Thai J. For. 9 : 129 – 138 (1990)   วารสารวนศาสตร์ ๙ : ๑๒๙–๑๓๘ (๒๕๓๓)

ESTIMATION OF STEM AND STAND VOLUME OF *EUCALYPTUS CAMALDULENSIS*

Koichi Kamo[1/]
Bopit Kiatvuttinon[2/]
Chingchai Viriyabuncha[2/]
Pin Kuerkool[2/]

บทคัดย่อ

ตารางปริมาตรไม้ยูคาลิปตัส คามาลดูเลนซิส ได้สร้างขึ้นโดยใช้ข้อมูลไม้ตัวอย่างจำนวน ๔๕๙ ต้น จากสวนป่าต่าง ๆ ทั่วประเทศไทย ทั้งในภาคกลาง ภาคตะวันตก ภาคเหนือ และภาคตะวันออกเฉียงเหนือ ปริมาตรไม้แต่ละต้นนั้นคำนวณจากเส้นผ่าศูนย์กลางเพียงอก (D) และความสูง (H) อย่างไรก็ตาม การใช้สมการเพียงสมการเดียวไปคำนวณหาปริมาตรของไม้ทุกขนาดนั้นย่อมก่อให้เกิดความผิดพลาดได้ง่าย โดยเฉพาะอย่างยิ่งหากต้นไม้นั้นมีขนาดใหญ่ ดังนั้น จึงแนะนำให้ใช้สมการแรกสำหรับไม้ขนาดเล็ก และใช้สมการที่สองสำหรับไม้ขนาดใหญ่ คือ

ไม้ที่มีค่า D^2H เท่ากับหรือน้อยกว่า ๓,๐๐๐ ซม²•ม ให้ใช้สมการ :

$V = 0.000084 (D^2H)^{0.889883}$

$R = 0.998184$

ไม้ที่มีค่า D^2H มากกว่า ๓,๐๐๐ ซม²•ม ให้ใช้สมการ :

$V = 0.000059 (D^2H)^{0.940717}$

$R = 0.985955$

ส่วนปริมาตรของไม้ยูคาลิปตัสในสวนป่าที่มีระยะปลูกใกล้เคียงกันก็สามารถคำนวณได้จากพื้นที่หน้าตัด (b) และความสูงเฉลี่ย (h) ของไม้ในสวนป่าดังสมการข้างล่างนี้

สวนป่าที่มีระยะปลูกต่ำกว่า ๑×๒ ม. ใช้สมการ :

$Y_v = 0.929061 (bh)^{0.931664}$

$R = 0.994066$

สวนป่าที่มีระยะปลูกเกินกว่า ๒×๒ ม. ใช้สมการ :

$Y_v = 0.606675 (bh)^{0.964673}$

$R = 0.978601$

1/ Kansai Research Center Forestry and Forest Products Research Institute, Kyoto 612, Japan.
2/ Royal Forest Department, Bangkhen, Bangkok 10900, Thailand.

ABSTRACT

Stem volume table of *Eucalyptus camaldulensis* was constructed covering the main plantation areas of this species in Thailand. The data obtained were 458 sample trees coming from central, western, northern, and northeastern parts of Thailand. Multiplicative model was applied for to estimate the stem volume from the diameter at breast height (D) and height (H) of the tree. Application of one equation for all data showed some deviation in the bigger trees. Therefore, the data were separared into two parts according to the size of tree. For each part the following equation was applied.

$V = 0.000084\ (D_2H)^{\text{[illegible]}}$ $(R = 0.998184)$

(For the values $\leq$ 3,000 $cm^2 \cdot m$ in D^2H)

$V = 0.000059\ (D_2H)^{\text{[illegible]}}$ $(R = 0.985955)$

(For the values $>$ 3,000 $cm^2 \cdot m$ in D^2H)

By using these equation, the stem volume table of *E. camaldulensus* was constructed.

INTRODUCTION

In Thailand, some exotic fast growing broad leaved tree species have often been planted on denuded or cut over areas to promote reforestation. Among them, *E. camaldulensis* is widely planted and grows in central, north and northeastern parts of Thailand. At present this species is of great importance as a tree species for reforestation in the main part of Thailand, although, an overall silvicultural system for this species has not yet been established. Assessment of standing stock of *E. camaldulensis* on the basis of sound methodology gives the first step for evaluating growth and development of *E. camaldulensis* stands. This could bring the basis for developing a well oriented silvicultural system of *E. camaldulensis*.

