YIELD TABLE STUDY OF CRYPTOMERIA GROWING IN NORTHERN KYUSHU

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YIELD TABLE STUDY OF CRYPTOMERIA GROWING IN NORTHERN KYUSHU

Kenkichi KINASHI

Preface

According to Bruce and Schumacher's FOREST MENSURATION, 1950, pp 387, we are understanding the following sentences ;

" Fully stocked stands are termed *normal stands*, and the resulting yield table is termed a *normal yield table*. In some cases, however, the volume stated may be that which has been obtained with average stand conditions as found in nature. The yield table resulting from such stands is termed an empirical yield table."

Same authors say that it is evident that the methods of sampling that have been described in that book are not applicable to this case. Additionally, the following paragraph must be pointed out from the book.

" This seems an abandonment of the basic principle of sampling but is permissible because of the unusual character of the study. No attempt is being made in this instance to determine the average age of the stands being sampled or the average site or the average density. The universe that is being sampled in this instance is one composed of normal stands, and it is not known in advance even where this universe is located."

Recently, forest inventory shows some tendency where the sampling technique over the world takes place gradually. Japanese forestry also has this tendency and rather the procedure seems to be made in much developed way. In such situation, especially from a point of view of sampling, sampling data would be utilized for yield table preparation. Actually many different types of the table are appearing. The average or empirical yield table is also one case. The data used here came from random data of Sugi stands, private plantations, Fukuoka prefecture in Japan, taken 1956. A broad picture was made with modified procedure of Duerr and Gevorkiantz method, which consists of 125 combinations, $5\times5\times5$. Making 5 levels in 3 factors, diameter, number of trees and height respectively, well-stocked and average-stocked stands may be chosen. There may be a well-stocked data group, an average-stocked data group and whole data group, that is a random stocked data group.

F. X. Schumacher presented multiple regression methods applied to yield table. They consist of stocking percentage equation and volume equation. Fortunately the main calculations and analyses were done in the School of Forestry, Duke University, N. C., under direction of Prof. Schumacher.

I would like to express great appreciation to Prof. Schumacher and the Rockefeller Foundation which gave me such grateful opportunity. Preparation of the original data was made incooperation with Mr. Yoshiaki Ito and many other foresters in the forestry section of Fukuoka prefecture. Miss G. M. Byler corrected my English sentences and Mr. Masamichi Cho drew many graphs. Mrs. Michi Kinashi at Durham and Miss Fumiko

Harada have assisted in the numerical calculations. To all these I wish to express my sincere thanks.

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Chapter 1 Introduction

1. General description of the forests in Fukuoka prefecture

Fukuoka prefecture is located in the northern part of Kyushu Island, Japan. It is one of the largest prefectures of industry and agriculture in west Japan. The total area is 491 thousand ha and the population 3860 thousand according to the census of 1955. This private forest area is 209 thousand ha and it is 87.9% of the total forest area. The object of this reseach is Sugi (Cryptomeria) plantation which occupies 58 thousand ha, 27.87% of the total private forest area. The volume is about 5718 thousand cubic meters, 55.05% of the total. This fact indicates that Sugi plantations have higher efficency in productivity than any other species, here as well as in the other prefectures in Japan.

2. The first design of sampling inventory

The private forests are divided into 6 basic districts, which have several units each, as shown in the following table; Each unit has about 10 age classes, interval 5 years, for instance 6–10, 11–15, 16–20, and so on. There are 33 units, so $33\times10=330$ substrata may be considered. One stand was drawn at random from each age class in each unit. Next stage, 20×20m square plot was selected at random from one stand in a field. Actually, the private plantation is a small area, less than 1 ha in most cases. With section paper a forester can draw boundary lines and square patterns of the objective stand with survey tools in the field. In such way, some what like sub-sampling, a total of 288 plots were collected in 1956.

Table 1. Forest area and devision in Fukuoka prefecture

District	area (ha)	center city	unit number						
A	18169	Chikugo	1	2	3	4	5		
B	10982	Amagi	6	7	8	9	10	11	
C	9967	Fukuoka	12	13	14	15	16	17	18
D	13792	Yawata	19	20	21	22	28		
E	5270	Iizuka	23	24	25	26	27		
F		Yukuhashi	29	30	31	32	33		

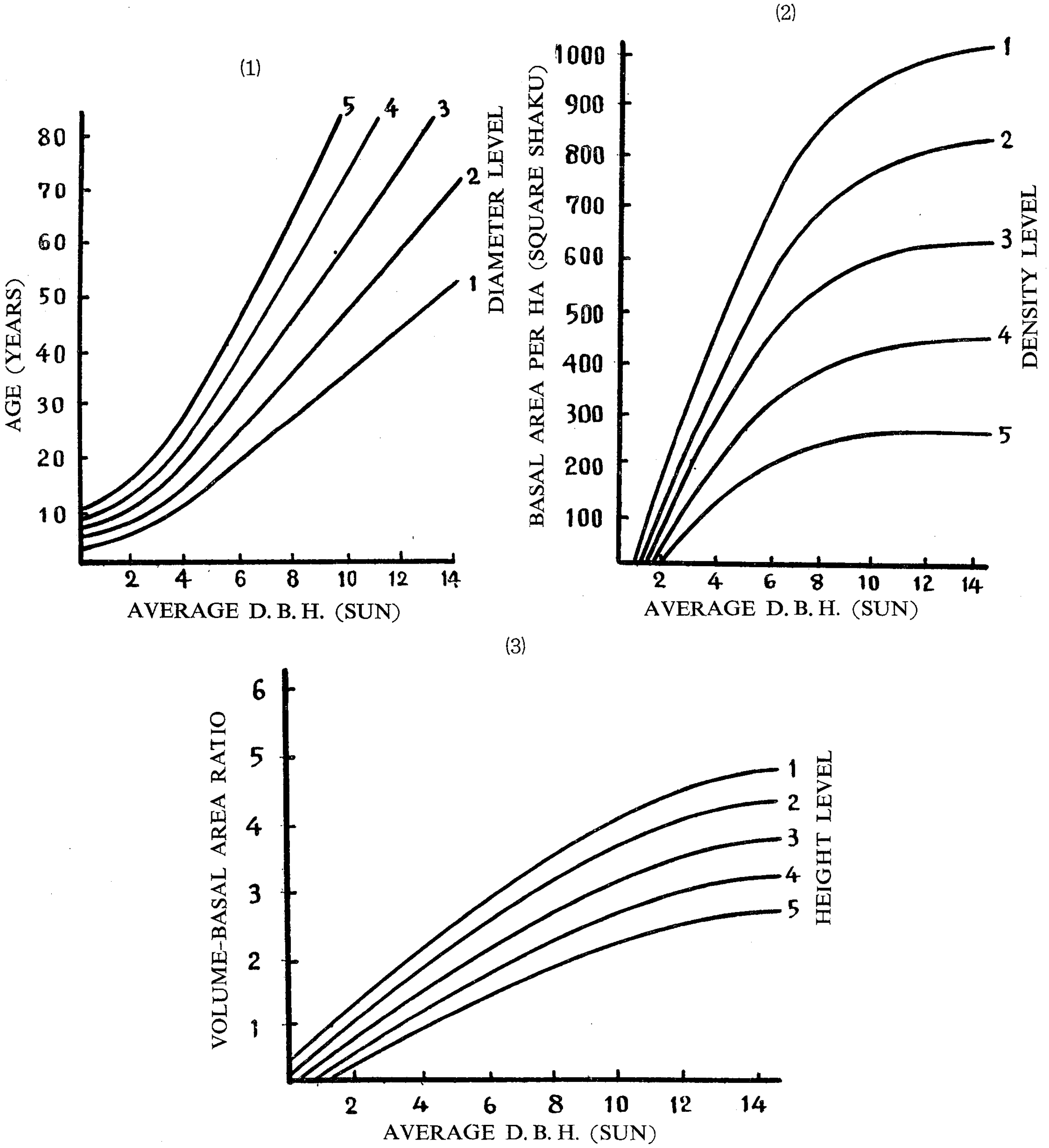
3. Measurement of trees

Every tree within the plot was measured. Diameter at breast height and total height of trees were measured by apropriate ways. The Measuring unit used was the old system, Sun and Ken respectively. Roughly speaking, 1 Sun equals about 1 inch and 1 Ken about 6 feet.

4. Official computation work

Based on 1 hectare, average diameter, basal area, volume and ratio between the volume and the basal area were computed. According to Duerr and Gevorkiantz method, the following three graphs were made; (1) The relation between average diameter and age, (2) The relation between basal area and average diameter, (3) The relation between the volume-basal area ratios and average diameter. These curves may be shown as the following graphs. (Fig. 1) Each graph has five curves which may be considered five levels.

Fig. 1. (1) The relation between age and average diameter
(2) The relation between basal area and average diameter
(3) The relation between volume-basal area ratios and average diametr



5. 125 combination prediction and volume tables

Basal area and the ratio may be converted into the number of trees and average height respectively. These curved intervals are the standard deviation in each term. Consequently, there are 3 facters, average diameter, number of trees and average height, in other words diameter, density and site which have 5 levels each, 1, 2, 3, 4 and 5. Finally, $5 \times 5 \times 5$, 125 combination prediction and volume tables were derived in 1956.

6. Classification of actual plot based on the level

Based on the above table, 288 plots were classified into each level shown in the following table:

Table 2. The number of plots in classification

	level		level		level		level		level	
Well-stocked stand 66	111		211		311	1	411		511	2
	112		212		312	2	412	2	512	
	113		213	1	313	4	413		513	1
	114		214	1	314	2	414		514	1
	115		215	1	315		415	1	515	
	121		221	1	321	3	421	1	521	
	122		222	3	322	2	422	7	522	1
	123	1	223	2	323	8	423	2	523	1
	124	1	224	6	324	1	424	1	524	2
	125	2	225	1	325		425	1	525	
	sum	4		16		23		15		8
Average-stocked stand 133	131		231	2	331	2	431	2	531	3
	132		232	3	332	10	432	10	532	6
	133	2	233	5	333	28	433	11	533	3
	134	3	234	17	334	12	434	5	534	3
	135	2	235	2	335	1	435	1	535	
	sum	7		29		53		29		15
Poorly stocked stand 89	141		241		341		441	2	541	
	142		242	2	342	14	442	6	542	7
	143	1	243	6	343	9	443	7	543	7
	144	1	244	4	344	10	444	4	544	2
	145		245		345		445		545	
	151		251		351		451		551	
	152		252		352	1	452		552	
	153		253	3	353	1	453		553	
	154		254		354		454	1	554	1
	155		255		355		455		555	
	sum	2		15		35		20		17
	total	13		60		111		64		40

The first figure in the above level is average diameter, the second figure is density or the number of trees, and the third figure is site or average height. And a well-stocked stand has the density level 1 and 2. An average-stocked stand has the density level 3 and poorly stocked stand has the density level 4 and 5.

It is understandable that the frequency of the number of plots is concentrated near the central zone and is very rarely in the extreme level on both sides.

7. Well-stocked stand as the normal stand

There may be some evidence that a well-stocked stand, density level 1 and 2, corresponds to the normal yield table in the number of trees shown in the following table: This normal table was constructed for the northern district of Kyushu, by Tokumoto, in 1914. As showing in the above table, level 1 in density is fitted quite well to the number of trees of the normal yield table made about forty years ago. Consequently level 1 and 2 may be considered as well-stocked stands. It is also reasonable that level 3 may be average density and less than level 3 may be a poorly stocked stand (not including level 3).

Table 3. The number of trees

Age	Site I		Site II		Site III	
	normal	level 1	normal	level 1	normal	level 1
30	1950	1993	3332	3163	4150	3630
40	1560	1447	2510	2362	3414	2806
50	1241	1064	1990	2362	2714	2227
60	973	802	1571	1527	2147	1847
70	870	631	1263	1265	1779	1538

8. Three universes of different stocking grade stands

Now we have three different stocking stand data groups, that is, well-stocked, average-stocked and poorly stocked. Random sampling from such population will present different results. How are they different, especially in stocking percentage? This is the main contribution of this article. Multiple regressions were used to make a well-stocked stand yield table, average-stocked yield table and random stocked stand yield table. Many tables of analysis of variance were also used to decide significant effects in least square solutions.

Chapter 2 Principle and procedures

9. Height regression

Prof. Schumacher presented a multiple regression method for yield table construction which consists of four multiple regressions and one normal approach equation. The first regression is a height curve which is well known in his text book. This equation will be shown as follows:

$$\log H = b_0 + b_1(1/A) \quad \cdots\cdots (1)$$

where H ··············height of stand

A ··············age of stand

b_0, b_1 ·········coefficent of regression.

The site curve may be derived from this height equation. If site index will be defined as the height of trees 40 years in age, in Japanese Sugi plantations, the tree height of the same site index in any age may be calculated from the following equation:

$$\log H = \log (SI) + b_1(1/A - 1/40) \quad \cdots\cdots (2)$$

In this article site index will be 6, 8, 10, 12 and 14 Ken in 40 years in age.

10. Stocking percentage regression

This formula may be quite a peculiar form compared to other stocking equations. It, however, is a reasonable one. Schumacher and Coil give us in the article, named " Yields of well stocked stands of coastal plain Loblolly pine," the following definition. By stocking percentage is meant the ground area that an even-aged stand or sample plot of given age, height of dominant stand, and d. b. h. distribution, would have utilized in a well-stocked stand relative to the actual ground area of the stand or sample plot. It is the percentage ratio of the calculated ground area to actual ground area. Thus if B represents basal area per ha in square Shaku on all trees; and if H represents height of average, while A represents the age of stand in years, then

$$S = B\left[b_0 + b_1(H/10) + b_2(10/A) + b_3(H/A)\right] \quad \cdots\cdots (3)$$

in which S is stocking percentage.

The stocking percentage equation is a property of its basic data. If the calculated stocking percentage, obtained by inserting into the equation the numerical values of B, H, and A of an actual stand should turn out to be 100, one does not assert that the stand is normally stocked, but merely that its stocking is about the average of the data that provided the equation; and this average may, or may not correspond to the ideal of normal stocking.

In the other words, equation (3) must be understood as following:

$$S=B\left[(a+bH)+(c+dH)\frac{1}{A}\right]$$

where $b_1=a+bH$

$b_2=c+dH$

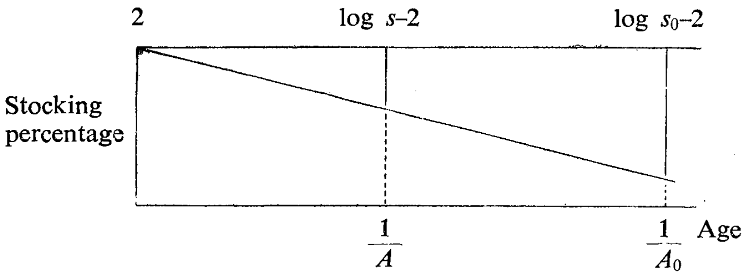
$$=B\left[b_1+b_2\frac{1}{A}\right]=Bb \qquad \cdots\cdots (3')$$

11. Normal approach assumption

Normal approach will be assumed in linear type in logarithms showing as the following formula.

$$\frac{\log s-2}{\log s_0-2}=\frac{A_0}{A} \qquad \cdots\cdots (4)$$

This formula is shown as the following pattern:



If A_0 is fixed 20 years, b in equation (3′) will be gained. Then initial basal area at 20 years may be from 100 to 600 square Shaku. From $s=Bb$, s_0 will be obtained. From equation (4) any s correspoding to any age can be expressed. Finally we can get B from equation $B=s/b$. We may understand that expression (4) will express the change of stand stocking in percentage for normal approach made in the series of stand development. It is available to estimate the stand volume in any under or over-stoked stand at any age.

12. Number of tree equation

If N is number of trees, the following equation will be called equation of number of trees:

$$\log N=b_0+b_1 \log H+b_2 \log B+b_3(1/A) \qquad \cdots\cdots (5)$$

Here, H, B and A are independent variables. Which of these variables will contribute most to dependent variable N? In each case, the analysis of variance may be made.

13. Volume equation

If V is volume per ha, the following equation will be called equation of volume:

$$\log V=b_0+b_1 \log B+b_2 \log H+b_3 \log N \qquad \cdots\cdots (6)$$

B, H and N are independent variables, V is a dependent variable. These independent variable effects may be tested by analyses of variances. In each case, they may be shown later.

These six equations, from (1) to (6) described just above, may cover a whole set of yield study of data in forestry. If it is true, skilful practice for the least square calculation and analysis of variance would be more needed for students of forest mensuration. Site equation (1), (2), stocking percentage equation (3), normal approach equation (4) and number of tree equation (5) may be called the group of growth equations. The last equation (6) is not growth equation, but volume equation which does not include the term age.

Chapter 3 Well-stocked stand yield table

14. Well-stocked stand data

Original data of well-stocked stand came from level 1 and 2 in density. The 64 plots are listed in the the following table.

