widehat{D}_{31}$= 31st diameter percentile, $\widehat{D}_{50}$= 50th diameter percentile, D_{63}= 63rd diameter percentile, $\widehat{D}_{95}$= 95th diameter percentile

Application Procedures for Yield Prediction

Example yield table for teak stand constructed by using Weibull parameters in method 1 are presented in table 8. In this example, a = 18.30, b = 28.72, c = 4.15, and number of trees per hectare (N) = 280. The procedures to construct this kind of yield table are as follow.

i. Set 0.05 ha sample plot (20 m x 25 m) in a teak stand. Measure the height of five trees which are the tallest in the sample plot. Then calculate average height of these trees. Record age (A). Count the number of trees (n) in the sample plot and convert these numbers of trees to per-hectare level (N). Compute relative spacing from Equation 7. Predict $\widehat{D}_{31}$ and $\widehat{D}_{63}$by using Equation 6 and Table 5.

ii. Calculate Weibull parameters (a, b, and c) by applying the formulae for method 1 in Table 4.

iii. Set diameter classes. In each diameter class, define the lower and upper limits of the class. In order to get class probability (Pi) in each diameter class, use Equation 3.

iv. The proportion of trees in each diameter class can be obtained by multiplying class probability by the number of trees per hectare.
v. Compute individual tree heights (h) by using Equation 9 and class midpoint diameters.
vi. The resultant class midpoint diameter and individual tree height can be used to calculate individual tree volume (V). Apply Equation 10.
vii. To get class volume, multiply number of trees in the class by individual tree volume.
viii. Finally, sum all class volumes to get total volume per hectare.

Table 8. Yield table for teak stand constructed by applying method 1 and validation dataset from stand no. 8

DBH Class	Lower Limit (cm)	Upper Limit (cm)	Class Probability (P_i)	Class Frequency (trees/hectare) ($N \times P_i$)	Class Midpoint (cm)	Per-Tree Height (m)	Per-Tree Volume (m^3)	Class Volume (m^3ha^{-1})
1	26	28	0.007	2	27	22.702	1.096	2.193
2	28	30	0.013	4	29	23.496	1.327	5.308
3	30	32	0.021	6	31	24.211	1.580	9.483
4	32	34	0.033	9	33	24.856	1.857	16.715
5	34	36	0.047	13	35	25.442	2.157	28.044
6	36	38	0.063	18	37	25.977	2.480	44.652
7	38	40	0.080	22	39	26.466	2.827	62.207
8	40	42	0.094	26	41	26.915	3.198	83.150
9	42	44	0.105	29	43	27.329	3.592	104.170
10	44	46	0.109	31	45	27.712	4.009	124.301
11	46	48	0.106	30	47	28.067	4.450	133.529
12	48	50	0.095	27	49	28.397	4.915	132.730
13	50	52	0.078	22	51	28.705	5.404	118.900
14	52	54	0.059	16	53	28.992	5.916	94.671
15	54	56	0.039	11	55	29.261	6.453	70.983
16	56	58	0.023	7	57	29.513	7.012	49.090
17	58	60	0.012	4	59	29.751	7.596	30.386
18	60	62	0.005	2	61	29.974	8.203	16.407
19	62	64	0.002	1	63	30.185	8.835	8.835
			Total	280 (N)				1135.763

Conclusions

The analyses shown in this study highlighted that the predicted $\hat{D}_{31}$ and $\hat{D}_{63}$ played a significant role in recovering parameters of the Weibull that characterized the diameter distribution of teak stands because two methods (method 1 and 4) involved $\hat{D}_{31}$, and $\hat{D}_{63}$ produced the lowest error indices. Based on the results of this work, it is recommended that method 1 can be considered as the best diameter distribution yield prediction one and should be applied to construct yield table for teak stands in the study area. Moreover, one can use this kind of yield estimation and also yield table for thinning purpose by calculating basal area.

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