In this report, stem and stand volume of *E. camaldulensis* were assessed with emphasis on their methodology. The report consists of two parts. One is to construct a volume table from the data in various areas, gearing to be used in main plantation areas of Thailand. Another is to examine the method for estimating stand volume from the data of every tree census on a given stand.

MATERIALS AND METHODS

The stem volume table of the *E. camaldulensis* was set up.

Collection of data

The original data on height (H), diameter at breast height (DBH) and stem volume (V) of each tree were collected from not only field survey but also materials which had been surveyed by others (Kasetsart University, Royal Forest Department and Japan Paper Association)

In surveyed areas, some samples of *E. camaldulensis* had been fallen and H, DBH and diameter of each strata (0 m, 0.3 m, 1.3 m, 2.3 m - - - above the ground level) were measured. The volume for sample trees were estimated by Smalian formula.

The areas surveyed were in Chang Mai, Kanchanaburi, Ratchaburi, Si Sa Ket, Brachin Buri, Na Khorn Na Yok, Na Khorn Sa Wan, Lop Buri, Chon Buri, Chachoengsao, and Ra Yong, covering central, western, northern, and northeastern parts of Thailand.

The number of sample trees amounted to 458 trees.

The values of sample trees ranged from 2.3 m to 26.5 m in height and from 0.8 cm to 23.3 cm in diameter at breast height, respectively. The age of sample trees was from 0.8 year-old to 7 year-old.

Choosing equation to estimate stem volume

1. Determining independent variable for the equation.

Before fitting the equation to the data available, independent variable was examined. Recently, an attempt was made to estimate the stem volume by using simple V - DBH relations. This was due to relatively low reliability in measuring height of bigger tree. However, this method would give an appreciable error to estimate stem volume which covers different stands established in even the same areas. Fig. 1 and Fig. 2 showed the relationship between V and square of DBH on the log-log coordinate for stands with different density in the same area and for stands in different areas. The relation between V and DBH was found to vary among the stands with different density in the same areas and among the stands in different areas to some extent, suggesting invalidity of fitting one regression line to various stands. Incompatibility of V - DBH relations was observed among many stands with different growth stage (Yoda, K, 1971) as well. This was due mainly to different height-diameter relations in different stands. In addition to this, the V - DBH relations on the log-log coordinates might not be linear but curvilinear in a strict sense. Therefore, it might not valid to approximate one regression line between V and DBH over the range of data which contain different stands of the same areas as well as of different areas. It can be said that the error of the estimation caused by less exact measurement of height of larger trees may be much smaller than the errors due to the application of simple V - DBH regression.

On the contrary, independent variables combining diameter with height could give a higher accuracy of estimating stem volume over a wide range of data which include different stands not only in the same areas but also in different areas. There was no appreciable inter-stand difference concerning V - $DBH^2 * H$ (D^2H) relation in terms of different spacing (Fig. 3) and different areas (Fig. 4). This is due to the fact that D^2H is a quantity closely related to the stem volume.

These would show that height measurement is indispensable for estimating accurately stem volume over the wide range of data. Therefore, in this calculation, D^2H was used as an independent variable for fitting the curve.

2. Fitting curve.

The models including linear, multiplicative exponential, reciprocal, and polynomial were approximated for the relation between V - D^2H by the method of least squares. Among them, the multiplicative model gave the best fitness ($R = 0.998366$)

The equation was given by:

$$V = 0.000081\ D^2H^{0.896480} \quad \ldots\ldots\ldots\ldots (1)$$

However, equation (1) which was the best fitted among the models could not cover the whole range of data concerned. The estimated value of stem volume for bigger trees ($D^2H > 3{,}000\ cm^2 \cdot m$) from formula 1) was subject to be a bit smaller than observed one. Relative error of the estimated values tended to be deviated lower from 0 point in bigger D^2H classes ($D^2H > 3{,}000\ cm^2 \cdot m$), while relative error was almost evenly scattered around 0 point in smaller D^2H classes ($D^2H < 3{,}000\ cm^2 \cdot m$), as shown in Fig. 5. Thus it would be reasonable to separate the data into two parts being more than $3{,}000\ cm^2 \cdot m$ in D^2H and less than $3{,}000\ cm^2 \cdot m$ in D^2H.