Table 4. Well-stocked data

Plot No.	Age	Ave. DBH	Ave. Ht.	Number of trees	Volume per. ha	Basal area per ha
D-XIX-2	14	3.6	4.18	3700	525.000	378.561
D-XXIV-3	14	2.9	3.36	4750	355.433	310.534
F-XXXIX-2	14	4.0	5.71	3150	705.850	395.454
B-XI-3	18	4.0	3.48	3225	339.940	334.870
B-XII-3	18	4.0	5.03	3375	738.624	431.182
E-XXVI-3	18	5.1	5.00	2225	751.500	452.288
E-XXVII-3	18	5.2	4.97	2225	776.675	469.812
F-XXIX-3	19	4.2	4.27	2850	554.680	384.352
A-II-3	20	5.0	5.97	2275	958.675	509.225
A-IV-3	20	4.0	5.42	3800	845.690	485.770
A-I-4	22	4.6	5.55	3775	1118.675	633.809
A-III-4	22	4.9	5.44	2350	800.090	466.474
C-XVIII-4	22	6.1	5.08	2000	682.125	413.952
B-XI-4	23	7.5	6.26	1300	901.350	338.288
A-II-4	25	7.0	7.65	1500	1320.650	580.700
B-VI-4	25	6.3	7.38	1850	1259.225	588.120
B-XII-4	25	5.5	8.34	2400	1374.725	565.633
B-XIII-4	25	4.3	5.78	3225	857.025	467.778
D-XXI-4	25	4.9	5.42	2625	850.650	489.224
C-XVIII-5	26	6.0	6.80	2200	1441.875	613.606
D-XXVIII-5	26	5.9	4.43	1850	831.125	507.808
B-X-5	28	7.0	7.38	1750	1432.775	655.850
B-XIII-5	28	5.6	6.63	3225	1698.250	825.612
F-XXX-5	28	5.8	6.72	2475	1344.250	650.504
F-XXXI-5	28	6.0	6.73	2100	1211.900	586.200
A-II-5	29	5 0	7.07	2925	1343.625	627.900
C-XIV-5	30	6.4	6.65	1950	1385.575	636.960
A-III-6	31	8.5	10.27	1200	1924.950	688.059
B-IX-6	31	7.0	7.41	1500	1224.825	560.380
B-XII-6	31	5.9	7.50	2275	1431.575	618.308
E-XXIV-7	32	6.1	6.70	2100	1298.275	622.672
E-XXVII-6	33	4.3	4.77	3000	723.028	431.950
F-XXXIX-6	33	6.1	7.05	2200	1373.700	638.531
F-XXIX-6	35	7.3	6.95	1600	1416.200	661.016
F-XXXIX-6	35	5.6	7.61	2200	1226.950	537.359
A-II-7	37	5.5	7.33	2075	1654.125	666.625
F-XXXIX-7	37	6.0	7.12	2075	1274.075	584.625
A-I-7	38	9.1	12.38	1300	2759.150	853.828
E-XXV-7	38	7.7	7.91	1400	1521.900	647.357
B-XII-7	39	6.4	8.42	2275	1878.300	746.127
E-XXV-8	41	7.5	8.73	1875	1498.600	608.537
A-V-8	42	8.7	11.64	1200	2209.880	721.340
B-XIII-8	42	5.0	6.51	2650	1231.850	529.640
F-XXXIX-8	42	5.9	3.31	2550	1688.500	691.542
C-XVIII-8	43	7.7	12.08	1750	2636.050	812.839
A-IV-8	44	7.2	10.99	1625	1938.250	652.080
C-XIV-8	44	6.2	5.79	1900	1173.050	576.306
E-XXII-8	44	8.1	9.01	1525	2124.800	794.234
A-I-8	45	10.4	14.54	1025	2759.150	853.828
B-XIII-10	46	6.2	7.56	2175	1531.650	659.088
C-XVI-9	46	7.8	10.15	1250	1743.225	600.094
C-XVII-9	46	9.3	11.57	1250	2620.250	855.005
F-XXIX-9	46	7.0	8.17	1575	1445.025	614.134
B-VIII-9	47	5.6	6.85	2475	1301.450	616.490
A-I-9	48	10.5	11.31	1050	2953.070	983.425
A-III-9	48	9.1	14.34	1375	3345,850	891.857
A-IV-9	48	5.5	7.48	2050	1106.230	482.670
E-XXII-9	48	7.8	10.31	1850	2529.895	890.105
A-I-10	53	12.5	14.84	700	3298.100	871.990
D-XXI-10	53	8.2	7.92	1625	1391.225	608.126
A-II-10	55	11.5	14.33	900	3584.200	742.550
E-XXVI-10	60	10.4	11.78	875	2727.000	608.002
A-III-10	66	8.4	14.71	1425	3040.150	787.350
E-XXVII-10	70	10.7	9.62	925	2233.475	826.389

15. Height curve

The least square calculation for well-stocked stands may be shown as the following:

	1	$1/A$	$\log H$	ck
1	64	2.1359	55.3227	121.4586
$1/A$		0.0835	1.7457	3.9651
$\log H$			49.4332	106.4916
0.0333734375		0.0122	−0.1006	0.0884
0.864417187			1.6013	1.5007
−8.24590153			0.7718	0.7718

The height curve for well-stocked stands is shown to be the following:

$$\log H = 1.1396 - 8.2459(1/A)$$

If the site index is defined as the height of average trees at the age of 40 years, each height curve may be calculated from the following equation:

$$\log H = \log(\text{Site Index}) - 8.2459(1/A - 1/40).$$

Fig. 2 Height curves, in terms of age and site index, of well-stocked stands.

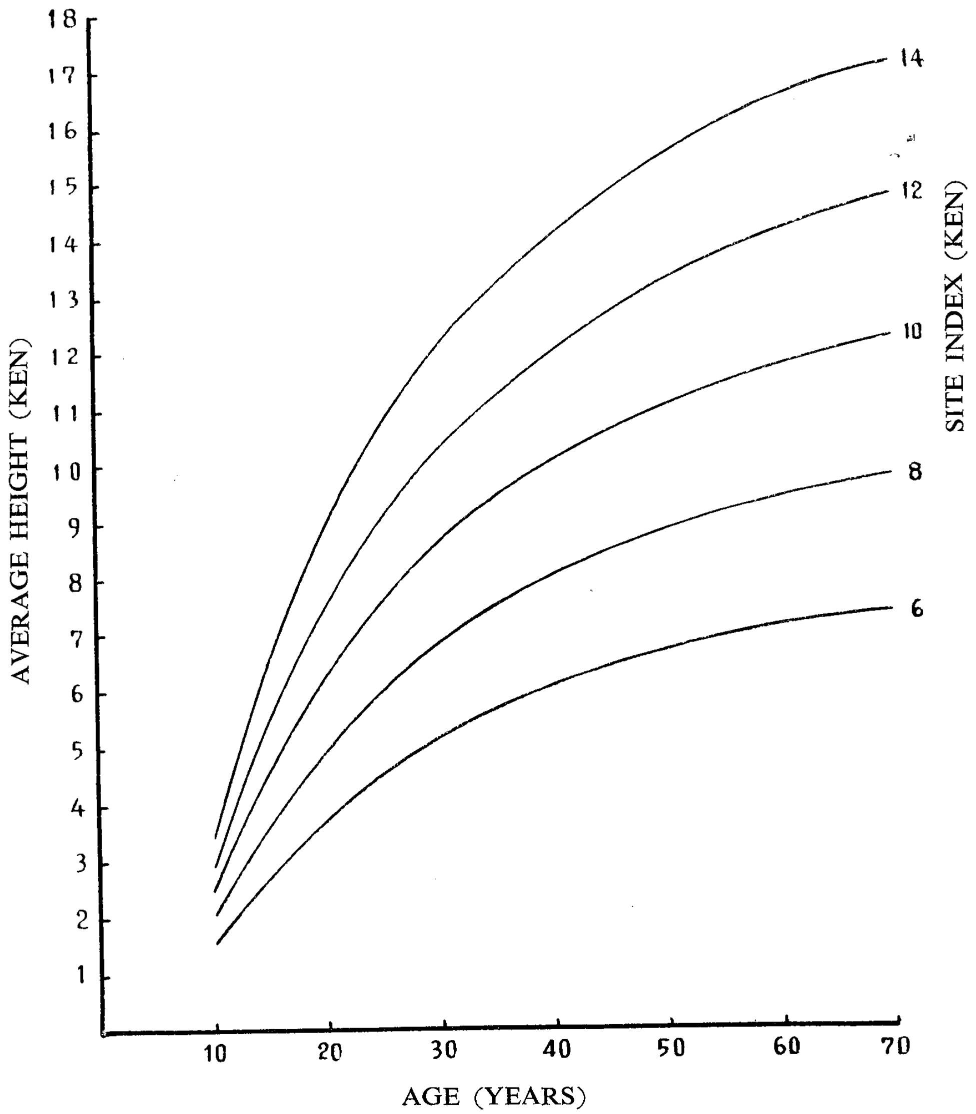


Table 5. Height curve (Ken)

Site Index	Age						
	10	20	30	40	50	60	70
6	1.45	3.71	5.13	6.00	6.60	7.02	7.35
8	1.93	4.98	6.83	8.00	8.80	9.37	9.80
10	2.41	6.22	8.54	10.00	11.00	11.66	12.25
12	2.89	7.46	10.25	12.00	13.20	14.03	14.70
14	3.37	8.71	11.96	14.00	15.40	16.39	17.15

The analysis of variance for the well-stocked height curve will be shown as below:

Source	*SS*	*DF*	*MS*
1	47.8219	1	**
$1/A$	0.8295	1	**
Error	0.7718	62	0.0124
Total	49.4232	64	

The reciplocal of age or $1/A$ is highly sighificant.

16. Stocking equation of well-stocked stands

The least square solution may be shown to be the following pattern:

	B	$BH/10$	$10B/A$	BH/A	s	ck
B	25706595	23018309	7402786	6039819	3936100	66103609
$BH/10$		23114999	6050430	5599029	3309900	61092667
$10B/A$			2439476	1792555	1214000	18899247
BH/A				1500905	920100	15852408
s					640000	10020100
0.895424267		2503847	−578204	190828	−214579	1901892
0.2879722499			307679	53255	80512	−136758
0.2349521202				81837	−4695	321225
0.1531163501					37319	−101443
−0.2309262506			174157	97322	30960	302439
0.076213922				67293	11659	176274
−0.0856997252					18930	61549
0.5588176185				12908	−5642	7266
0.1777706322					13426	7784
−0.4370932754					10960	10960

Then the stocking equation for well-stocked stand is

$$S=0.0939B+0.0451(BH/10)+0.42203(10B/A)-0.4371(BH/A)$$

B will be outside of the bracket

$$S=B\{0.0939+0.0045(H)+4.2203(1/A)-0.4371(H/A)\}$$

The analysis of variance will be shown in the following

Source	*SS*	*DF*	*MS*	*F*
B	602681	1		**
$BH/10$	18389	1		**
$10B/A$	5504	1		**
BH/A	2466	1		**
Error	10960	60	183	
Total	640000	64		

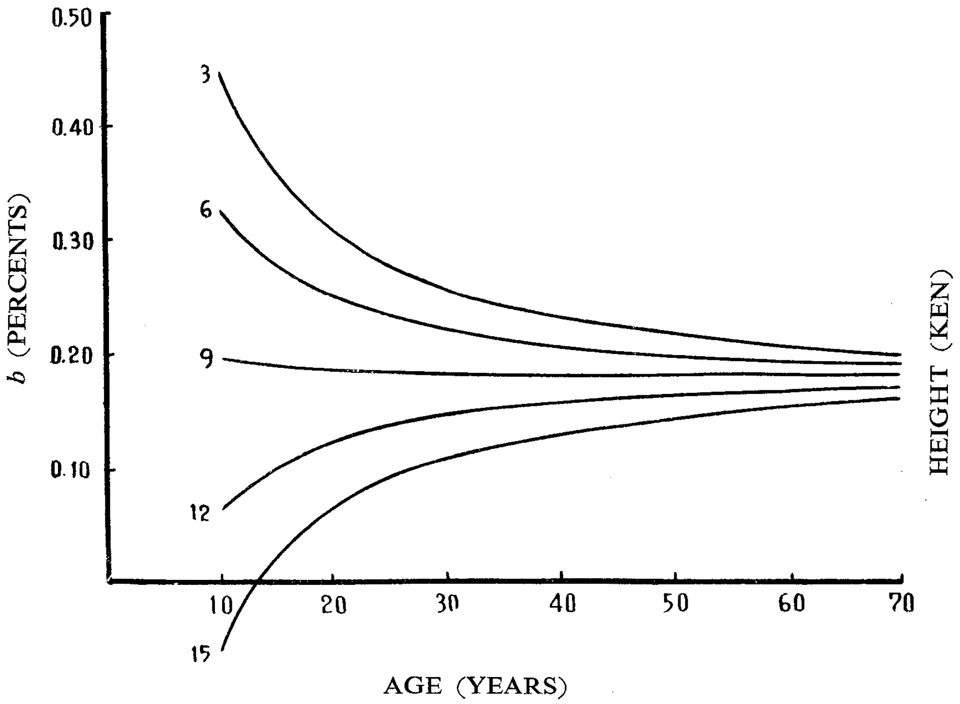
B, BH, B/A and BH/A all effects are highly significant.

If $b=0.0939+0.0045H+4.2203(1/A)-0.4371(H/A)$ and this b is called coefficent of basal area for well-stocked stands, the value of b will be shown in the following table.

Table 6. Coefficent of basal area

Height	Age						
	10	20	30	40	50	60	70
3	0.3983	0.2528	0.2042	0.1801	0.1656	0.1560	0.1490
6	0.2806	0.2008	0.1741	0.1608	0.1528	0.1476	0.1438
9	0.1630	0.1487	0.1439	0.1416	0.1401	0.1392	0.1385
12	0.0454	0.0966	0.1137	0.1223	0.1274	0.1308	0.1333
15	−0.0723	0.0446	0.0836	0.1030	0.1144	0.1224	0.1280

Fig. 3. Coefficent of basal area in well-stocked stands.



17. Normal approach of stocking percentage

In each site, the normal approach of stocking percentage will be calculated from fixed basal area at age 20.

Table 7. Stocking percentage

Basal area	Age						
	10	20	30	40	50	60	70
	Site 6						
100	7.26	24.02	38.68	49.01	56.52	61.22	66.51
200	23.08	48.04	61.36	69.31	74.58	77.71	81.08
300	51.93	72.06	80.39	84.88	87.72	89.33	91.05
400	92.30	96.07	97.36	98.02	98.40	98.63	98.86
500	144.20	120.1	113.0	109.6	107.6	106.5	105.4
600	207.7	144.1	127.6	120.1	115.7	113.4	111.0
	Site 8						
100	4.78	21.85	36.32	46.74	54.42	59.27	64.73
200	19.10	43.70	57.62	66.10	71.81	75.21	78.92
300	42.97	65.55	75.49	80.97	84.45	86.48	88.61
400	76.38	87.40	91.41	93.48	94.75	95.48	96.23
500	119.5	109.3	106.1	104.5	103.6	103.1	102.5
600	171.9	131.1	119.8	114.5	111.4	109.8	108.0
	Site 10						
100	3.88	19.70	33.89	44.38	52.22	57.19	62.83
200	15.52	39.40	53.78	62.76	68.90	72.59	76.44
300	34.93	59.10	70.45	76.88	81.02	83.44	88.04
400	62.09	78.80	85.33	88.76	90.91	92.13	93.41
500	97.01	98.50	98.99	99.24	99.40	99.47	99.56
600	139.7	118.2	111.8	108.7	106.9	105.9	104.9
	Site 12						
100	3.08	17.55	31.38	41.89	49.85	54.95	60.80
200	12.32	35.10	49.80	59.24	65.78	69.76	74.14
300	27.72	52.65	65.24	72.56	77.37	80.20	83.23
400	49.27	70.20	78.77	83.77	86.80	88.53	90.36
500	76.98	87.74	91.66	93.67	94.91	95.61	96.34
600	110.9	105.3	103.5	102.6	102.1	101.8	101.5

continued next page

	Site 14						
100	2.36	15.36	28.71	39.19	47.27	52.49	58.52
200	9.46	30.72	45.37	55.42	62.37	66.63	71.35
300	21.23	46.08	59.69	67.87	73.35	76.59	80.32
400	37.76	61.45	72.29	78.38	82.30	84.57	87.00
500	58.99	76.81	83.89	87.64	89.99	91.33	92.73
600	85.70	92.15	95.00	96.20	96.96	97.39	97.81

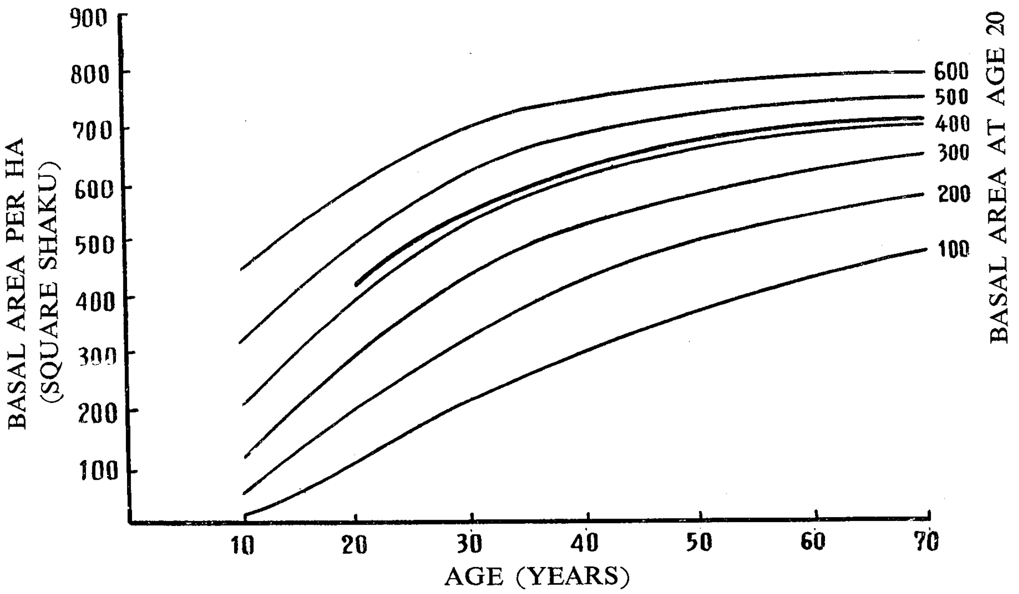
From the above table the basal area 400, 500 and 600 square Shaku per ha are proper for poor site, medium site and good site respectively. In that case stocking percentage may be sufficent.

18. Basal area

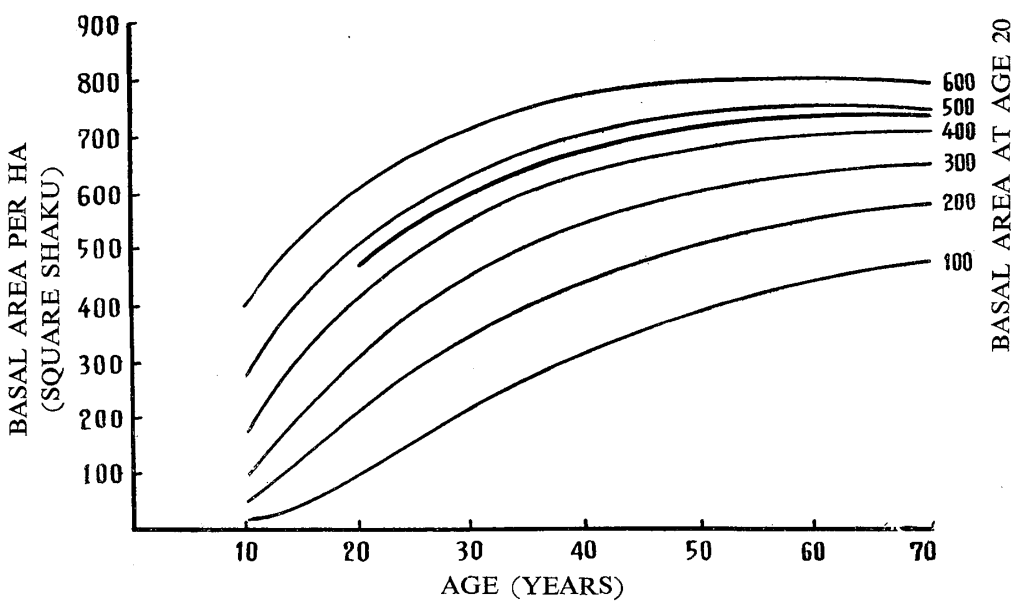
Basal area per ha will be calculated in the following table: (Tadle 8)

Fig. 4. Basal area of Well-stocked stands

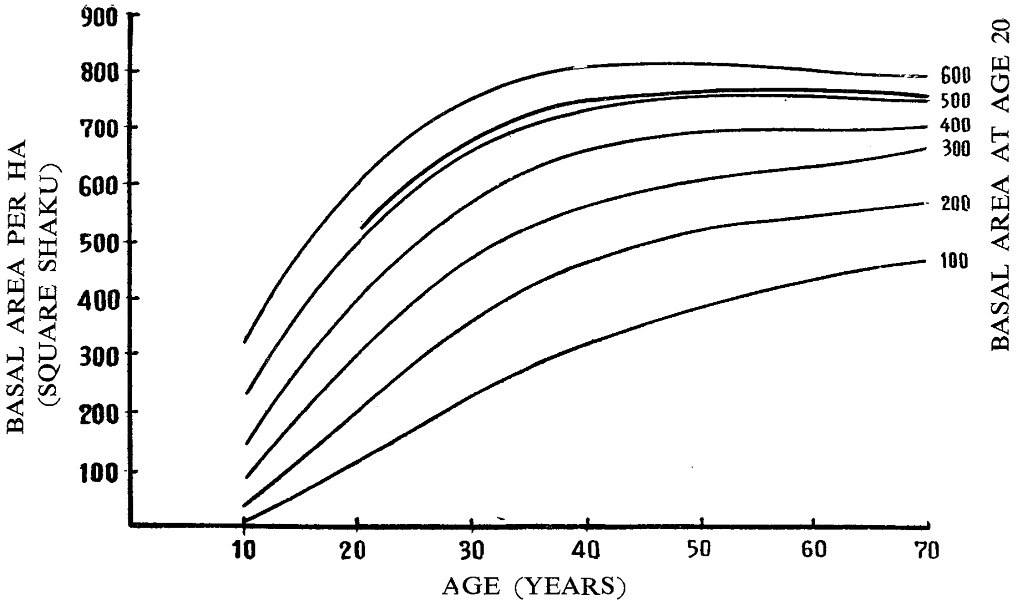
SITE INDEX 6 KEN AT AGE 40



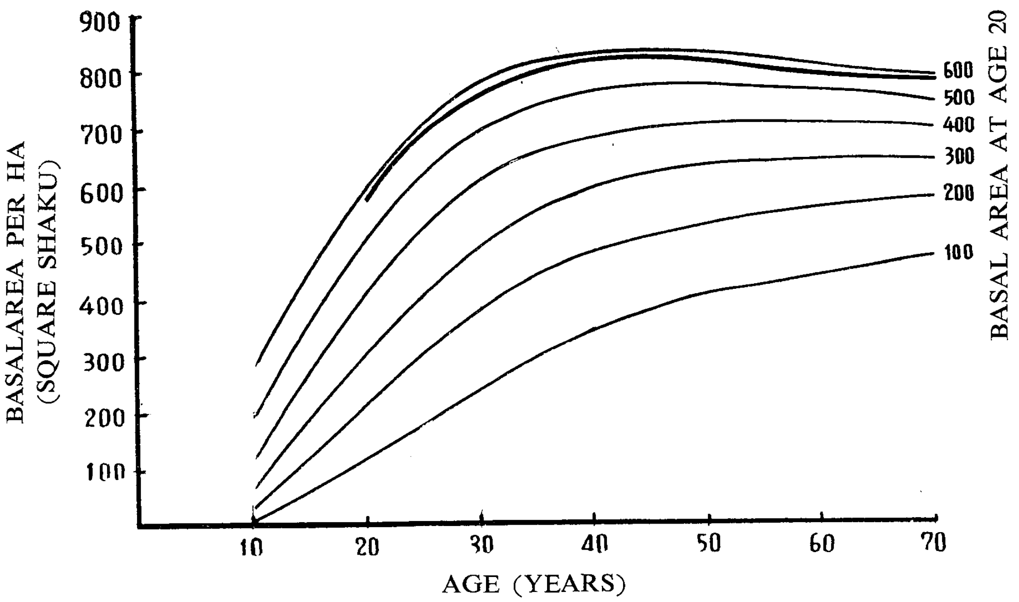
SITE INDEY 8 KEN AT AGE 40



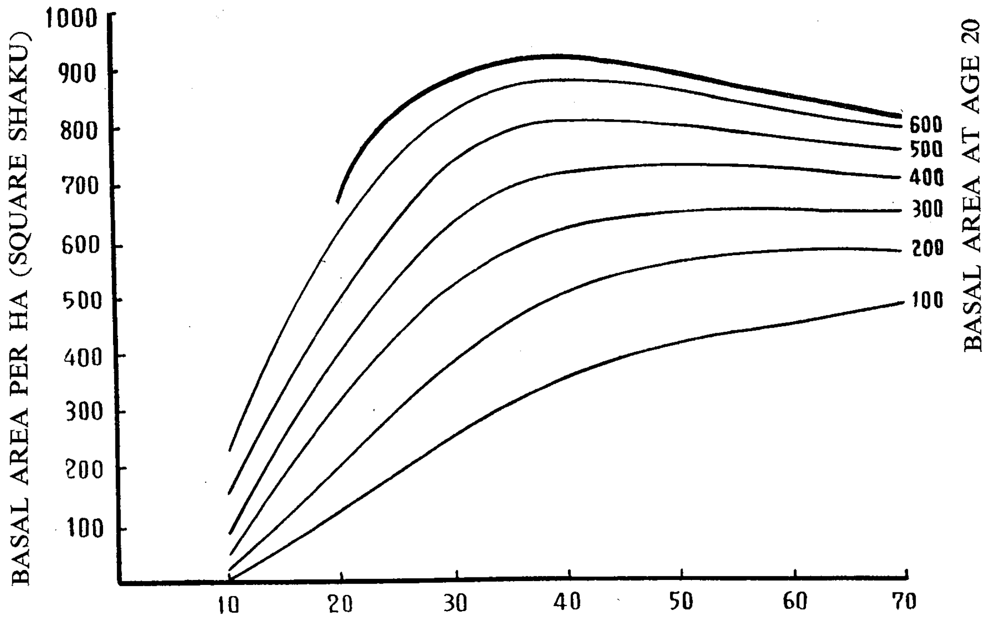
SITE INDEX 10 KEN AT AGE 40



SITE INDFX 12 KEN AT AGE 40



SITE INDEX 14 KEN AT AGE 40



(Bold lines show the basal area of 100 stocking percentage stands in each site)

Table 8. Basal area per ha

Site	Age						
	10	20	30	40	50	60	70
6	15.83	100.00	211.60	304.79	376.05	422.79	470.04
	51.19	200.00	335.67	431.03	496.21	536.67	573.00
	113.14	300.00	439.77	527.86	583.63	616.92	643.46
	201.09	400.00	532.60	609.58	654.69	681.15	698.66
	314.16	500.00	618.16	681.59	715.90	735.50	744.88
	452.51	600.00	698.03	746.89	769.79	783.15	784.45
8	10.85	100.00	219.19	315.81	385.96	428.87	471.79
	43.39	200.00	347.74	446.62	509.30	544.21	575.22
	93.07	300.00	455.58	547.09	598.94	625.76	645.85
	173.51	400.00	551.66	631.62	671.99	690.88	701.38
	271.47	500.00	640.31	706.08	734.75	746.02	747.08
	390.50	600.00	722.99	773.99	790.07	794.50	787.17
10	9.21	100.00	228.22	328.50	396.81	433.92	473.12
	36.83	200.00	362.15	464.54	523.56	550.76	575.60
	82.89	300.00	474.41	569.06	615.65	633.08	662.95
	147.34	400.00	574.61	656.99	690.81	699.01	703.39
	230.20	500.00	666.60	734.57	755.32	754.70	749.70
	331.51	600.00	752.86	804.59	812.31	803.49	789.91
12	7.65	100.00	238.99	342.52	407.60	439.25	472.78
	30.60	200.00	379.28	484.38	537.86	557.63	576.52
	68.65	300.00	496.88	593.11	632.62	641.09	647.20
	122.38	400.00	601.60	684.95	709.73	707.67	702.64
	191.21	500.00	698.10	765.90	776.04	764.27	749.14
	275.46	600.00	788.27	838.92	834.83	813.75	789.27
14	6.14	100.00	251.62	358.23	418.32	442.58	470.80
	24.59	200.00	397.63	506.58	551.95	561.80	574.01
	55.32	300.00	523.14	602.38	649.12	645.78	646.18
	97.34	400.00	633.57	716.45	728.32	713.07	699.92
	153.69	500.00	735.23	801.10	796.37	770.07	746.02

It is noticeable that basal areas have a maximum point somewhere, near age 40 or 50 years. These cases show that stocking percentage is over 100 and just below 100. These situations may be too high in density and stocking may decrease gradually (Fig. 4).

19. The umber of trees per ha

The normal equation and least square calculation will be shown in the following pattern: (Bold type digits may be eliminated)

	1	$\log H$	$\log B$	$1/A$	$\log N$	ck	SS due to
1	64	55.3227	177.5824	2.1359	210.4195	509.4605	691.8182
$\log H$		49.4232	154.4057	1.7457	180.5016	441.3989	659.2213
$\log B$			493.5556	5.8492	583.0920	1414.4849	688.8713
$1/A$				0.0835	7.1258	16.9401	608.1081
$\log N$					693.7195	1674.8584	
0.864417187		1.6013	0.9004	−0.1006	−1.3886	1.0125	1.2042
2.77472500			0.8133	−0.0773	−0.7642	0.8722	0.7181
0.0333734375				0.0122	0.1034	−0.0623	0.3181
3.28780468		$1/A$			1.9013	−0.1481	
		0.0059	−0.0207		0.0162	0.0014	0.0445
0.5622931368			0.3070	**−0.0207**	0.0166	0.3029	0.0009
−0.0628239555				**0.0059**	**0.0162**	**0.0014**	0.0445
−0.867170424					0.6971	0.7299	
−3.50847457			0.2344		0.0734	0.3078	0.0229
2.74576271					0.6526	0.7260	
−0.06742671				0.0045	0.0173	0.0218	0.0665
0.0540716612					0.6962	0.7135	
0.3131399317					0.6296	0.6296	
3.84444444					0.6297	0.6297	

Reduction of SS according to each effect will be shown in the following pattern:

ss due to first indep.	Keeping N additional eff.	Keeping $N.H$ additional eff.	Keeping $N.H.B$ additional eff.	Keeping $N.H.A$ additional eff.	
691.8182					N alone
659.2213	1.2043				H alone
688.8713	0.7181	0.0009		0.0229	B alone
608.1081	0.3181	0.0445	0.0665		A alone

The analysis of variance will be shown in the following:

Source	SS	DF	MS	F
N	691.8182	1		**
H(fixed$N$)	1.2043	1		**
A(fixedNH)	0.0445	1		*
B(fixedNHA)	0.0229	1		non sig.
Error	0.6296	60	0.0105	
Total	693.7195	64		

Then $\log B$ will be dropped and the resulting equation will be

$$\log N = 3.7967 - 0.6947 \log H + 2.7458(1/A).$$

If instead of A we use square root A, then we will have the following equation

$$\log H = 3.6653 - 0.6751 \log H + 1.1496(1/A)^{\frac{1}{2}}$$

which is not much difierent from the former equation.

Tabie 9. The number of trees per ha

Site	Age						
	10	20	30	40	50	60	70
6		3440	2484	2113	1916	1797	1714
8		2817	2033	1730	1569	1471	1404
10		2413	1742	1482	1344	1260	1202
12		2126	1534	1305	1219	1110	1050
14		1910	1379	1173	1064	998	952

At the age of 10 years the number of trees is too large compared to actual number.

20. Volume per ha

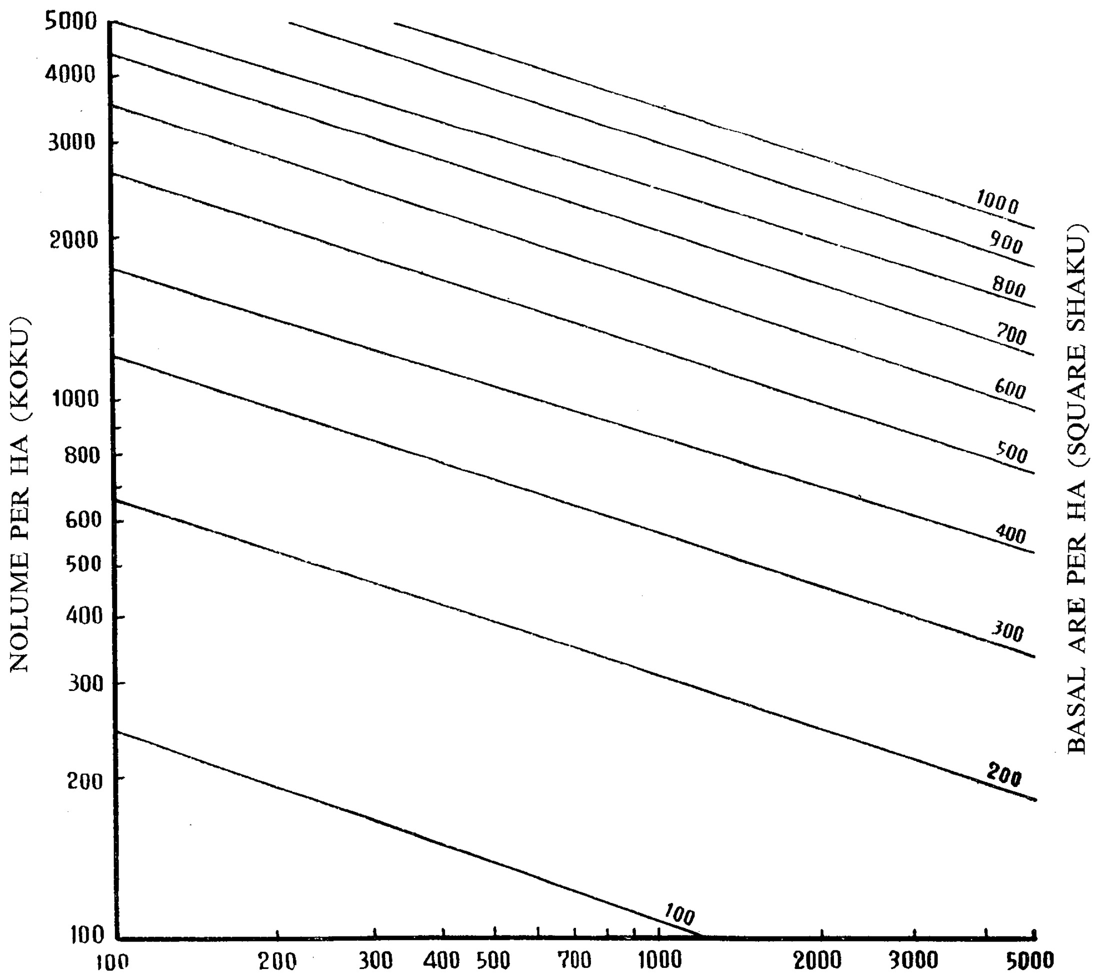
Volume equation will be calculated from the following pattern.

	log$B$	1	log$H$	log$N$	log$V$	ck	SS
log$B$	493.5556	177.5824	154.4057	583.0920	553.6333	1962.2690	621.1239
1		64.0000	55.3227	210.4195	198.9983	706.3229	618.7551
log$H$			49.4232	180.5016	173.9010	613.5542	611.8899
log$N$				693.7195	652.4735	2320.2061	613.6798
log$V$	log$N$				622.6716	2201.6777	
	4.8482	0.6217	—1.9150		—1.5950	1.9599	0.5247
		0.1055	—0.2328		—0.2002	0.2942	0.3799
			1.1184		0.7004	—0.3290	0.4143
log$H$					1.6477	0.5529	
0.3620	0.0128				0.0704	0.4452	0.0137
	0.0258				0.0043	0.0429	0.0007
					1.1230	1.1977	
0.0353591160	0.0253				0.0018	0.0271	0 0001
0.194475138					1.1093	1.1111	
0.071146245					1.1092	1.1092	

SS due to effach eect will be shown as the following table.

Effects	ss due to first indp	Keepiug B additional eff.	Keeping $B.N$ additional eff.	Keeping $B.N.H$ additional eff.
B alone	621.0239			
V alone	618.7551	0.3799	0.0007	0.0001
H alone	611.8899	0.4143	0.0137	
N alone	613.6798	0.5247		

Fig. 5. Volume per ha of well-stocked stands.