Two parts of data were approximated separately by multiplicative model. The equation for each part was as follows.

$$V = 0.000084\ D^2H^{0.889843}\ (R = 0.998184) \quad \ldots\ldots\ldots\ldots (2)$$

(For the values $\leq 3{,}000\ cm^2 \cdot m$ in D^2H)

$$V = 0.000059\ D^2H^{0.940717}\ (R = 0.985955) \quad \ldots\ldots\ldots\ldots (3)$$

(For the values $> 3{,}000\ cm^2 \cdot m$ in D^2H)

The relative error calculated from equations (2) and (3) was scattered evenly around 0 point (Fig. 6). Therefore, instead of equation (1), equations (2) and (3) were used for estimating stem volume.

Table 1 shows the volume table calculated from equations (2) and (3). The volume table calculated here might cover the main plantation areas for *E. camaldulensis* including northern, northeastern, western, and central part of Thailand. Though, effort should be made to revise the volume table by collecting more data in an extreme range of growth conditions in various areas according to the procedure described above.

RESULTS AND DISCUSSION

Estimation of the stand volume in a given stand is sometimes a time-consuming task. In this section, one simple method for estimating stand volume is presented.

Stand volume was calculated by use of equations (2) and (3) according to the size of the trees in various *E. camaldulensis* stands with different areas. The data concerned included the stands of Ratchaburi, Somdet and Si Sa Ket. This data ranged from 0.5 m * 0.5 m to 4 m * 4 m in spacing and from one year to six years in stand age. A positive relation was found to exist between stand volume (y_v) and basal area (b) * mean height of stand (h) on log-log coordinate (Fig. 7). The regression line of stand volume on basal area * mean height seemed to be separated into two lines according to the spacing of the stand, being less than 1 m * 2 m and more than 2 m * 2 m in spacing (Fig. 7). For each group, the following equation was fitted.

$$y_v = 0.929061\ (b \cdot h)^{0.931664}$$
$$(R = 0.994046) \quad \ldots\ldots\ldots\ldots\ldots (4)$$

(For the group less than 1 m * 2 m in spacing.)

$$y_v = 0.606675\ (b \cdot h)^{0.964673}$$
$$(R = 0.978601) \quad \ldots\ldots\ldots\ldots\ldots (5)$$

(For the group more than 2 m * 2 m in spacing.)

Regardless of the difference in growth stage, site conditions for each areas, the regression was approximated well to one line in the stands with similar spacing.

In general form, equations (4) and (5) were given by:

$$y_v = a \cdot (b \cdot h)^b \quad \ldots\ldots\ldots\ldots\ldots (6)$$

a is a constant and b is a coefficient. In equation (6), $y_v/(b \cdot h)$ might denote mean breast height form factor.

Mean breast height form factor of a given stand is expressed as follows (Shidei, T et al., 1974) :

Individual stem volume is :

$$V = (\pi / 4) \cdot F \cdot D^2 \cdot H$$

V : Individual stem volume
F : breast height form factor
D : DBH
H : Height

Therefore

$$y_v/h = (1/h) \cdot \Sigma\ ((\pi / 4) \cdot F \cdot D^2 H)$$
$$= (1/h) \cdot h \cdot f \cdot \Sigma((\pi / 4) \cdot D^2)$$
$$= f \cdot \Sigma\ ((\pi / 4) \cdot D^2)$$

f : mean breast height form factor

Thus :

$$y_v = f \cdot b \cdot h \quad \ldots\ldots\ldots\ldots\ldots (7)$$

And

$$f : y_v / (b \cdot h) \quad \ldots\ldots\ldots\ldots\ldots (8)$$

In the case that power b is equal to one in equation (6), equation (6) is equivalent to equation (7), showing that coefficient a is the mean breast height form factor (equation (8)).

Since power b in equations (4) and (5) is regarded as nearly one, coefficient a in equations (4) and (5) is approximately the same as mean breast height form factor. Breast height form factor is equivalent to stem form. It is widely accepted that stem form is easily changed by spacing. This suggested that the mean breast height form factor was affected by spacing of stand, being smaller in the stand with wider spacing. Therefore, it is inferred that separation of the regression line between the stands with wider spacing and with narrower spacing could be caused by difference of stem form due to the different spacing. It might be, therefore, reasonable that the y_v - $b \cdot h$ relation was separated according to the spacing of stands.