The analysis of variance will be shown in the following:

Source	SS	DF	MS	F
B	621.0239	1		**
N	0.5247	1		**
H	0.0137	1		no sig.
1	0.0001	1		no sig.
Error	1.1092	60	0.0184	
total	622.6716	64		

Then the volume equation is:

$$\log V = 1.5103 \log B - 0.3290 \log N.$$

Table 10. Volume per ha

Basal area per ha	Number of trees per ha 4000	3000	2000	1000	500
100	68.47	75.27	86.02	108.0	135.7
200	195.0	214.4	245.0	307.8	386.5
300	359.8	395.5	452.1	567.8	713.2
400	555.8	611.0	698.3	877.0	1102
500	778.4	855.7	978.0	1228	1543
600	1025	1127	1288	1618	2032
700	1294	1422	1589	2040	2565
800	1583	1740	1989	2498	3138
900	1891	2078	2375	2983	3747
1000	2217	2437	2768	3499	4394

21. Well stocked yield table

Table 11. Well-stocked yield table

Age	Average Height Ken	m	Basal area per ha sq. Shaku	sq. meter	Number of trees per ha	Average D.B.H Sun	cm	Volume per ha Koku	cubic m
	Site 6 (11)								
20	3.73	6.78	416	38.19	3440	3.9	11.8	619.5	172.35
30	5.13	9.33	547	55.68	2484	5.3	16.1	1043	290.16
40	6.00	10.91	622	57.10	2113	6.1	18.5	1335	371.40
50	6.60	12.00	665	74.35	1916	6.6	20.0	1525	424.26
60	7.02	12.76	691	63.43	1797	7.0	21.2	1651	460.96
70	7.35	13.36	706	64.81	1714	7.2	21.8	1732	481.84
	Site 8 (15)								
20	4.98	9.05	458	42.04	2817	4.6	13.9	765.2	212.88
30	6.83	12.42	604	55.45	2033	6.2	18.8	1299	361.38
40	8.00	14.54	676	68.82	1730	7.1	21.5	1617	449.85
50	8.80	16.00	709	72.18	1569	7.6	23.0	1794	499.09
60	9.37	17.03	724	73.70	1417	7.9	23.9	1892	526.35
70	9.80	17.82	729	74.21	1404	8.1	24.5	1941	539.99
	Site 10 (18)								
20	6.22	11.31	508	51.71	2413	5.2	15.8	941.4	261.90
30	8.54	15.53	673	61.78	1742	7.1	21.5	1602	445.68
40	10.00	18.18	740	67.93	1482	8.0	24.2	1951	542.77
50	11.00	20.00	760	69.77	1344	8.5	25.8	2097	583.39
60	11.66	21.20	759	69.68	1260	8.8	26.7	2138	594.79
70	12.25	22.27	753	69.13	1202	8.9	27.0	2145	596.74
	Site 12 (22)								
20	7.46	13.56	570	52.33	2126	5.9	17.9	1168	324.94
30	10.25	18.63	762	69.95	1534	8.0	24.2	2017	561.13
40	12.00	21.82	818	75.09	1305	8.9	27.0	2367	658.50
50	13.20	24.00	818	75.09	1219	9.2	27.9	2420	673.24
60	14.03	25.51	799	73.35	1110	9.6	29.1	2408	669.91
70	14.70	26.72	778	71.42	1050	9.7	29.4	2357	655.72

continued next page

	Site 14 (25)								
20	8.71	15.83	651	59.76	1910	6.6	20.0	1478	411.46
30	11.96	21.74	877	80.51	1379	9.0	27.3	2582	718.31
40	14.00	25.45	914	83.91	1173	10.0	30.3	2897	805.95
50	15.40	28.00	885	81.24	1064	10.3	31.2	2850	792.87
60	16.39	29.79	843	77.39	998	10.4	31.5	2661	740.29
70	17.15	31.18	805	73.90	952	10.4	31.5	2562	712.75

Site index is height of tree in Ken (meters) at age 40 years (1 Ken=1.818m, 1 sq Shaku=0.0918 sq. meter, 1 Sun=3.03cm and 1 Koku=0.2782 cubic meter) In the above table basal area is computed when stocking percentage is always 100 in each age.

Chapter 4 Average-stocked stand yield table

22. Average-stocked stand data

Original data of average-stocked stand came from level 3 in density. The 64 plots are listed in the following table:

Table 12. Average-stocked data

Plot No.	Age	Ave. Dbh	Ave. Height	Number of trees	Volume per ha	Basal area per ha
D-XX-1	8	2.1	1.74	3200	22.635	44
A-I-2	13	2.8	1.93	3050	196.008	196
B-XIII-2	13	3.9	4.41	2700	490.000	328
E-XXVII-2	13	4.1	3.84	2650	476.378	351
A-V-2	14	3.1	2.52	2625	168.498	198
A-III-2	15	3.9	3.64	3300	520.800	407
A-IV-2	15	3.5	3.66	2700	331.145	258
B-X-2	15	4.0	4.28	2325	414.000	287
B-XII-2	15	4.0	6.53	2225	669.600	331
F-XXIX-2	15	3.4	3.56	2650	304.210	241
E-XXIII-3	17	3.7	3.97	2500	377.058	273
C-XVII-3	18	4.7	5.75	2225	701.050	387
F-XXX-3	18	5.0	5.33	2175	744.750	415
D-XXVIII-3	19	4.6	4.37	2300	556.225	381
E-XXV-3	19	4.3	4.77	2550	579.475	379
C-XVIII-3	20	5.1	5.47	1675	629.600	342
F-XXXI-3	20	5.7	7.24	1700	874.600	438
D-XIX-4	23	3.3	3.31	2250	232.860	193
E-XXIV-5	23	5.2	4.96	2200	778.350	456
E-XVII-4	24	7.0	6.79	1300	1067.775	506
E-XXVI-4	24	5.1	5.31	1775	621.125	367
B-VII-4	25	4.0	6.05	2500	595.500	313
C-XIV-4	25	6.2	6.59	1450	880.775	435
F-XXXII-4	25	6.9	6.34	1375	1010.300	513
F-XXXIII-4	25	6.1	6.84	1550	937.300	450
E-XXVII-5	26	5.4	5.18	2050	778.750	447
A-I-5	28	7.6	8.11	1275	1355.400	580
B-IX-5	28	7.0	7.65	1450	1213.900	531
DXXI-5	28	4.8	6.16	2075	733.150	372
B-XI-5	30	6.5	6.59	1525	1131.875	544
C-XVII-5	30	6.0	8.31	1550	1061.425	434
D-XIX-6	31	5.5	5.60	1725	733.125	408
A-IV-6	32	8.3	8.80	1225	1440.825	446
E-XXV-6	32	4.7	6.49	2300	773.875	393
E-XXVI-6	32	6.3	7.01	1475	953.625	453
A-V-6	33	5.4	8.13	1975	1046.300	446
A-II-6	35	8.5	11.68	950	1623.400	527
B-VII-6	35	6.3	8.23	1225	979.825	384
B-VIII-6	35	5.8	7.68	1875	1108.675	493
C-XVI-7	36	6.5	7.53	1500	1123.875	496
D-XXVIII-7	36	6.7	6.38	1275	884.275	452
F-XXIX-7	36	7.8	8.39	1050	1269.525	501
B-XIII-7	37	5.2	6.03	2000	846.950	424
B-X-7	38	7.5	8.56	1375	1534.575	627
C-XVII-7	38	5.8	8.78	1625	1079.550	431
D-XX-7	38	7.7	8.85	1250	1513.250	587
A-III-7	40	7.8	9.63	1100	1425.875	535

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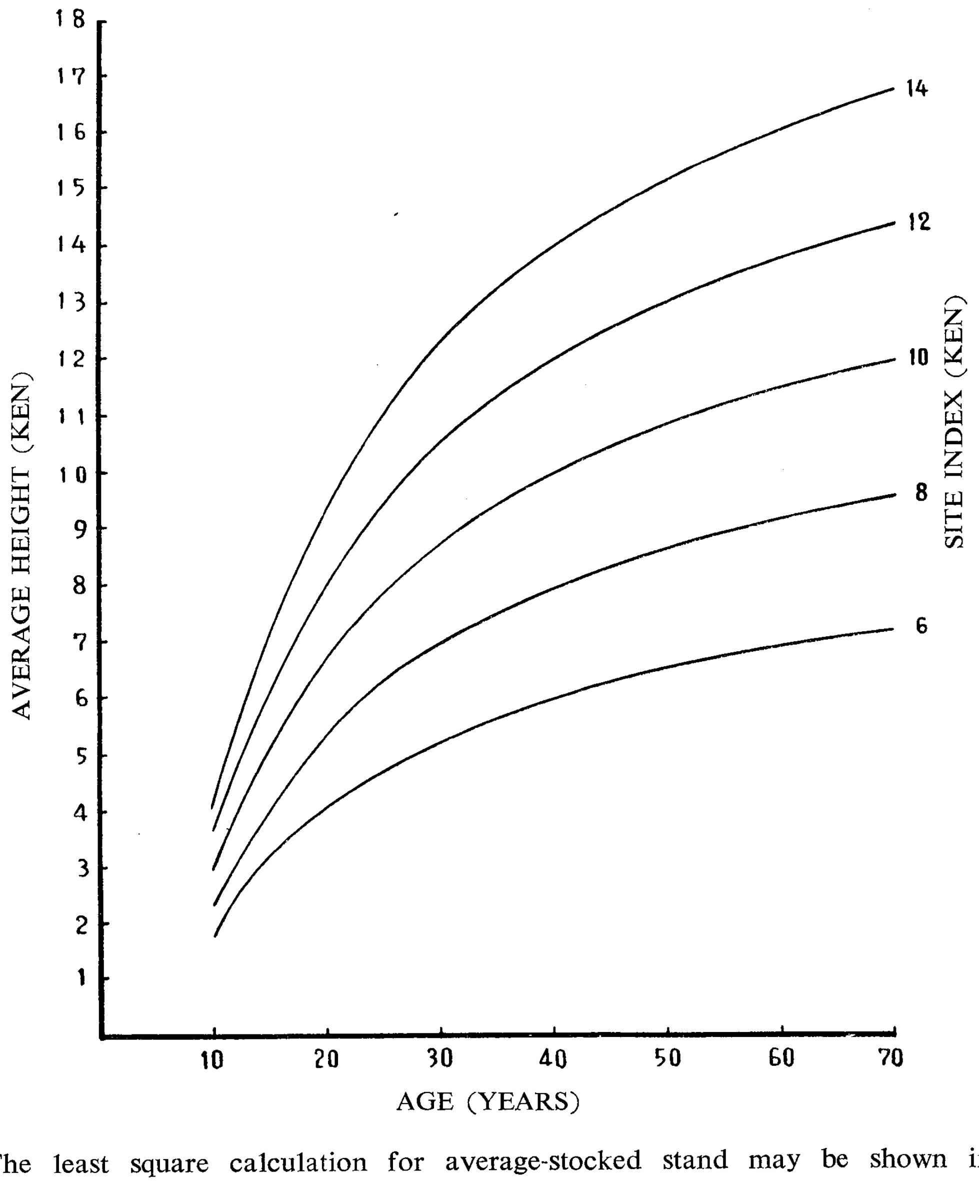
D-XXI-8	41	6.5	8.66	1675	1419.600	565
E-XXIII-8	41	5.5	5.70	1900	901.450	445
F-XXX-8	43	8.4	8.93	950	1325.000	527
F-XXXI-8	43	7.5	9.81	1250	1486.850	452
B-VII-8	44	8.3	8.86	1025	1412.725	563
B-XI-8	45	8.0	8.67	1175	1647.425	643
B-XII-8	45	7.3	8.47	1225	1361.425	503
E-XXIV-9	45	8.6	11.07	975	1700.075	460
F-XXXII-8	45	7.1	7.11	1500	1348.535	592
C-XV-9	47	6.2	9.79	1575	1256.075	480
B-VII-9	50	7.4	8.72	1200	1384.550	523
A-V-10	54	7.1	11.54	1325	1631.200	517
C-XIV-10	56	9.9	9.88	750	1595.835	577
CXVIII-10	61	8.4	12.20	1075	2042.250	598
F-XXXI-10	61	9.3	10.19	1050	2016.000	712
B-XII-10	62	8.9	10.03	1000	1768.775	615
C-XVI-10	68	9.9	12.74	850	2208.000	654

23. Height curve for average-stocked stand

Fig. 6. Height curves of average-stocked stands



The least square calculation for average-stocked stand may be shown in the following:

	1	$1/A$	$\log H$	ck
1	64	2.483	51.1597	117.6429
$1/A$		0.1225	1.7960	4.4017
$\log H$			43.5126	96.4683
0.0388		0.0262	−0.1890	−0.1628
0.799370312			2.6171	2.4281
−7.21374045			1.2537	1.2537

The height curve for average-stocked stand is

$$\log H = 1.0793 - 7.2137(1/A)$$

and site index curve is

$$\log H = \log(S.I.) - 7.2137(1/A - 1/40).$$

Table 13. Height for average-stocked stand

Site Index	Age						
	10	20	30	40	50	60	70
6	1.73	3.96	5.23	6.00	6.52	6.89	7.17
8	2.32	5.28	6.97	8.00	8.69	9.18	9.56
10	2.88	6.62	8.71	10.00	10.87	11.48	11.95
12	3.45	7.92	10.45	12.00	13.04	13.78	14.34
14	4.03	9.24	12.20	14.00	15.21	16.07	16.72

The analysis of variance for average stocked stand height curve will be shown as below:

Source	SS	DF	MS	F
1	40.8955	1		**
$1/A$	1.3634	1		**
Error	1.2537	62	0.0202	
Total	43.5126	64		

Both H and A are highly significant.

24. Stocking equation of average-stocked stand

The least square solution may be shown in the following pattern:

	B	$BH/10$	$10B/A$	BH/A	s	ck
B	13875612	11129542	4348375	3144287	2865800	35363616
$BH/10$		9600308	3145717	2492891	2183600	28552058
$10B/A$			1631762	1045404	977600	11148858
BH/A				747569	658500	8088651
s					640000	7325500
0.802093774		673372	−342088	−29122	−115040	187142
0.3133825736			269057	60039	79508	66585
0.2266052841				35057	9095	75146
0.2065350342					48112	21654
−0.508022311			95269	45244	21065	161657
−0.0432480115				33798	4120	83240
−0.170841674					28458	53625
0.474907892				12311	−5884	6468
0.221110749					23800	17882
−0.4779465518					20988	20988

The stocking equation is

$$S = 0.1454B + 0.0036BH + 4.4809(B/A) - 0.4779(BH/A)$$

and $$S = B[0.1454 + 0.0036H + 4.4809(1/A) - 0.4779(H/A)]$$

The analysis of variance will be shown in the following:

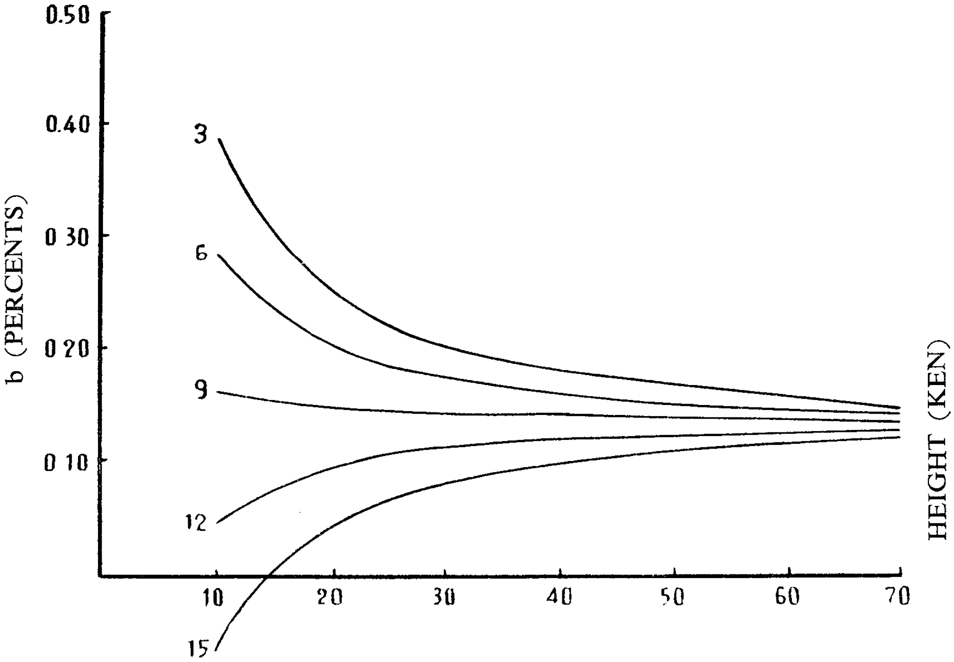
Source	SS	DF	MS	F
B	591888	1		**
$BH/10$	19654	1		**
$10B/A$	4658	1		**
BH/A	2812	1		**
Error	20988	60	350	
Total	640000	64		

B, *BH*, *B*/*A* and *BH*/*A* all effects are highly significant as well as in the case of well-stocked stand, but mean square is larger. Coefficent of basal area for average-stocked stand is shown in the following table:

Table 14. Coefficent of basal area

Height	Age 10	20	30	40	50	60	70
3	0.4929	0.3245	0.2684	0.2404	0.2235	0 2125	0.2044
6	0.3604	0.2636	0.2314	0.2153	0.2057	0.1993	0.1947
9	0.2278	0.2027	0.1945	0.1903	0.1878	0.1862	0.1850
12	0.0950	0.1419	0.1574	0.1652	0.1699	0.1730	0.1753
14	−0.0374	0.0810	0.1206	0.1402	0.1520	0.1599	0.1656

Fig. 7. Coefficent of basal area in average-stocked stands



25. Approach of stocking percentage to average

In each site, stocking percentage will be calculated from fixed basal area at age 20.

Table 15. Stocking percentage

Basal area	Age 10	20	30	40	50	60	70
Site 6							
100	8.36	28.91	43.76	53.76	60.87	65.25	70.13
200	33.43	57.82	69.44	76.03	80.32	82.83	85.51
300	75.23	86.74	90.95	93.13	94.47	95.21	96.01
400	133.8	115.7	110.2	107.6	106.0	105.2	104.3
500	209.1	144.6	127.9	120.5	115.9	113.5	111.1
600	301.0	173.5	144.3	131.7	124.7	120.9	117.1
Site 8							
100	6.87	26.22	41.00	51.21	58.55	63.10	68.19
200	27.51	52.44	65.06	72.41	77.25	80.09	83.14
300	61.89	78.67	85.23	88.70	90.85	92.09	93.37
400	110.0	104.9	103.3	102.4	101.9	101.6	101.4
500	171.6	131.0	119.7	114.5	111.4	109.8	108.0
600	247.4	157.3	135.2	125.4	119.9	116.9	113.8

continued next page

	Site 10						
100	5.52	23.50	38.12	48.47	56.03	60.77	66.08
200	22.09	47.00	60.58	68.55	73.93	77.13	80.57
300	49.17	70.50	79.23	83.97	86.96	88.67	90.49
400	88.35	94.00	95.96	96.94	97.54	97.88	98.24
500	138.1	117.5	111.3	108.4	106.7	105.7	104.7
600	198.8	141.0	125.7	118.7	114.7	112.5	110.3
	Site 12						
100	4.35	20.87	35.22	45.68	53.43	58.33	68.89
200	17.43	41.74	55.42	64.61	70.50	74.04	77.89
300	39.19	62.60	73.20	79.12	82.91	85.11	87.46
400	69.69	83.48	88.67	91.37	93.02	93.97	94.97
500	109.0	104.4	102.9	102.2	101.7	101.5	101.2
600	156.7	125.2	116.1	111.9	109.4	108.0	106.6
	Site 14						
100	3.31	18.19	32.14	42.65	50.57	55.64	61.42
200	13.24	36.37	51.00	60.31	66.74	70.61	74.89
300	29.79	54.58	66.80	73.87	78.49	81.21	84.10
400	52.94	72.76	80.91	85.29	88.06	89.64	91.31
500	82.72	90.95	93.89	95.37	96.27	96.78	97.32
600	119.0	109.1	106.0	104.5	103.5	103.0	102.5

This stocking percentage indicates average condition. In such case stocking percentage 100 may not mean normal stocking.

26. Basal area for average stocking stand

Basal area per ha for average stocking will be shown in the following table:

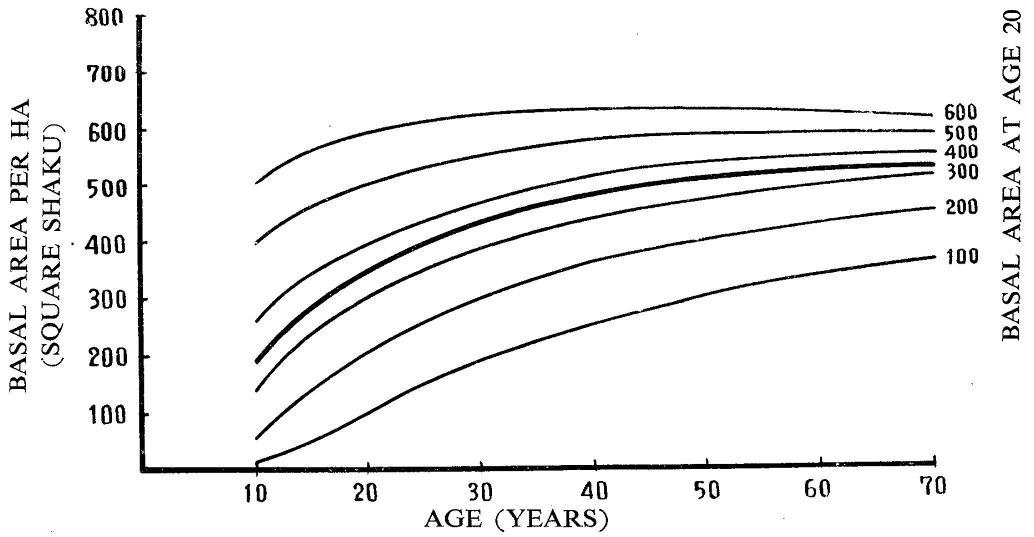
Table 16. Basal area for average stocking

Site	Age						
	10	20	30	40	50	60	70
6	16.17	100.00	190.18	259.33	310.24	342.88	376.44
	64.67	200.00	301.78	366.76	409.38	435.26	458.99
	145.54	300.00	395.26	449.25	481.50	500.32	515.35
	258.85	400.00	478.92	519.05	540.27	552.81	559.85
	404.53	500.00	555.85	581.28	590.72	596.43	596.35
	508.32	600.00	627.12	635.31	635.58	635.31	628.56
8	14.00	100.00	196.36	268.68	319.60	350.75	381.80
	56.04	200.00	311.59	379.91	421.67	445.19	465.51
	126.07	300.00	408.19	465.37	495.91	511.90	522.79
	224.07	400.00	494.73	537.25	556.22	564.76	567.75
	349.56	500.00	573.28	600.73	608.07	610.34	604.70
	503.97	600.00	647.51	657.92	654.48	649.81	637.18
10	11.85	100.00	203.42	279.04	329.20	357.68	386.89
	47.38	200.00	323.27	394.65	434.37	453.97	471.72
	106.63	300.00	422.79	483.42	510.93	521.90	529.80
	189.51	400.00	512.06	558.09	573.09	576.10	575.18
	296.22	500.00	593.92	624.06	626.91	622.13	613.00
	426.43	600.00	670.76	683.36	673.91	662.15	645.78
12	9.88	100.00	212.30	290.59	339.67	365.02	391.72
	39.53	200.00	334.06	411.01	448.19	463.33	477.56
	88.89	300.00	441.23	503.31	527.08	532.60	536.24
	158.06	400.00	534.48	581.23	591.35	588.05	582.28
	247.22	500.00	620.25	650.13	646.53	635.16	620.48
	355.41	600.00	699.82	711.83	695.48	675.84	653.59
14	7.97	100.00	222.58	303.56	350.45	371.43	395.24
	31.88	200.00	353.19	429.25	462.51	471.36	481.92
	71.73	300.00	462.60	525.77	543.94	542.12	541.18
	127.47	400.00	560.32	607.05	610.26	598.40	587.58
	199.18	500.00	650.21	678.79	667.15	646.06	626.25
	286.54	600.00	734.07	743.77	717.26	687.58	659.59

It is also noticable that the basal areas have the maximum point somewhere age 40 and 50 years.

Fig. 8. Basal area of average-stocked stands

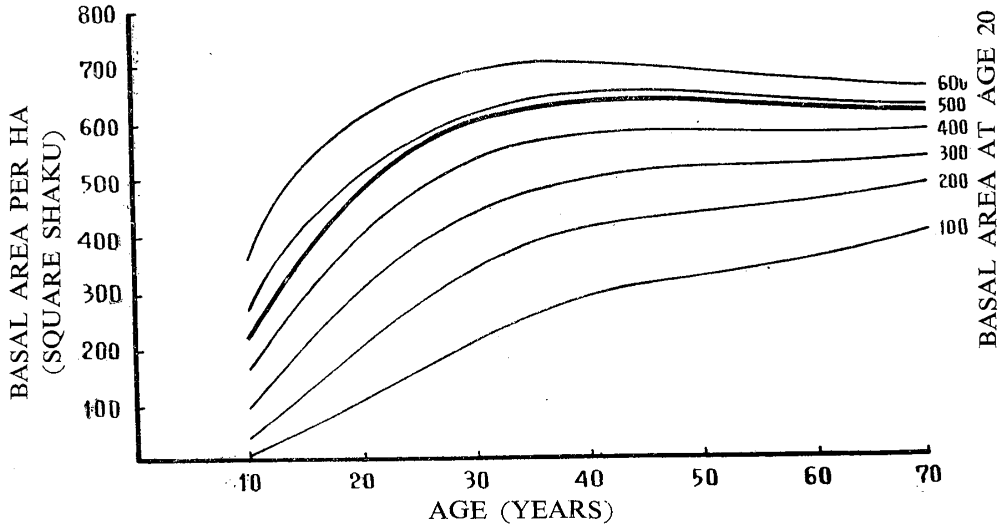
SITE INDEX 6 KEN AT AGE 40



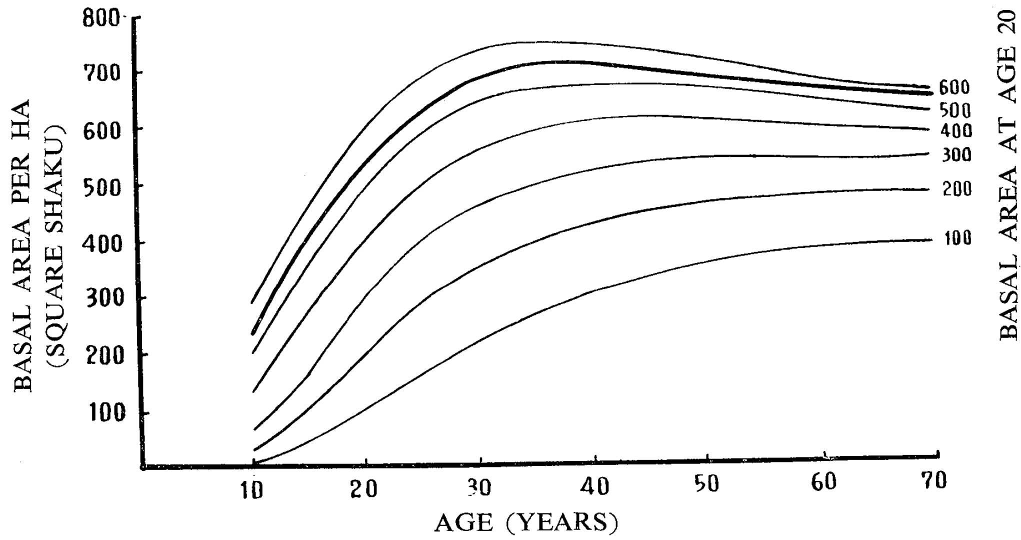
SITE INDEX 8 KEN AT AGE 40

SITE INDEX 10 KEN AT AGE 40

SITE INDEX 12 KEN AT AGE 40



SITE INDEX 14 KEN AT AGE 40



(Bold lines show the basal area of 100 stocking percentage stands in each site)

27. Number of tree equation

The number of trees per ha for average stocking stand will be calculated in the following table. (Bold type digits may be eliminated)

	1	log*H*	log*B*	1/*A*	log*N*	*ck*	*SS*
1	64	51.1597	167.9755	2.4832	205.6185	491.2369	660.6087
log*H*		43.5126	135.9486	1.7960	163.0532	395.4701	611.0034
log*B*			442.8738	6.3245	538.4391	1291.5615	654.6259
1/A				0.1225	8.1376	18.8638	540.5758
log*N*	1/A				662.1486	1577.3970	
	0.0262	—0.1890	—0.1929		0.1596	—0.1961	
0.799370312		2.6171	1.6740	**—0.1890**	—1.3121	2.7900	0.6578
2.62461718			2.0024	**—0.1929**	—1.2307	2.2528	0.7564
0.038800000				**0.0262**	**0.0262**	**0.1596**	0.9722
3.21278606					1.5397	—0.8435	
—7.213740		1.2537	0.2825		—0.1608	1.3754	0.0206
—7.362595			0.5822		—0.0556	0.8091	0.0053
6.091603					0.5675	0.3511	
0.2253330142			0.5185		—0.0194	0.4991	0.0007
—0.1282603493					0.5469	0.5275	
—0.0374156219					0.5462	0.5462	

Sum of squared residuals due to each effect will be shown in the following table:

	ss due to first indep.	Keeping N additional eff.	Keeping N,A add. eff.	Keeping N,A,H add. eff.	Keeping N,A,B add. eff.
N alone	660.6089				
H alone	611.0034	0.6578	0.0206		0.0160
B alone	654.6259	0.7564	0.0053	0.0007	
A alone	540.5758	0.9722			

The analysis of variance will be shown in the following table:

Source	SS	DF	MS	F
N	660.6089	1		**
A	0.9722	1		**
H	0.0206	1		non sig.
B	0.0007	1		non sig.
Error	0.5462	60	0.0091	
Total	662.1486	64		

Then resulting equation will be

$$\log N = 2.9764 + 6.0916(1/A)$$

which does not include term H and B, but term A only.

The number of trees for average-stocked stand will be shown in the following table:

Table 17. Number of trees for average-stocked stand

Age						
10	20	30	40	50	60	70
3851	1910	1511	1345	1254	1197	1157

28. Volume per ha

Volume equation will be calculated from the following pattern: (Bold type digits may be eliminated)

	$\log B$	1	$\log B$	$\log H$	$\log N$	$\log V$	ck	SS
$\log B$	442.8738	167.9755		135.9486	538.4391	495.8783	1781.1153	555.2265
1		64	167.9755	51.1597	205.6185	187.6118	676.3655	549.9717
$\log B$			442.8738	135.9486	538.4391	495.8783	1781.1153	555.2265
$\log H$				43.5126	163.0532	153.0855	546.7596	538.5835
$\log N$					662.1486	600.2795	2169.5389	544.1913
$\log V$	$\log N$					556.3580	1993.2131	
	7.5227	1.3965		−2.2310		−2.6016	4.0866	0.8997
0.379285250		0.2894		−0.4036	**1.3965**	−0.4675	0.8148	0.7552
0.306969163				1.7806	**−2.2310**	0.8662	0.0122	0.4214
1.215784496					**7.5227**	**−2.6016**	**4.0866**	0.8997
1.119683079						1.1315	−1.0714	
0.185638135		0.0302		0.0106		0.0155	0.0563	0.0080
−0.296569051				1.1190		0.0946	1.2242	0.0080
−0.345833277						0.2318	0.3419	
0.350993377				1.1153		0.0892	1.2044	0.0071
0.513245033						0.2238	0.3130	
0.07997848112						0.2167	0.2167	

The analysis of variance will be shown as follows:

Source	SS	DF	MS	F
$\log B$	555.2265	1		**
$\log N$	0.8997	1		**
1	0.0080	1		2.22 non sig.
$\log H$	0.0071	1		1.97 non sig.
Error	0.2167	60	0.0036	
Total	556.3580	64		

The volume equation for average stocking stand is

$$\log V = 1.5401 \log B - 0.3458 \log N$$

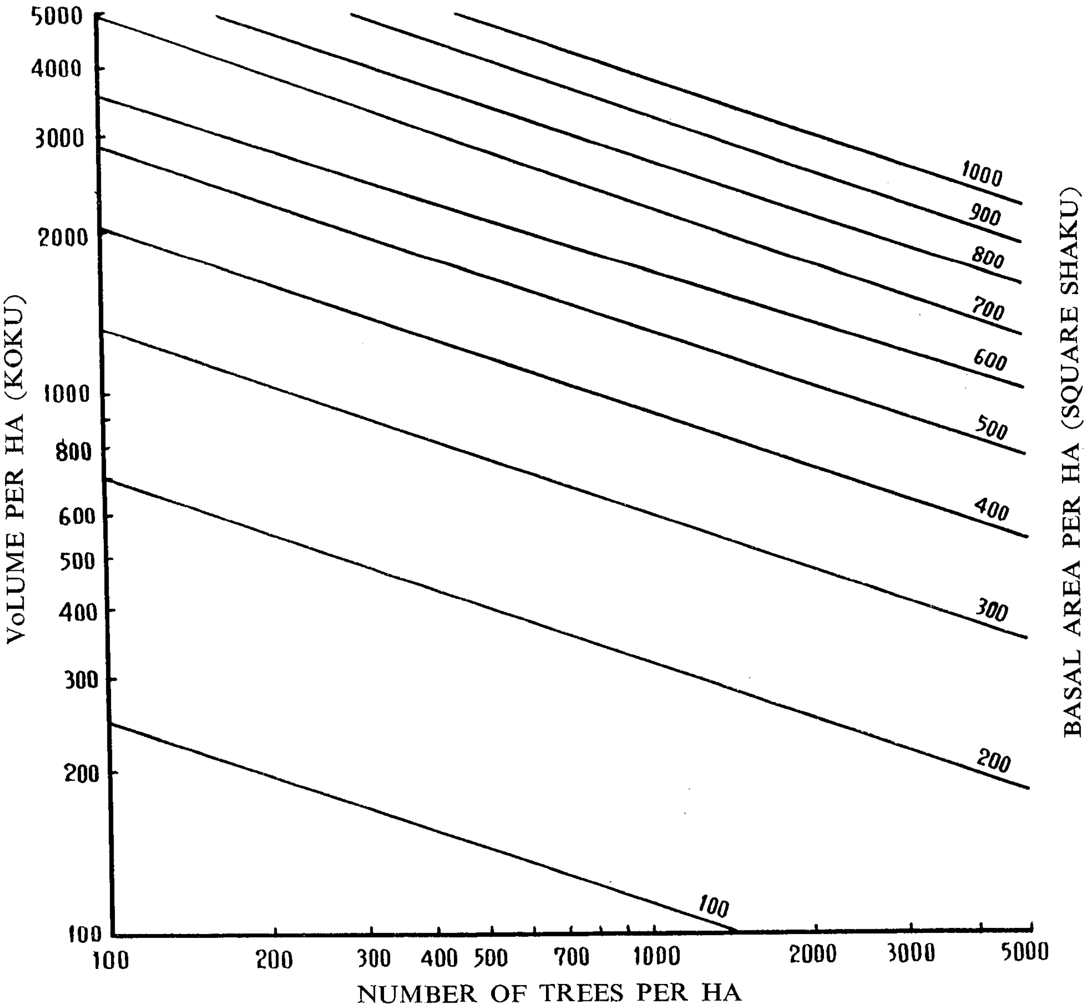
The volume per ha will be shown as the following table:

Table 18. Volume per ha

Basal area per ha	Number of trees per ha 4000	3000	2000	1000	500
100	67.68	75.47	86.84	110.36	140.32
200	198.71	219.49	252.53	320.93	408.04
300	371.03	409.83	471.52	600.73	761.91
400	577.97	638.42	734.52	933.29	1186.9
500	814.90	900.12	1110.7	1316.2	1673.5
600	1079.2	1192.1	1371.6	1743.1	2216.2
700	1368.1	1511.2	1737.9	2209.6	2809.4
800	1680.8	1856.6	2136.0	2714.6	3451.5
900	2014.7	2225.4	2560.4	3253.9	4137.2
1000	2369.8	2617.6	3011.7	3827.4	4866.4

It will be shown in the following graph:

Fig. 9. Volume per ha of average-stocked stands



29. The average yield table

The average yield table will be shown in the following table:

Table 19. Average yield table

Age	Ave. Ht. Ken	Ave. Ht. m	Basal area sq. Shaku	Basal area sq. m	Number	Ave. D.b.h Sun	Ave. D.b.h cm	Volume Koku	Volume cubic m
	Site 6 (11)								
10	1.76	3.15	193	17.76	3851	2.5	7.6	190.6	53.02
20	3.96	7.20	346	31.75	1910	4.8	14.5	594.2	165.31
30	5.23	9.51	435	39.90	1511	6.1	18.5	918	255.25
40	6.00	10.91	482	44.28	1345	6.5	19.7	1123	312.42
50	6.52	11.85	510	46.79	1254	6.9	20.9	1251	348.03
60	6.89	12.53	525	48.24	1197	7.2	21.8	1333	370.84
70	7.17	13.04	537	49.28	1157	7.4	22.4	1392	387.25
	Site 8 (15)								
10	2.32	4.22	204	18.70	3851	2.5	7.6	206.0	57.31
20	5.28	9.60	381	35.01	1910	4.8	14.5	692.2	192.57
30	6.97	12.67	479	43.97	1511	6.1	18.5	1065	296.28
40	8.00	14.54	525	48.16	1345	6.8	20.6	1277	355.26
50	8.69	15.80	546	50.11	1254	7.1	21.5	1389	386.42
60	9.18	16.69	556	51.03	1197	7.4	22.4	1452	403.95
70	9.56	17.38	560	51.40	1157	7.5	22.7	1486	413.41
	Site 10 (18)								
10	2.88	5.24	215	19.69	3851	2.6	7.9	223.4	62.15
20	6.62	12.04	426	39.06	1910	5.1	15.5	819.2	227.90
30	8.71	15.83	534	48.99	1511	6.4	19.4	1258	349.38
40	10.00	18.18	576	52.85	1345	7.1	21.5	1473	409.79
50	10.87	19.76	588	53.94	1254	7.4	22.4	1557	433.16
60	11.48	20.87	589	54.03	1197	7.6	23.0	1588	441.78
70	11.95	21.73	586	53.75	1157	7.7	23.3	1594	443.46
	Site 12 (22)								
10	3.45	6.27	227	20.82	3851	2.6	7.6	243.0	67.60
20	7.92	14.40	479	43.99	1910	5.7	17.3	984.9	273.92
30	10.45	19.00	603	55.33	1511	6.8	20.6	1518	422.31
40	12.00	21.82	636	58.40	1345	7.4	22.4	1721	478.78
50	13.04	23.71	636	58.36	1254	7.7	23.3	1759	489.35
60	13.78	25.05	626	57.45	1197	7.8	23.6	1744	485.18
70	14.34	26.07	613	56.28	1157	7.9	23.9	1712	476.28
	Site 14 (25)								
10	4.03	7.33	241	22.10	3851	2.7	8.1	266.4	74.11
20	9.24	16.10	550	50.47	1910	5.8	17.6	1215	338.01
30	12.20	22.18	693	63.57	1511	7.3	22.1	1882	523.57
40	14.00	25.45	712	65.34	1345	7.9	23.9	2043	568.36
50	15.21	27.65	693	63.62	1254	8.0	24.2	2012	559.74
60	16.07	29.22	668	61.28	1197	8.1	24.5	1927	536.09
70	16.72	30.40	644	59.07	1157	8.1	24.5	1843	512.72

In this case, stocking perentage is 100 which means average condition.