Power b in equations (4) and (5) was actually a bit smaller than one. This implies that the mean breast height form factor became somewhat smaller as the stand became larger. In fact, the breast height form factor is known to become smaller with tree growth.

From these findings, it might be concluded that although equation (6) is an empirical one, this equation could be rationally explained by modification of stem form (breast height form factor) caused by stand density and growth stage of stand. This justifies in using the equations (4) and (5) to estimate stand volume from basal area and mean height of the stands with similar spacing.

The data used here is rather limited. Therefore, equations (4) and (5) may be preliminary ones. In future, coefficient a and power b in the equations and grouping of equation according to the spacing will be revised after more data are gathered.

ACKNOWLEDGEMENTS

We wish to express our sincere thanks to Dr. Pongsak Sahunalu (Kasetsart University), Mr. Thiti Visaratana (Royal Forest Department) and Mr. Somboon Kirtiprayoon (Royal Forest Department) for allowing us to use the original data. Our thanks are also due to the Japan Paper Association for permitting us to use the data. We owe much to Dr. Ryosuke Kato (Research and Training in Reafforestation project, Royal Forest Department) for his kind review and advice in preparation of the manuscript, to Dr. Seiichi Oohata (Kyoto University) for his reading of the manuscript, Mr. Bunchoob Buntawee (Royal Forest Department) and Mr. Vichien Sumantakul (Royal Forest Department) for their kind support for this research, and to Mr. Somboon Boonyuen for his cooperation in field work.

REFERENCES

Shidei, T., *et al.* 1974. Japanese cypress forest. Chikyusha, Tokyo. 375 p.

Yoda, K. 1971. Forest Ecology. Tsukiji Shokan, Tokyo. 331 p.

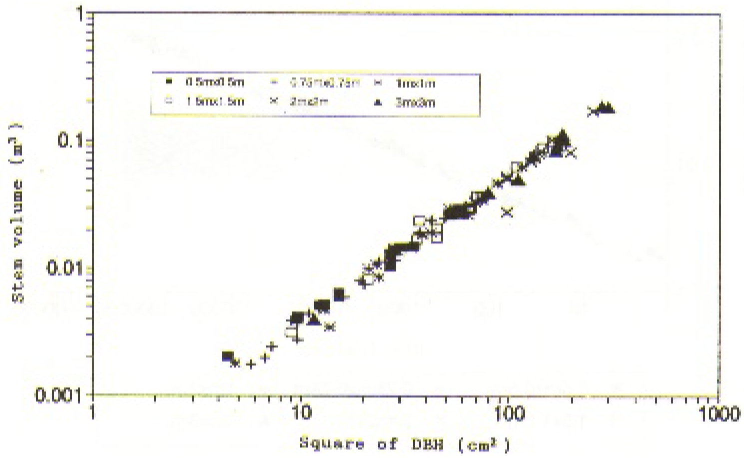

Fig. 1. Relationship between stem volume and DBH in the stands with different spacing.

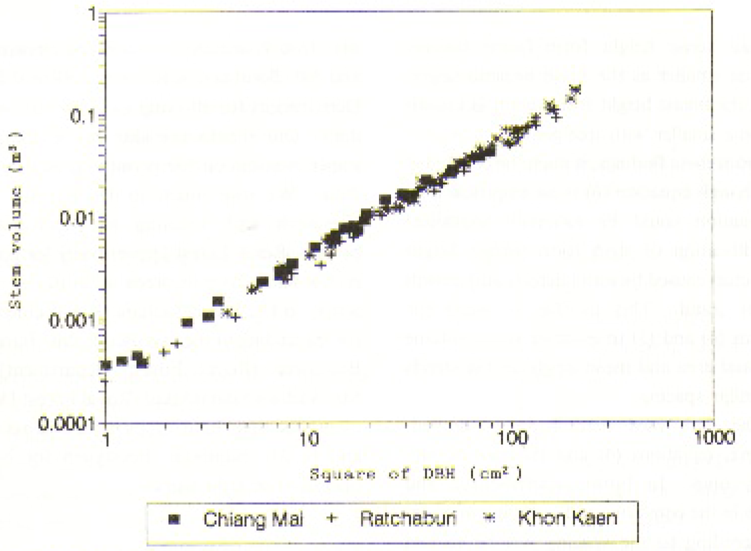

Fig. 2. Relationship between stem volume and DBH in the different locality.