Chapter 5 Random data yield table

30. Random data

Random data came from level 1, 2, 3, 4 and 5 in density. The 58 plots are chosen mechanically and listed in the following table :

Table 20. Random data

Plot No.	Age	Ave. D.b.h	Ave. Ht.	Number of trees	Volume per ha	Basal area per ha
C-XVIII-1	6	2.5	1.75	1400	25.908	53.465
B-VI-1	7	1.5	2.32	1225	26.463	34.660
D-XXI-1	8	1.1	1.49	3350	16.495	32.771
F-XXX-1	8	1.3	1.41	2175	13.710	34.451
E-XXVI-1	8	2.3	1.85	4375	146.555	179.474
A-III-1	8	2.4	3.13	3175	131.250	149.500
B-IX-1	9	2.5	2.04	1125	34.448	59.940
B-VII-1	10	1.7	1.99	1750	25.548	40.250
BXI-2	13	3.0	3.36	2475	253.585	216.720
CVV-2	13	3.9	4.30	1800	309.150	207.001

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C-XVIII-2	13	4.1	3.71	2450	423.325	319.493
A-V-2	14	3.1	2.52	2625	168.498	197.780
A-II-2	15	4.0	5.22	2025	449.950	262.900
B-X-2	15	4.0	4.28	2325	414.000	287.060
B-XII-2	15	4.0	6.53	2225	669.600	331.000
C-XVI-3	18	4.7	5.75	2225	701.050	386.951
E-XXVI-3	18	5.1	5.00	2225	751.500	452.288
A-IV-3	20	4.0	5.42	3800	845.690	485.770
C-XVI-3	20	3.7	3.82	1925	263.330	203.933
F-XXXI-3	20	5.7	7.24	1700	874.600	438.239
E-XXII-4	24	7.0	6.79	1300	1067.775	505.845
F-XXXII-4	25	6.9	6.34	1375	1010.300	513.064
F-XXXIII-4	25	6.1	6.84	1550	937.300	449.791
D-VIX-5	28	4.5	4.97	2200	588.235	342.579
E-XXIII-5	28	4.6	5.45	1850	557.825	312.438
B-XIII-5	28	5.6	6.63	3325	1698.250	852.612
A-I-5	28	7.6	8.11	1275	1355.400	579.528
B-VII-5	29	4.3	6.51	2250	642.800	320.880
E-XXV-5	29	4.6	4.87	2075	638.550	345.462
D-XXI-6	32	6.0	5.83	1175	605.800	329.351
F-XXXII-6	32	7.9	8.86	675	854.350	336.739
E-XXVI-6	32	6.3	7.01	1475	933.625	452.684
A-V-6	33	5.4	8.13	1975	1046.300	445.660
C-XIV-6	35	7.0	7.28	900	728.675	345.172
F-XXXI-6	35	5.6	7.61	2200	1226.950	537.359
B-XIII-7	37	5.2	6.03	2000	846.950	424.314
B-VI-7	38	7.7	11.75	1100	1681.600	540.400
E-XXV-7	38	7.7	7.97	1400	1521.900	647.357
B-VIII-7	39	5.4	6.22	1450	647.300	329.720
A-III-7	40	7.8	9.63	1100	1425.875	533.496
D-XX-8	42	8.0	8.99	900	1208.750	446.008
F-XXIX-8	42	5.9	8.81	2550	1688.500	691.542
C-XIV-8	44	6.2	5.79	1900	1173.050	576.306
A-IV-8	44	7.2	10.99	1625	1983.250	652.080
A-I-8	45	10.4	14.54	1025	3133.875	878.563
B-XI-8	45	8.0	8.67	1175	1647.425	642.947
E-XXIV-9	45	8.6	11.07	975	1700.075	559.548
C-XVII-9	46	9.3	11.57	1250	2620.250	855.005
C-VV-9	47	6.2	9.79	1575	1256.075	480.418
B-VIII-9	47	5.6	6.85	2485	1301.450	616.490
A-II-9	48	10.5	11.31	1050	2953.070	983.425
D-XX-10	53	8.5	10.87	1225	2073.200	698.118
F-XXIX-10	54	8.4	8.76	900	1243.250	497.157
B-X-10	58	11.0	13.67	500	1601.200	458.380
B-XII-10	62	8.9	10.03	1000	1768.775	615.137
C-XIV-10	68	9.9	12.74	850	2208.000	653.795
B-IV-10	70	11.0	15.22	550	2021.350	509.330
E-XXVII-10	70	10.7	9.62	925	2233.475	826.389

31. Height curve

Height curve from random data will be calculated in the following table:

	1	$1/A$	$\log H$	ck
1	58	2.6379	45.2665	105.9044
$1/A$		0.1840	1.6515	4.4734
$\log H$			39.1057	86.0237
0.0454810344		0.0640	—0.4073	—0.3432
0.780456896			3.7771	3.3699
—6.36406250			1.1850	1.1850

The analysis of variance will be shown in the following table:

Source	SS	DF	MS	F
1	35.3286	1		**
$1/A$	2.5921	1		**
Error	1.1850	56	0.0217	
Total	39.1057	58		

Then resulting height curve is

$$\log H = 1.0699 - 6.3641(1/A)$$

Site index curve will be

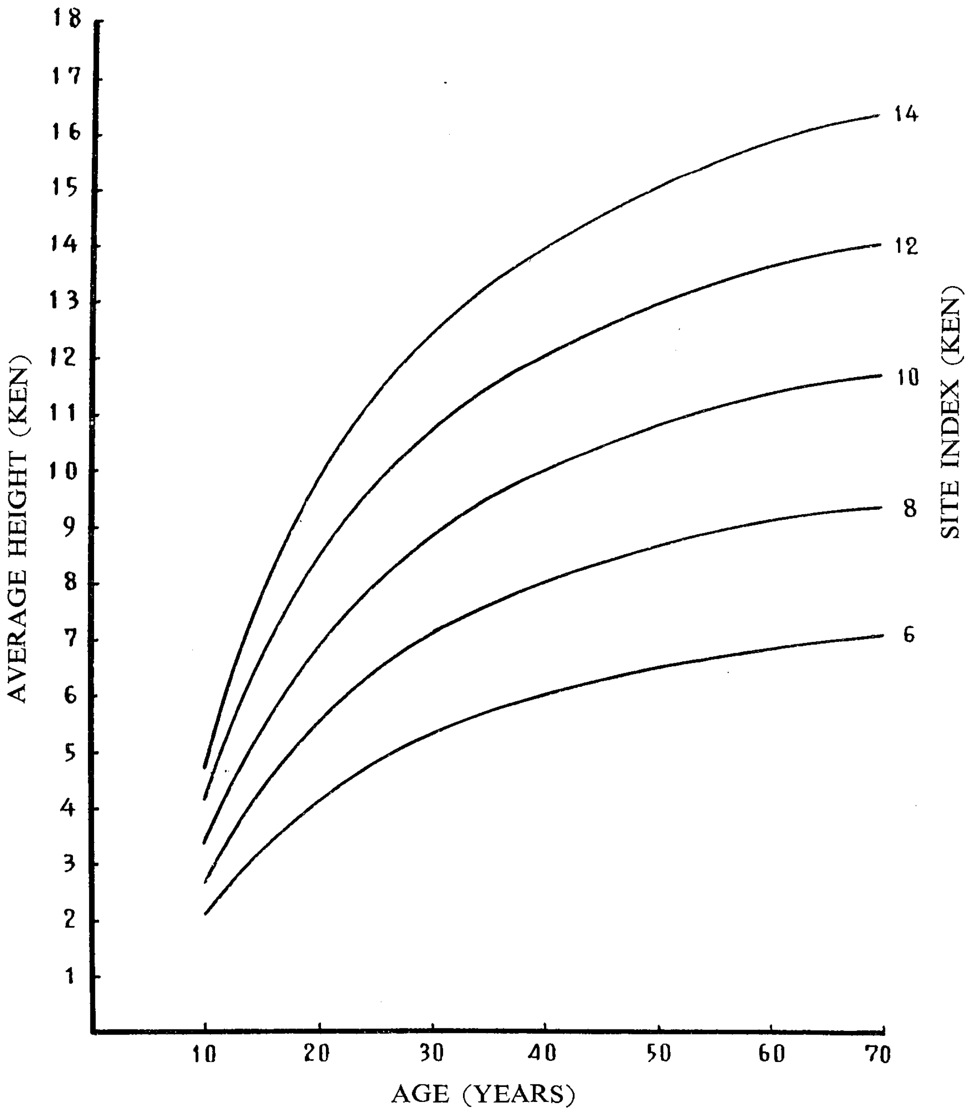
$$\log H = \log(\text{Site Inedex}) - 6.3641(1/A - 1/40).$$

Height curve will be shown in the following table:

Table 21. Height curve (Ken)

Site Index	Age						
	10	20	30	40	50	60	70
6	2.00	4.16	5.31	6.00	6.46	6.77	7.02
8	2.67	5.55	7.08	8.00	8.61	9.03	9.36
10	3.33	6.93	8.86	10.00	10.76	11.30	11.70
12	4.00	8.32	10.63	12.00	12.91	13.50	14.05
14	4.67	9.71	12.40	14.00	13.06	15.81	16.38

Fig. 10. Height curves of random stocked stands.



32. Stocking equation from random data

The least square calculation will be shown in the following pattern: (Bold type digits may be eliminated)

	$10B/A$	B	$BH/10$	$10B/A$	BH/A	s	ck	SS
$10B/A$	1388054	3918814	3074728		941859	826800	10150255	492487
B		13855758	12141614	**3918814**	3075365	2515800	35507351	456796
$BH/10$			12010707	**3074728**	2912154	2049300	32188503	349657
$10B/A$				**1388054**	**941859**	**826800**	**10150255**	492487
BH/A					934867	604300	8468545	390621
s						580000	6576200	
2.823243187		2791993	3460909		416268	181543	6850713	11804
2.215135722			5199767		825808	217826	9704311	9125
0.6785463677					295772	43278	1581126	6333
0.5956540595						87513	530159	
		233709	309809			16211	559729	
1.239583695			909681		**309809**	—7212	1212278	57
0.149093497					**233709**	**16211**	**559729**	1124
0.0650227274						75709	84708	
1.325618611			498992			—28702	470291	1651
0.0693640381						74585	45883	
—0.0575199602						72934	72934	

The analysis of variance will be shown in the following table:

Source	SS		DF		MS	F
B/A	492487		1			**
B	11804		1			**
BH	1124	2775	1	2		non sig.
BH/A	1651		1			
Error	72934		54		1351	
Total	580000		58			

Then, stocking equation from random data is

$$S=B\{0.0650+4.1208(1/A)\}$$

BH and BH/A terms are not significant.

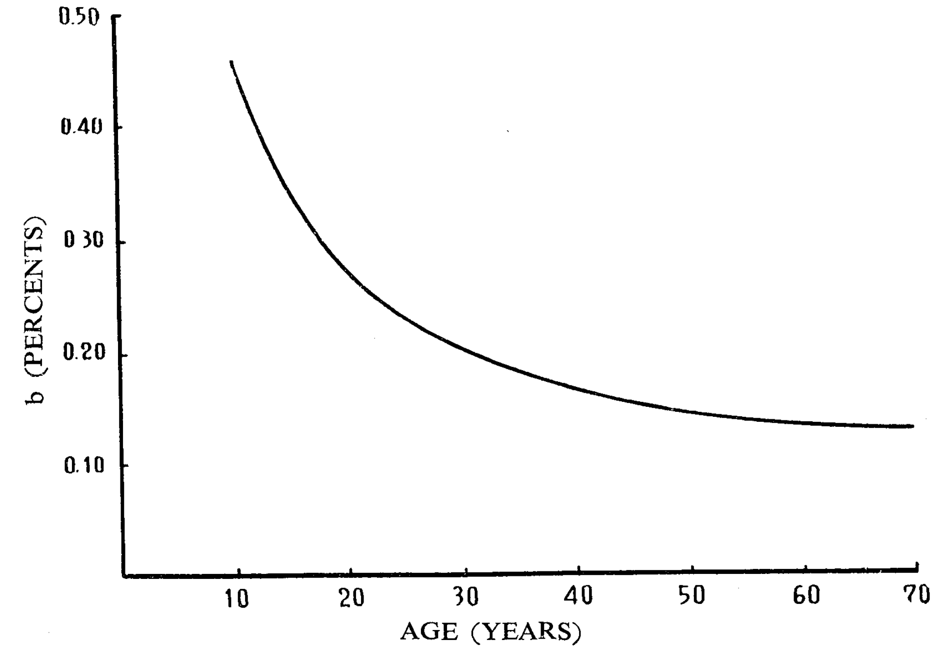
Coefficent of basal area will be shown in the following table:

Table 22. b value

Age	10	20	30	40	50	60	70
b	0.4771	0.2710	0.2022	0.1680	0.1474	0.1338	0.1239

This curve will be shown in the following graph:

Fig. 11. Coefficent of basal area of random stocked stands.



33. Normal approach of stocking percentage

For the fixed basal area at age 20, stocking percentage will be developed in the following table:

Table 23. Stocking percentage

Basal arsa	Age						
	10	20	30	40	50	60	70
	all site						
100	7.35	27.10	41.92	52.12	59.32	64.66	68.83
200	29.38	54.20	66.50	73.62	78.27	81.51	83.93
300	66.10	81.30	87.12	90.16	92.05	93.33	94.25
400	117.49	108.39	105.51	104.11	103.28	102.73	102.33
500	183.57	135.49	122.41	116.41	112.93	110.69	109.07
600	264.36	162.59	138.23	127.53	121.45	117.63	114.92

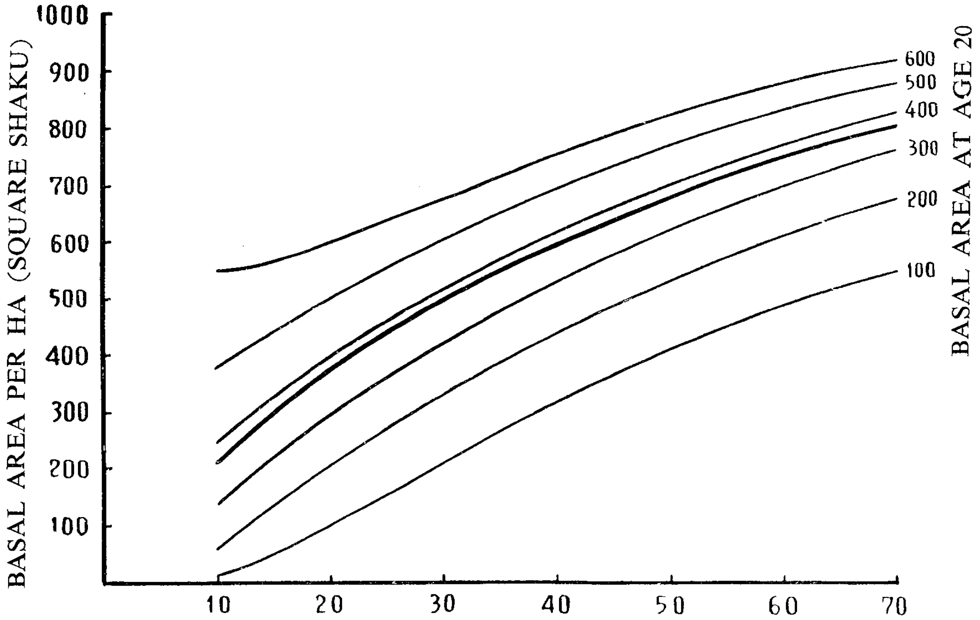
Regardless of site, stocking percentage development will be shown in the above table.

34. Basal area per ha

Basal area per ha will be shown in the following table:

Fig. 12. Basal area of random stocked stands

FOR ALL SITE



Bold line shows the basal area of 100 stocking percnetage stands

Table 24. Basal area per ha

Site	Age						
	10	20	30	40	50	60	70
6	15.40	100	207.31	310.24	402.44	483.22	555.56
	61.57	200	328.87	438.22	531.01	609.18	677.38
	138.55	300	430.84	536.65	624.46	697.50	760.73
	246.26	400	521.81	619.70	700.68	767.79	825.91
	384.76	500	605.39	692.92	766.15	827.28	880.31
	554.10	600	683.63	759.11	823.95	879.15	927.52

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8	15.40	100	207.31	310.24	402.44	483.22	555.56
	61.57	200	328.87	438.22	531.01	609.18	677.38
	138.55	300	430.84	536.65	624.46	697.50	760.73
	246.26	400	521.81	619.70	700.68	767.79	825.91
	384.76	500	605.39	692.92	766.15	827.28	880.31
	554.10	600	683.63	759.11	823.95	879.15	927.52
10	15.40	100	207.31	310.24	402.44	483.22	555.56
	61.57	200	328.87	483.22	531.01	609.18	677.38
	138.55	300	430.84	536.65	624.46	697.50	760.73
	246.26	400	521.81	619.70	700.68	767.79	825.91
	384.76	500	605.39	692.92	776.15	827.28	880.31
	554.10	600	683.63	759.11	823.95	879.15	927.52
12	15.40	100	207.31	310.24	402.44	483.22	555.56
	61.57	200	328.87	483.22	531.01	609.18	677.38
	138.55	300	430.84	536.65	624.46	697.50	760.73
	246.26	400	521.81	619.70	700.68	767.79	825.91
	384.76	500	605.39	692.92	776.15	827.28	880.31
	554.10	600	683.63	759.11	823.95	879.15	927.52
14	15.40	100	207.31	310.24	402.44	483.22	555.56
	61.57	200	328.87	483.22	531.01	609.18	677.38
	138.55	300	430.84	536.65	624.46	667.50	760.73
	246.26	400	521.81	619.70	700.68	767.79	825.91
	384.76	500	605.39	692.92	776.15	827.28	880.31
	554.10	600	683.63	759.11	823.95	879.15	927.52

35. Number of trees per ha

Number of trees per ha will be calculated in the following table:

	1	log$H$	log$B$	$1/A$	log$N$	SS
1	58	45.2665	146.9087	2.6379	186.5111	599.7654
log$H$		39.1057	119.3750	1.6515	144.0100	530.3288
log$B$			379.6767	6.1252	471.2948	585.0209
$1/A$				0.1840	8.6541	407.0216
log$N$					602.5733	
0.78045689		3.7771	4.7191	—0.4073	—1.5539	0.6393
2.53290862			7.5704	—0.5564	—1.1208	0.1659
0.0454810344				0.0640	0.1714	0.4590
3.21570862					2.8079	
1.249397686			1.6744	—0.0475	0.8206	0.4022
—0.1078340525				0.0201	0.0038	0.0007
—0.411400280					2.1686	
—0.02836837075				0.0188	0.0271	0.0391
0.4900860009					1.7664	
1.441489361					1.7273	

Analysis of variance

Source	SS	DF	MS	F
1	599.7654	1		**
H	0.6393	1		**
B	0.4022	1		**
A	0.0391	1		non sig.
Error	1.7273	54	0.0320	
Totai	602.5733	58		

The number of tree equation is

$$\log N = 2.7733 - 1.0237 \log H + 0.4901 \log B$$

The number of trees per ha will be shown in the following table:

Table 25. Number of trees per ha

Site	10	20	30	40	50	60	70
6	4009	2498	2239	2170	2146	2141	2146
8	2986	1861	1671	1617	1599	1596	1599
10	2376	1481	1330	1287	1272	1270	1272
12	1972	1229	1104	1067	1056	1054	1056
14	1684	1050	943	912	902	900	902

It is not desirable that in all sites the number of trees begins to increase at 70 years of age.

36. Volume equation from random data

The least square calculation from random data will be shown in the following table :

	1	log*B*	log*H*	log*N*	log*V*	*ck*	*SS*
1	58	146.9087	45.2665	186.5111	162.4044	599.0907	454.7446
log*B*		379.6767	119.3750	471.2948	423.3250	1540.5802	471.9925
log*H*			39.1057	144.0100	134.8589	482.6161	465.0701
log*N*				602.5733	520.0375	1924.4267	448.7998
log*V*					474.2797	1714.9055	
2.53290862		7.5704	4.7191	−1.1208	11.9695	23.1382	18.9249
0.780456896			3.7771	−1.5539	8.1093	15.0516	17.4104
3.21570862				2.8079	−2.2077	−2.0745	1.7358
2.80007586					19.5351	37.4062	
0.623362041			0.8354	−0.8552	0.6480	0.6281	0.5026
−0.148050301				2·6420	−0.4356	1.3512	0.0718
1.58109214					0.6102	0.8226	
−1.023701220				1.7665	0.2278	1.9943	0.0294
0.775676322					0.1076	0.3354	
0.1289555618					0.0782	0.0783	

Analysis of variance will be shown in the following table :

Source	*SS*	*DF*	*MS*	*F*
1	454.7446	1		**
log*B*	18.9249	1		**
log*H*	0.5026	1		**
iog*N*	0.0294	1		**
Error	0.0782	54	0.0014	
Total	474.2797	58		

All effects are highly significant, so there is no need to change terms. Then the resulting equation is

$$\log V = -0.9430 + 1.0344 \log B + 0.9077 \log H + 0.1290 \log N$$

37. Yield table from random data

Yield table from random data is shown in the following table : In this case the stocking percentage is also 100, which we can not understand, but is something like average.

Table 26. Random stocked yield table

Age	Ave. Ht.		Basal area		Number of trees	Ave. D.b.h		Volume per ha	
	Ken	meter	sq. Shaku	sq. meter		Sun	cm	Koku	cubic meter
	Site 6 (11)								
10	2.00	3.64	210	19.24	4009	2.5	7.6	157.11	43.71
20	4.16	7.56	369	33.87	2498	4.3	13.0	515.95	143.54
30	5.31	9.65	495	45.40	2239	5.3	16.1	859.32	239.04
40	6.00	10.91	595	54.64	2170	5.9	17.9	1158.00	322.16
50	6.46	11.74	678	62.28	2146	6.4	19.4	1414.5	393.51
60	6.78	12.33	747	68.61	2142	6.7	20.3	1633.4	454.41
70	7.02	12.76	807	74.09	2146	6.9	20.9	1827.7	508.47
	Site 8 (15)								
10	2.67	4.85	210	19.24	2986	3.0	9.1	196.39	54.64
20	5.55	10.09	369	33.87	1861	5.0	15.2	644.77	179.38
30	7.08	12.87	495	45.40	1671	6.1	18.5	1074.0	298.79
40	8.00	14.54	595	54.64	1617	6.9	20 9	1447.2	402.61
50	8.61	15.65	678	62.28	1599	7.4	22.4	1768.1	491.89
60	9.03	16.42	747	68.61	1596	7.7	23.3	2041.8	568.03
70	9.36	17.02	807	74.09	1599	8.0	24.2	2284.6	635.58

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	Site 10 (18)								
10	3.33	6.05	210	19.24	2376	3.4	10.3	233.52	64.97
20	6.93	12.60	369	33.87	1481	5.6	17.0	766.66	213.28
30	8.86	16.11	495	45.40	1330	6.9	20.9	1277.1	355.29
40	10.00	18.18	595	54.64	1287	7.7	23.3	1720.7	478.70
50	10.76	19.56	678	62.28	1272	8.2	24.8	2102.3	584.86
60	11.30	20.54	747	68.61	1270	8.7	26.4	2427.2	675.25
70	11.70	21.27	807	74.09	1272	9.0	27.3	2715.9	755.56
	Site 12 (22)								
10	4.00	7.27	210	19.24	1972	3.7	11.2	268.91	74.81
20	8.32	15.13	369	33.87	1229	6.2	18.8	883.08	245.67
30	10.63	19.33	395	45.40	1104	7.6	23.0	1471.0	409.23
40	12.00	21.82	595	54.64	1067	8.4	25.5	1982.4	551.50
50	12.91	23.47	678	62.28	1056	9.0	27.3	2421.6	673.67
60	13.50	24.54	747	68.61	1054	9.5	28.8	2795.7	777.76
70	14.05	25.54	807	74.09	1056	9.9	30.0	3128.3	870.29
	Site 14 (25)								
10	4.67	8.49	210	19.24	1684	4.0	12.1	303.11	84.33
20	9.71	17.65	369	33.87	1050	6.7	20.3	995.18	276.86
30	12.40	22.54	395	45.40	943	8.2	24.8	1657.7	461.17
40	14.00	25.45	595	54.64	912	9.1	27.6	2233.6	621.39
50	15.06	27.38	678	62.28	902	9.8	29.7	2666.9	741.93
60	15.81	28.74	747	68.61	900	10.3	31.2	3149.9	876.30
70	16.38	29.78	807	74.09	902	10.7	32.4	3525.4	980.77

Chapter 6 Difference in stocking percentage between well-stocked stand and average stand

38. General regression for well and average-stocked stands

We have three stocking equations here:

for well-stocked stand: $S=B\{0.0939+0.0045H+4.2203(1/A)-0.4371(H/A)\}$

for ave.-stocked stand: $S=B\{0.1454+0.0036H+4.4809(1/A)-0.4779(H/A)\}$

for random : $S=B\{0.0650+4.1208(1/A)\}$

Except in random case, is there some difference between well-stocked and average-stocked stand? General regression for well and average-stocked stand will be shown in the following table:

	B_w+B_a	BH_w+BH_a	$\frac{B}{A_w}+\frac{B}{A_a}$	$\frac{BH}{A_w}+\frac{BH}{A_a}$	s	ck
B	39582207	34147851	11751161	9184106	6801900	101467225
BH		32715307	9196147	8091920	5493500	89644725
B/A			4071238	2837959	2191600	30048105
BH/A				2248474	1578600	23941059
s					1280000	17345600
0.862707099		3255714	−941663	168727	−374547	2108230
0.296879883			582550	111383	172253	−75473
0.2320261222				117521	382	398012
0.1718423634					111145	−90768
−0.2892339437			310189	160185	63921	534299
0.0518248838				108777	19793	288753
−0.1150429675					68056	151769
0.516410962				26056	−13217	12835
0.2060711372					54884	41665
−0.507253607					48180	48176

Analysis of variance will be shown in the following:

Source	SS	DF	MS	F
B	1168855	1		**
BH	43089	1		**
B/A	13172	1		**
BH/A	6704	1		**
Error	48180	124	388.55	
Total	1280000	128		

All effects are highly significant. Difference between regressions is shown in the following analysis of variance:

Source	*SS*	*DF*	*MS*	*F*
Diff. between Reg.	16232	4	4058.00	15.24**
Indp. of Indiv. Reg.	31948	120	266.23	
Indep. of General Reg.	48180	124		

Difference between regressions is highly significant. This difference will be shown in the following section.

39. Combined equation and the difference between two stocked stands

The least square is shown in the following pattern:

	$B_w + B_a$	$BH_w + BH_a$	$B/A_w + B/A_a$	$BH/A_w + BH/A_a$	$B_w - B_a$	$BH_w - BH_a$	$B/A_w - B/A_a$	$BH/A_w - BH/A_a$	s	ck
B_w+B_a	39582207	34147851	11751161	9184106	11830983	11888767	3054411	2895532	6801900	131136918
BH_w+BH_a		32715307	9196147	8091920	11888767	13514691	2904713	3106138	5493500	121059034
$B/A_w+B/A_a$			4071238	2837959	3054411	2904713	807714	747151	2191600	37562094
$BH/A_w+BH/A_a$				2248474	2895532	3106138	747151	753336	1578600	31443216
B_w-B_a					39582207	34147851	11751161	9184106	1070300	125405318
BH_w-BH_a						32715307	9196147	8091920	1126300	116691834
$B/A_w-B/A_a$							4071238	2837959	236400	35606894
$BH/A_w-BH/A_a$								2248474	261600	30126216
s									1280000	20040200
0.862707099		3255714	-941663	168727	1682094	3258167	269651	608142	−374547	7926284
0.296879883			582555	111383	−457970	−624823	−99079	−112474	172253	−1369819
0.2320261222				117521	150435	347633	38448	81497	382	1016025
0.298896496					36045968	30594340	10838208	8318642	−962764	86208953
0.300356344						29144440	8278735	7222229	−916694	77304029
0.0771662631							3835541	2614522	−288477	25487548
0.0731523636								2036659	−235975	20533240
0.1718423634									111145	−2494678
−0.2892339437			310189	160185	28549	317549	−21087	63421	63921	922731
0.0518248838				108777	63261	178779	24473	49980	19793	605246
0.516659018					35176899	28910979	10698890	8004440	−769251	82113767
1.000753444						25883818	8008881	6613629	−541865	69371773
0.0828239212							3813207	2564153	−257456	24831062
0.1867922059								1923063	−166013	19052672
−0.1150429675									68056	−1582815
0.516410962				26056	48518	14793	35363	17229	− 13217	128738
0.0920374352					35174271	28881753	10700831	7998603	−775134	82028841
1.023727469						25558734	8030468	6548703	−607303	68427148
−0.0679811340							3811773	2568464	−253111	24893790
0.2044592168								1910096	−179082	18864011
0.2060711372									54884	−1772963
1.862066318					35083927	28854207	10634983	7966521	−750523	81789122
0.567738716						25550335	8010391	6538921	−599799	68354058
1.357192201							3763779	2545081	−235173	24719068
0.661229659								1898704	−170343	18778886
−0.507253607									48180	−1707660
0.822433788						1819660	−736178	−13015	17456	1087921
0.303129777							539999	130191	− 7667	− 73650
0.2270703903								89743	79	206998
−0.02139221758									32125	41991
−0.4045689854							242164	124926	− 605	366489
−0.00715243507								89650	204	214779
0.00959300089									31958	31555
0.515873540								25204	516	25717
0.002498306932									31960	32471
									31949	31944

Analysis of variance will be shown in the following:

Source	SS	DF	MS	F
B_w+B_a	1168855	1		**
BH_w+BH_a	43089	1		**
$B/A_w+B/A_a$	13172	1		**
$BH/A_w+BH/A_a$	6704	1		**
B_w-B_a	16055	1		**
BH_w-BH_a	167	1		non sig.
$B/A_w-B/A_a$	2	1		non sig.
$BH/A_w-BH/A_a$	11	1		non sig.
Error	31945	120	266	
Total	1280000	128		

Three terms, (BH_w-BH_a), $(B/A_w-B/A_a)$, and $(BH/A_w-BH/A_a)$ are non significant.
Then combined equation is

$$S=0.1099(B_w+B_a)+0.0502(BH_w+BH_a)+0.4494(B/A_w+B/A_a)$$
$$-0.4674(BH/A_w+BH/A_a)-0.0214(B_w-B_a)$$

Consequently we have the following equations:
for well-stocked

$$S_w=0.0885B+0.0502BH+0.4494B/A-0.4674BH/A$$

for average-stocked

$$S_a=0.1313B+0.0502BH+0.4494B/A-0.4674BH/A$$

40. Covariance analysis of three height curves

Three height curves, well-stocked stand, average-stocked stand and random stocked stand, may not differ significantly, as shown in the following covariance analysis:

Covariance analysis of height curve

Source	DF	$V(A)$	$Cov(AH)$	$V(H)$	b	DF	$Res.$	MS
Well	63	0.0122	−0.1006	1.6013	−8.2459	62	0.7718	0.0124
Average	63	0.0262	−0.1890	2.6171	−7.2137	62	1.2537	0.0202
Random	57	0.0640	−0.4073	3.7771	−6.3641	56	1.1850	0.0217
Within						180	3.2105	0.0178
Reg. coef.						2	0.0121	0.0061
Common	183	0.1024	−0.6969	7.9955	−6.8057	182	3.2526	0.0179
Adj. mean						2	0.0330	0.0167
Total	185	0.1069	−0.7275	8.2365	−6.8054	184	3.2856	0.0179

For reg. coeff. $F=\frac{0.0061}{0.0178}=0.34$, and for adj. mean; $F=\frac{0.0167}{0.0179}=0.95$ non sig. There are non significant differences between the three height curves. The relationship between height and age may be kept independent from the density of stand. It might be said that we shall be able to take the average height as site index. If we take a general equation, it must be:

$$\log H=1.0814-6.8054(1/A).$$

41. The difference between well-stocked stand and average-stocked stand

Stocking equations S_w and S_a in section 39 are entirely the same equation except in coefficents of B terms, because H's are same in general height curve in section 40. Then $S_a-S_w=0.1313B-0.0885B=0.0428B$. In this case for the same basal area the stocking percentage based on average standard is always higher $0.0428B$ than the stocking percentage based on well stocked standard. In other words the average standard is always under a well-stocked standard. If both stocking percentages are 100, or $S_a=S_w=100$, $0.1313B_a=0.0885B_w$, then

$$\frac{B_a}{B_w}=\frac{0.0885}{0.1313}=0.674.$$

This means that basal area in average standard is about 30 percent less than that in well stocked standard. In any case the stocking percentage is relative. Strictly speaking, in this article the well-stocked stand would not necessarily be a normal stand. Stocking percentage 100 in well-stocked stand may represent average in well stocked stand. In the same way, stocking percentage 100 in average stocked stand represents average-stocked stand.

Chapter 7 Conclusion

42. Stocking percentage examination for normal yield table

For the well-stocked stocking percentage equation,

$$S=B[0.0939+0.0045H+4.2203(1/A)-0.4371(H/A)],$$

the following normal yield table was examined, which was made for Sugi (Cryptomeria) in the northern half of Kyushu, by Mr. Takaya Tokumoto in 1914. Stocking percentage will be shown in the following table.

Table 27. Stocking percentage of normal yield table

Age	Height (Ken)	D.b.h (Sun)	Number of trees	Basal area (sq. Shaku)	Stocking percentage
Site I					
20	7.6	5.4	2681	613.95	106.21
30	10.4	7.2	2110	858.77	111.38
40	12.4	8.9	1630	1013.86	121.36
50	13.9	10.2	1310	1070.27	127.79
60	15.0	11.5	1060	1101.34	135.02
70	16.0	12.6	879	1096.11	138.55
Site II					
20	5.5	4.0	3485	439.11	91.99
30	8.4	5.5	2711	645.22	96.65
40	10.3	6.9	2090	781.66	104.12
50	11.7	8.1	1670	860.05	110.69
60	13.0	9.3	1350	916.65	117.51
70	14.0	10.4	1129	958.52	124.51
Site III					
20	3.7	2.9	4420	291.06	70.06
30	5.8	4.1	3501	462.13	81.34
40	7.6	5.2	2852	604.62	91.06
50	9.2	6.1	2290	668.68	93.15
60	10.4	7.0	1866	718.41	97.34
70	11.3	7.9	1585	776.65	104.61

In the above table the stocking percentage is not constant 100.00. If this yield table is normal yield table, stocking percentage should be always 100. Site I gives slightly higher stocking percentage and site III gives slightly lower stocking percentage. Through all sites stocking percentage is increasing according to age development. They must be almost the same percentage, near 100. Recently many yield tables have been published and they should be tested or examined for some reasonable stocking percentage equation.