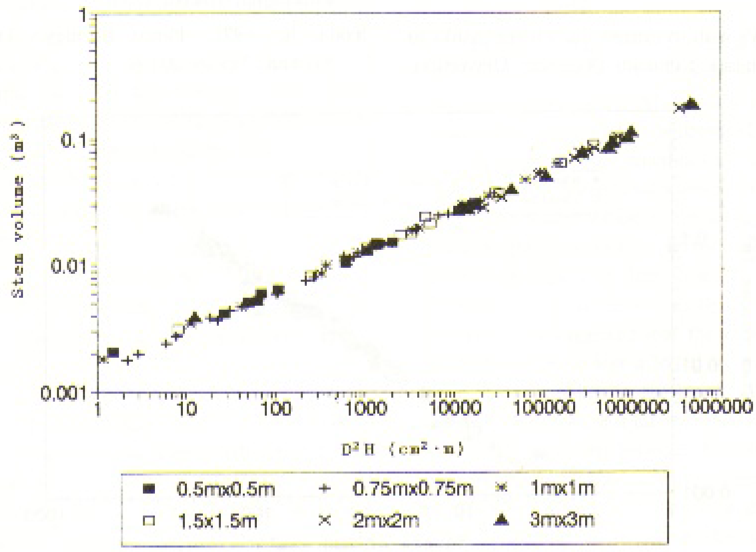

Fig. 3. Relationship between stem volume and D^2H in the stands with different spacing.

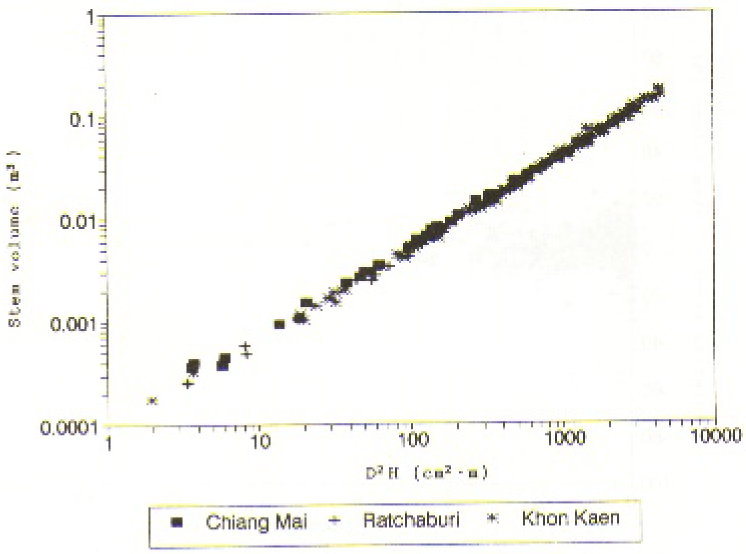

Fig. 4. Relationship between stem volume and D^2H in the differen locality.

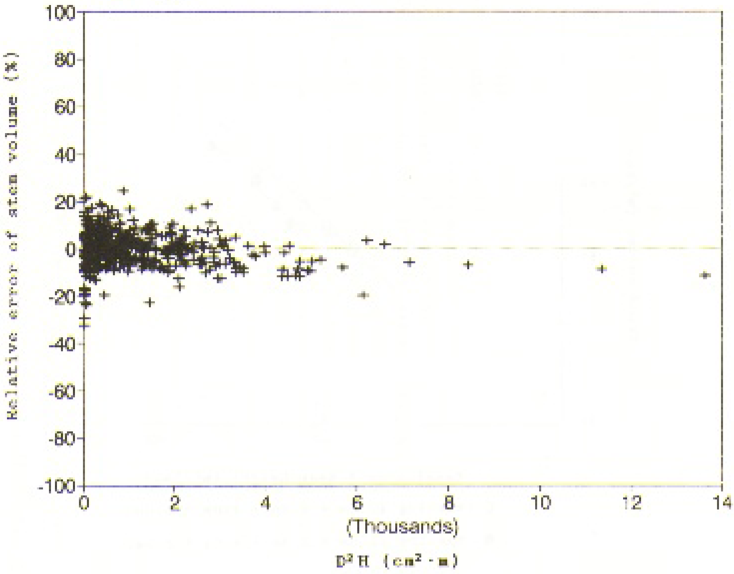

Fig. 5. Relationship between relative error of stem volume calculated from equation (1) and D^2H.

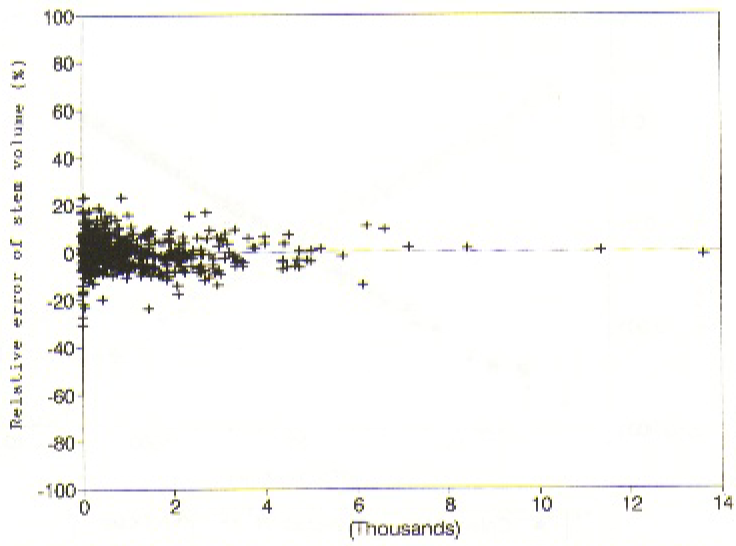

Fig. 6. Relationship between relative error of stem volume calculated from equation (2), (3) and D^2H.

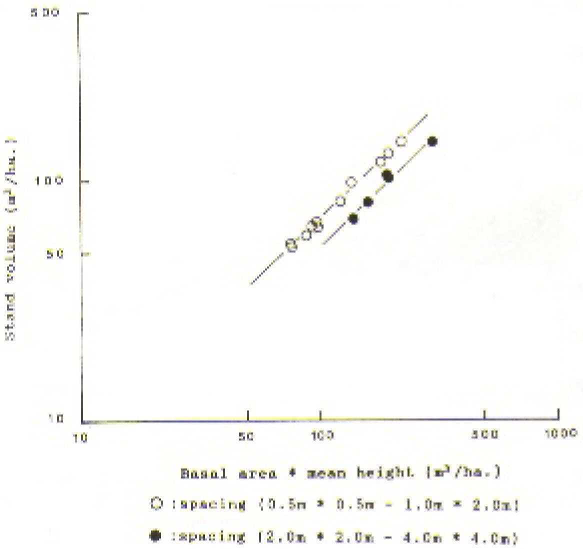

Fig. 7. Relationship between stand volume and basal area* mean height.

Table 1. Volume table of Eucalyptus camaldulensis (m^3)

$V=0.000084(D^2H)^{0.889883}$ ($r=0.998184$)

(For the values $\leq$ 3000 $cm^2 \cdot m$ in D^2H)

$V=0.000059(D^2H)^{0.940717}$ ($r=0.985955$)

(For the values > 3000 $cm^2 \cdot m$ in D^2H)

Height(m) / DBH(cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.000156	0.000223	0.000288											
2	0.000534	0.000767	0.000989	0.001208	0.001421	0.001630								
3	0.001100	0.001578	0.002036	0.002486	0.002924	0.003355	0.003778							
4	0.001825	0.002623	0.003401	0.004148	0.004878	0.005595	0.006302	0.006998	0.007686	0.008365				
5	0.002735	0.003916	0.005059	0.006170	0.007257	0.008324	0.009374	0.010410	0.011433	0.012445	0.013447	0.014440		
6	0.003776	0.005417	0.006998	0.008535	0.010037	0.011514	0.012967	0.014400	0.015816	0.017215	0.018601	0.019975	0.021337	0.022688
7	0.004959	0.007138	0.009207	0.011229	0.013207	0.015149	0.017061	0.018946	0.020808	0.022650	0.024474	0.026281	0.028074	0.029850
8	0.006302	0.009040	0.011677	0.014242	0.016751	0.019214	0.021638	0.024029	0.026391	0.028727	0.031039	0.033331	0.035603	0.037857
9	0.007771	0.011146	0.014400	0.017563	0.020657	0.023694	0.026684	0.029633	0.032545	0.035426	0.038278	0.041104	0.043906	0.046686
10	0.009374	0.013447	0.017370	0.021186	0.024918	0.028581	0.032188	0.035745	0.039258	0.042733	0.046173	0.049582	0.052962	0.056316
11		0.015928	0.020582	0.025102	0.029524	0.033865	0.038138	0.042352	0.046515	0.050633	0.054709	0.058748	0.062753	0.066726
12			0.024029	0.029307	0.034469	0.039537	0.044526	0.049446	0.054307	0.059114	0.063873	0.068588	0.073264	0.077903
13				0.033734	0.039747	0.045591	0.051343	0.057017	0.062621	0.068164	0.073652	0.079089	0.084481	0.089830
14					0.045381	0.052018	0.058582	0.065055	0.071450	0.077774	0.084036	0.090240	0.096392	0.102495
15						0.058811	0.066236	0.073555	0.080785	0.087935	0.095014	0.102030	0.115765	0.123015
16							0.074229	0.082108	0.090018	0.098839	0.112197	0.121403	0.130169	0.138891
17								0.091908	0.100942	0.116283	0.126733	0.136071	0.145856	0.155670
18									0.118381	0.129485	0.140310	0.151520	0.162485	0.173354
19										0.143350	0.155577	0.167744	0.179856	0.191916
20											0.171340	0.184738	0.198078	0.211360
21												0.202606	0.217171	0.231680
22														0.252872
23														
24														
25														