43. Relationship between the effect of site, age and density for volume

Main effects of age, site and density for volume and also interaction of these effects for volume may be tested with the method applied by factorial design. Factorial design $2[4\times3\times3]$ was applied. Four levels of age, 15, 25, 35 and 45, three levels of density 1, 3, 5 and three levels of site 1, 3, 5, and 2 replications for each combination of levels are taken in the following pattern :

Table 28. Factorial design of Sugi stands

Age	Density level	Site level	Volume (Koku) Repl. 1	Repl. 2	Total
15	1	1	525	734	1259
		3	706	355	1061
		5	299	518	817
	3	1	670	356	1026
		3	521	331	852
		5	414	423	837
	5	1	450	407	857
		3	91	223	314
		5	211	375	586
25	1	1	1375	857	2232
		3	1259	1205	2464
		5	1321	1442	2763
	3	1	596	927	1523
		3	937	888	1825
		5	881	536	1417
	5	1	614	535	1149
		3	342	491	833
		5	542	593	1135
35	1	1	1227	1654	2881
		3	1274	1846	3120
		5	1416	1228	2644
	3	1	1523	1109	2732
		3	980	1124	2104
		5	1223	1270	2493
	5	1	1438	945	2383
		3	875	880	1755
		5	1125	729	1854
45	1	1	3134	1983	5117
		3	1494	1743	3237
		5	1301	2125	3426
	3	1	1700	2620	4320
		3	1647	1361	3008
		5	1349	1173	2522
		1	916	1101	2017
		3	1211	699	1910
	5	5	843	991	1834
Total			36530	35777	72307

Analysis of variance will be shown in the following table

Source	*DF*	*SS*	*MS*	*F*
Replication	1	15105.9	15105.9	0.1927
D(Density)	2	4335768.1	2167884.1	27.6486**
S(Site)	2	720311.3	360155.7	4.5933**
A(Age)	3	12163313.1	4054437.7	51.7091**
$D\times S$	4	67247.7	16811.9	0.2144
$D\times A$	6	1167441.3	194573.6	2.4815*
$S\times A$	6	860536.7	143422.8	1.8292
$D\times S\times A$	12	849458.3	70788.2	0.9028
Error	35	2744299.6	78408.5	
Total	71	22923482		

This table may indicate that three main effects density, age and site all are significant for volume variation but interactions are not significant, except $D\times A$ interaction. It is noticeable that site effect is significant at 5% level and all interactions with site are not significant. Site is an important factor but age and density are more important factors for estimation of stand volume. Site is always independent.

44. Understocked stand estimation

Basal area development was shown in table 8, section 18, chapter 3. It is based upon the normal approach assumption, section 11, chapter 2. The number of trees equation was shown in section 19. Decreasing percentage of trees will be calculated according to table 9 (the number of trees per ha).

Table 29. Decreasing percentage of number of trees

Age					
20	30	40	50	60	70
100.00	72.2	61.4	55.7	52.2	49.8

The volume per tree equation will be shown as the following:

$$\log\left[100\frac{V}{N}\right]=-0.4223+2.0696\log D+0.7002\log H \qquad MS=0.0044$$

Fig. 13. Average volume per tree of well stocked stands

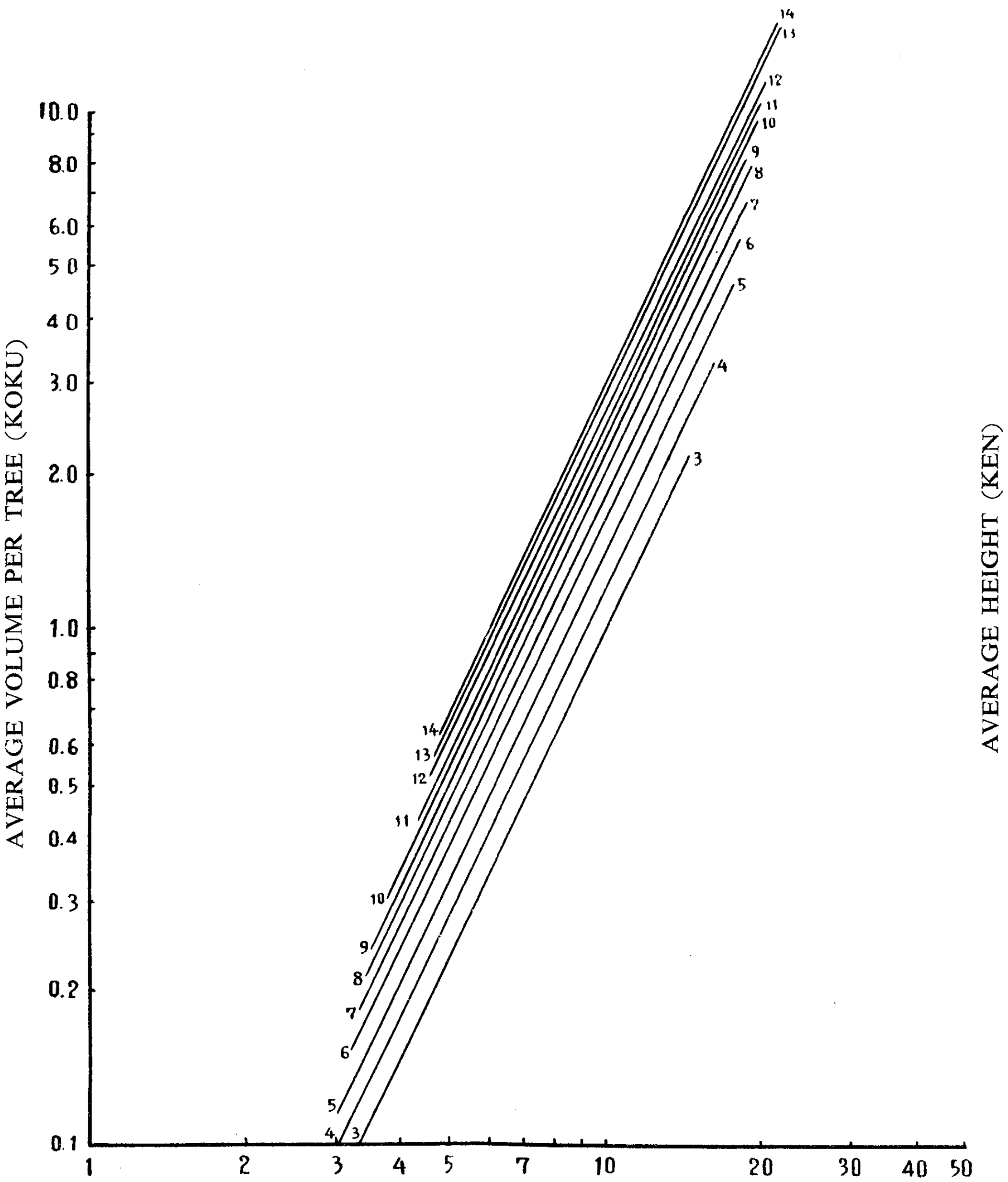

Figure 12 shows average volume in koku per tree in even-aged stands in terms of average stand d. b. h. and average height of stand.

If a 20-year stand is characterized by average height, basal area per ha, trees per ha, and average stand d. b. h., as given in the column headed " Present " in the tabulation below, as obtained from field measurements; then the corresponding variables, under the column headed " Predicted " are derived:

Table 30. Understocked stand prediction

Variable	Present	Predicted
Age in years	20	40
Average height of stand	6.2	10.0
Basal area per ha	400	657
Trees per ha	2000	1228
Average stand d. b. h.	5	8
Volume per tree	0.37	1.40
Volume per ha	740	1719

Overstocked stand which may show more than 100 stocking percentage should be thinned at appropriate times. Overstocked stand estimation also may be done in the above case.

Table 31. Volume per tree of well-stocked stands (Koku)

D.B.H.	Height (Ken)											
(Sun)	3	4	5	6	7	8	9	10	11	12	13	14
2	0.03425	0.04189										
3	0.07928	0.09698	0.1133									
4	0.1438	0.1759	0.2056	0.2337								
5	0.2282	0.2793	0.3264	0.3709	0.4132							
6		0.4072	0.4761	0.5410	0.6026	0.6617	0.7184	0.7735	0.8269			
7				0.7440	0.8287	0.9101	0.9881	1.0639	1.1374			
8				0.9810	1.0927	1.2001	1.3029	1.4030	1.5000	1.5941		
9					1.3938	1.5308	1.6619	1.7894	1.9130	2.0333	2.1504	2.2646
10						1.9042	2.0673	2.2259	2.3798	2.5293	2.6749	2.8171
11								2.7115	2.8987	3.0811	3.2590	3.4317
12									3.4706	3.6890	3.9013	4.1087
13										4.3522	4.6030	4.8474

45. Well-stocked stand yield table

Well-stocked stand yield table data should come from the group of the stand which is judged well-stocked stand. In this case data are not necessarily well-stocked stand, but stand which has many trees when comparing with other stands. Strictly speaking they are not normal stands. Some of them are normal and some are not normal. Consequently derived equations are not perfectly succeseful. However, from the point of view of statistical study for yield table construction, many conclusions may be obtained. And the resulting well-stocked stand yield table may be reasonable.

In summary, equations and errors may be shown as follows:

(1) Height equation

$$\log H = 1.1396 - 8.2459(1/A) \qquad \mathrm{MS} = 0.0124$$

(2) Stocking equation

$$S = B\{0.0939 + 0.0045(H) + 4.2203(1/A) - 0.4371(H/A)\} \quad \mathrm{MS} = 183$$

(3) Tree equation

$$\log N = 3.7967 - 0.6947 \log H + 2.7458(1/A) \qquad \mathrm{MS} = 0.0107$$

(4) Volume equation

$$\log V = 1.5103 \log B - 0.3290 \log N \qquad \mathrm{MS} = 0.0020$$

Height and stocking equations may be good, but the number of tree and volume eqnatlons are not satisfactory. In the number of tree equation term B was dropped and in the volume equation term H was dropped, because they are not significant as effects in these cases. The reason may be that data were selected forcibly by graphic method from large numbers of trees. This process may be out-dated. Consequently, the resulting well-stocked stand yield table (Table 10) is not succeseful in the column of volume. I question the fact that in this well-stocked stand yield table maximum volume points appeared in the ages 50 years and 40 years, site 12 and site 14 respectively. It is understandable that in this yield table stocking percentages are keeping always 100 in each age and each site. If one stand was treated and kept always in the 100 percentage stocking condition by means of thinning and the other appropriate managements, a better site stand should reache to maximum volume point faster than the other stands. However, the appearing of maximum point is not unusual in Japanese Cryptomeria yield table. This point may be improved by using the volume per tree equation in section 44. Using this equation, average diameter, average height and number of trees are available. Finally a well-stocked stand yield table will be obtained shown in following: (Table 32)

Table 32. Well-stocked stand yield table

Age years	Average height		Basal area per ha		Number of trees per ha	Average diameter		Volume per ha	
	Ken	m	sq. Shaku	sq. m		Sun	cm	Koku	cubic m
	Site 6 (11)								
20	3.73	6.78	416	38.19	3440	3.9	11.8	546.96	152.16
30	5.13	9.33	547	55.68	2484	5.3	16.1	931.25	259.07
40	6.00	10.91	622	57.10	2113	6.1	18.5	1196.17	332.77
50	6.60	12.00	665	74.35	1916	6.6	20.0	1348.67	375.20
60	7.02	12.76	691	63.43	1797	7.0	21.2	1492.23	415.14
70	7.35	13.36	706	64.81	1714	7.2	21.8	1558.20	433.49
	Site 8 (15)								
20	4.98	9.05	458	42.04	2817	4.6	13.9	771.58	214.88
30	6.83	12.42	604	55.45	2033	6.2	18.8	1288.31	358.41
40	8.00	14.54	676	68.82	1730	7.1	21.5	1334.35	371.22
50	8.80	16.00	709	72.18	1569	7.6	23.0	1809.06	503.28
60	9.37	17.03	724	73.70	1417	7.9	23.9	1850.60	514.84
70	9.80	17.82	729	74.21	1404	8.1	24.5	1992.28	554.25
	Site 10 (18)								
20	6.22	11.31	508	51.71	2413	5.2	15.8	995.12	276.84
30	8.54	15.53	673	61.78	1742	7.1	21.5	1709.42	475.56
40	10.00	18.18	740	67.93	1482	8.0	24.2	2079.25	578.45
50	11.00	20.00	760	69.77	1344	8.5	25.8	2284.80	635.63
60	11.66	21.20	759	69.68	1260	8.8	26.7	2396.52	666.71
70	12.25	22.27	753	69.13	1202	8.9	27.0	2464.10	685.51
	Site 12 (22)								
20	7.46	13.56	570	52.33	2126	5.9	17.9	1293.88	359.96
30	10.25	18.63	762	69.95	1534	8.0	24.2	2189.02	608.99
40	12.00	21.82	818	75.09	1305	8.9	27.0	2593.04	721.38
50	13.20	24.00	818	75.09	1219	9.2	27.9	2773.23	771.51
60	14.03	25.51	799	73.35	1110	9.6	29.1	2879.34	801.03
70	14 70	26.72	778	71.42	1050	9.7	29.4	2873.85	799.51
	Site 14 (25)								
20	8.71	15.83	651	59.76	1910	6.6	20.0	1632.86	454.26
30	11.96	21.74	877	80.51	1379	9.0	27.3	2796.61	778.02
40	14.00	25.45	914	83.91	1173	10.0	30.3	3304.34	919.27
50	15.40	28.00	885	81.24	1064	10.3	31.2	3351.60	932.42
60	16.39	29.79	843	77.39	998	10.4	31.5	3405.18	947.32
70	17.15	31.18	805	73.90	952	10.4	31.5	3353.04	932.82

Site in ken (in meters) at age of 40 years.

46. Average-stocked stand yield table

In this case average-stocked stand data came from the density level 3 only. Stocking percentage may be about 30 percent less than well stocked stand. The process that is fixed on the density level 3 only, takes off significant facts of height. Consequently this table always gives the same decreasing number of trees for all sites. This point should be improved. The maximum point of volume appears as well as the well stocked stand table.

In summary, the resulting equations and their errors are shown to be the following:

(1) Height equation

$$\log H = 1.0793 - 7.2137(1/A) \qquad MS = 0.0202$$

(2) Stocking equation

$$S = B[0.1454 + 0.0036H + 4.4809(1/A) - 0.4779(H/A)] \qquad MS = 350$$

(3) Tree equation

$$\log N = 2.9764 + 6.0916(1/A) \qquad MS = 0.0092$$

(4) Volume equation

$$\log V = 1.5401 \log B - 0.3458 \log N \qquad MS = 0.0037$$

Height and stocking equations may be good. Comparing with well stocked stand data they have larger errors. In the number of tree equation term B and H both were dropped because nonsignificant. Tree and volume equations are not perfect because they lack several terms which may be important factors. Consequently this average-stocked stand yield table is not satisfactory. In this case the volume per tree equation may be shown as follows:

(5) Volume per tree equation

$$\log [100V/N] = 2.2880 \log D \qquad MS = 0.0478$$

This equation is not precise comparing with equation (4).

47. Random stocked stand yield table

In this case the stocking equation process is not clear. If it means average stocking from whole data including from poor stocked stand to well-stocked stands, the resulting equation may be not efficent, because stocking variation of data will be very high. For this reason the mean square of error of the random stocking equation is higher than that of the other stocking equations. Moreover all factors of stocking equation were dropped except age term, because they were nonsignificant. It is a vital point.

In summary equations and errors are shown as follows:

(1) Height equation

$$\log H = 1.0699 - 6.3641(1/A) \qquad MS = 0.0217$$

(2) Stocking equation

$$S = B[0.0650 + 4.1208(1/A)] \qquad MS = 1352$$

(3) Tree equation

$$\log N = 2.7733 - 1.0237 \log H + 0.4901 \log B \qquad MS = 0.0321$$

(4) Volume equation

$$\log V = -0.9430 + 1.0237 \log B + 0.9077 \log H + 0.1290 \log N \quad MS = 0.0014$$

Height curve may be good and slightly lower than the two others, but there are no significant differences among these three curves. According to the above reason, stocking percentage is not perfect and not available.

The number of trees in equation is lacking in the term age, because nonsignificant. However the volume equation is perfect, because it includes all effects and the smallest error. It may be reasonable that in such case the volume equation will be useful, while the stocking equation from random data will be meaningless.

48. General conclusion

Through all cases, the final resulting well-stocked stand yield table (Table 32) may be successful but average and random stand yield tables may not be practical and some may be inaccurate. In even well stocked stand yield table, neither tree nor volume equations are perfect. It was improved fortunately by using volume per tree equation.

However in the average-stocked stand yield table there was not a precise equation of volume per tree. A numerical equivalent was found to correspond to the difference between well-stocked stand stocking and average-stocked stand stocking. Also old normal yield table was examined by means of the computation of stocking percentage. It may be quite reasonable that this old normal yield table has slightly higher stocking percentage comparing with well-stocked stand yield table stocking. In summary the resulting equation perfectness and mean square of errors in each case will be shown as follows:

Table 33. Perfectness of equation and mean square of errors

Equation	Well-stocked stand	Average-stocked stand	Random-stocked stand
Height	Perfect, 0.0124	Perfect, 0.0202	Perfect, 0.0217
Stocking	Perfect, 183	Perfect, 350	Imperfect, 1352
Tree	Imperfect, 0.0107	Imperfect, 0.0092	Imperfect, 0.0321
Volume	Imperfect, 0.0020	Imperfect, 0.0037	Perfect, 0.0014

Consequently none of them may be said completely perfect yield tables, however their treatment will give some contribution and suggestion for the construction of yield table study. If we take more than one hundred well or average stands carefully, then the family of more perfect growth equations (including stocking equation and volume equation) will be gained with the reasonable field plan and calculation analysis. And finally a more satisfactory yield table will be given.

49. Further development of yield study

In the future, the study and reseach of yield tables will be much concerned with experimental design and analysis of data. Some level in any term may be chosen and the reseach will be followed on this line in the frame of some factorial design. After this, several multiple regressions will be combined and analysis of variance and covariance should be made. Site representation must be backed into soil characteristics, for instance, the depth of A horizen and the moisture equivalent or imbibitional water value of B horizen. Variety, fertilization and other factors may be covered by appropriate design.

50 Reference books and notes

This study is mainly based upon the following reference books and notes.

(1) Bruce and Schumacher: Forest Mensuration, 1950
(2) Duerr and Gevorkiantz: Growth prediction and site determination in uneven-aged timber stands. Jour. Agr. Res., 56, 1958
(3) Schumacher and Coil: Yields of well-stocked stands of coastal plain Loblolly Pine and Growth prediction of even-aged Loblolly Pine stands. School of Forestry, Duke University, 1958
(4) Schumacher: Design of Forestry Experiments and Analysis of Data. No. 257, School of Forestry course, Duke University
(5) Snedecor: Statistical Methods, 1956
(6) Hayakawa: Yield tables of the main species of Japanese forests, 1939
(7) Kinashi: Predicton tables of Sugi stands in Fukuoka prefecture. 1956

—The End—