Table 1. (Cont.)

Height(m) / DBH(cm)	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1															
2															
3															
4															
5															
6															
7	0.031514	0.033367													
8	0.040095	0.042218	0.044128	0.046721											
9	0.049446	0.052187	0.054916	0.057617	0.060368	0.062984									
10	0.059345	0.062351	0.066236	0.069500	0.072746	0.075974	0.079185	0.082380							
11	0.070571	0.074188	0.078480	0.082348	0.086194	0.090013	0.093824	0.097610	0.101377	0.110976					
12	0.087508	0.087085	0.091524	0.096141	0.100831	0.110943	0.115904	0.120854	0.125791	0.130715	0.135628	0.140530			
13	0.093140	0.100414	0.111563	0.117384	0.123187	0.128972	0.134742	0.140496	0.146235	0.151960	0.157671	0.163370	0.169055	0.174729	
14	0.114803	0.121540	0.128254	0.134946	0.141618	0.148269	0.154902	0.161516	0.168114	0.174695	0.181262	0.187813	0.194349	0.200872	0.207381
15	0.130718	0.138367	0.146031	0.152651	0.161247	0.168820	0.176372	0.183904	0.191418	0.198910	0.206385	0.213845	0.221287	0.228714	0.236126
16	0.147391	0.156253	0.164883	0.173488	0.182065	0.190618	0.199143	0.207647	0.216129	0.224590	0.233031	0.241453	0.249856	0.258242	0.266611
17	0.165423	0.175132	0.184806	0.194443	0.204062	0.213648	0.223203	0.232735	0.242243	0.251723	0.261186	0.270623	0.280044	0.289443	0.298823
18	0.184395	0.195015	0.205788	0.216525	0.227230	0.237902	0.248545	0.259158	0.269744	0.280305	0.290840	0.301351	0.311839	0.322305	0.332750
19	0.203929	0.215897	0.227824	0.239711	0.251561	0.263378	0.275158	0.286908	0.298628	0.310319	0.321982	0.333619	0.345230	0.356817	0.368380
20	0.224590	0.237771	0.250906	0.263997	0.277048	0.290060	0.303036	0.315976	0.328884	0.341759	0.354604	0.367420	0.380207	0.392968	0.405702
21	0.246183	0.260630	0.275028	0.289378	0.303684	0.317947	0.332170	0.346353	0.360503	0.374616	0.388696	0.402744	0.416760	0.430748	0.444705
22	0.268700	0.284470	0.300184	0.315847	0.331461	0.347029	0.362553	0.378035	0.393477	0.408882	0.424249	0.439582	0.454881	0.470148	0.485383
23		0.308284	0.326369	0.343391	0.360375	0.377300	0.394178	0.411011	0.427800	0.444548	0.461257	0.477927	0.494560	0.511159	0.527723
24				0.372025	0.390418	0.408754	0.427040	0.445276	0.463465	0.481509	0.499710	0.517770	0.535790	0.553772	0.571717
25						0.441385	0.461130	0.480822	0.500463	0.520056	0.539602	0.559103	0.578562	0.597980	0.617358