GROWTH AND YIELD OF *PINUS MERKUSII* IN INDONESIA [1] [2]

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Pinus merkusii is indigenous in North Sumatra but has been planted extensively over Sumatra and Java. From data, derived from a number of sample plots (which as a result of the war, were far from perfect, however), a yield table has been computed for even-aged, pure stands, for five site quality classes and for ages up to 35 years. For the average site quality and the usual plant spacing of 3 × 3 meters the average annual increment culminates at the age of 25 years with 22.4 cubic meters per hectare (320 cubic feet per acre) thickwood volume excluding bark. The annual production depends on the initial plant spacing, ranging from 26 m^3 pro year pro hectare at the age of 20 years for 2 × 2 meters spacing, to 19 m^3 at 25 years for 4 × 4 meters spacing.

Introduction

Pinus merkusii Jungh. & de Vr. is indigenous in the north of Sumatra and known by the vernacular name of *ujam* (pronounce: uyam) or *tusam*. Since the early twenties the species has been tried in plantation in Sumatra and Java, together with various other exotic pines as *P. khasya* Royle, *P. insularis* Endl. and *P. caribaea* Morelet, the latter most probably originating from Florida; as a rule the ujam showed a better stem form and a more vigorous growth. From 1931 onward the ujam pine has been planted extensively in various districts on the isles of Sumatra, Java, Bali and Celebes (Sulawesi). Many thousands of hectares of pine forest have been raised on deteriorated soils, for production forest as well as for soil protection, in pure plantations or mixed with broadleaved trees.

This publication deals with the results of investigations in the two main centra of Forest Service plantations.

The first centre, historically and in extension, is the Aek na Uli-forest, in the Toba Lake district, north Sumatra: altitude about 1100 meters, annual rainfall about 2500 mm, the number of "dry months" (with less than 60 mm) averaging about two and the number of wet months (over 100 mm) about 8½, climate type B according to Schmidt & Ferguson (1951). The ujam was planted on waste lands with high grasses, ferns, and shrubs, in mere plant holes, spaced 3 × 3 meters as a rule. The vigorous growth in the first years only made necessary a minimum of tending, but a strict fire protection program is obligatory. The direct aim of these plantation was the protection of an important stream basin.

The other centre of investigation is near Lembang, on the southern slopes of the Tangkuban Perahu Mountain, north of Bandung, West Java: altitude and climate about the same as in the Aek na Uli forest. The Lembang plantations were preceded by wattle (*Acacia decurrens* Willd.) with a short rotation and by mixed broadleaved forest plantations. They are less extended but better tended. Most research by the Forest Research Institute started in this centre.

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If enough pulpwood will be produced in any centre the Forest Service expects them to be the origin of a pulp industry. The Toba-lake district with a pine area of 5000 hectares in 1952 and a potential area of 30.000 hectares at least, seems to be especially well situated for this purpose.

Investigations on growth and yield started immediately with the first plantations and eventually became more important as the number of permanent sample plots increased. The first provisional yield table (for one site quality only) was computed by BECKING in 1950. The results may be compared with medium site quality of the yield tables of this paper. Another yield table was constructed in 1941 by OOSTERLING (not published) from data collected in the pine-balsam district in Atjeh, North Sumatra, partly from second growth stands of natural origin and partly from wide spaced plantations; this table is not quite comparable to that from the timber stands of the Forest Service.

The results of 50 permanent sample plots are available for investigation. Many of them cannot be used for all stages of the yield research, however, for reasons which will be mentioned later.

In 1949 the first post-war remeasurement took place and many plots were thinned for the first time. In 1952, October and November, the plots were remeasured and thinned again. Now sufficient data should be available for a – may it be provisional – yield table. The ages of the permanent sample plots were by then:

1 plot aged 27 years
2 plots aged 23 years
5 plots aged 20 years
3 plots aged 16–17 years
11 plots aged 13–15 years
28 plots aged 10–11 years.

As the Forest Service provisionally fixed the rotation at 30 years it was desirable to extend the tables to the age of 35 years at least. So it is clear that quite an amount of extrapolation was necessary.

The author wishes to express his thanks to the Head of the Indonesia Forest Service who asked him to fulfill the task of constructing these yield tables, and to the staffs of the Forest Research Institute and the Division of Forest Planning for their kind cooperation.

AVAILABLE DATA

The computations are based on the following data:

1 50 permanent sample plots of the Forest Research Institute. They can be subdivided as follows:
   - a 32 plots in the Lembang district. The oldest plots date from 1932 (planted in 1931) and 1936 (planted in 1924). Ten plots were established in 1941 in plantations from 1935 until 1938; 17 plots were established in 1942, and 3 in 1949, both in plantations of 1941 with various plant spacings ("spacing trial");
   - b 4 plots in Eastern Java, established in 1951 in plantations from 1938 to 1941;
   - c 14 plots in the Aek na Uli Forest, all of them established in 1952 in plantations dating from 1928 until 1940, differently spaced, but usually 3 × 3 meters.

2 Data from line strip enumerations in the Lembang and Aek na Uli forests, carried out in 1948 and 1949 by the Planning Division of the Forest Service. The strips were 10 meters wide and the records were closed every 100 meters. The data of each complete hectometer of pure even-aged pine forest were transferred to a separate card; they proved to be a valuable supplement to the sample-plot records.

As a result of the war and political difficulties afterwards the forests have not been tended normally. In the plots thinnings were not or just casually performed during the years from 1940 until 1949 which is a rather long period for young stands of fast growing pines. Even from 1949 until 1952 uncontrolled fellings occurred in all the plots in the Lembang district. As all trees are always numbered and recorded individually it was in most cases possible to compute the volume of the lost trees and to allow for their increment.
It should be mentioned that the stands are never pruned.

Site quality table

The first job was to draft a site quality table. It is generally accepted that the growth in height of the dominating trees in a forest stand not too extremely dense or open is not influenced by the density of stocking and consequently depends only on soil and climate. Following the general practice in Indonesia, the "upperheight", i.e. the average height of the hundred highest trees per hectare equally scattered over the stand is used as an indicator of the site quality.

Table 1. Site quality classes for *Pinus merkusii.*

Age Years	Site class: 1	2	3	4	5	6	7
	Site index: 18	21	24	27	30	33	36
	Upperheight (meters)						
5	3.2	4.6	6.0	7.4	8.6	10.1	11.6
10	8.0	10.2	12.3	14.7	17.0	19.6	22.0
15	13.0	15.8	18.6	21.4	24.1	27.0	29.7
20	18.0	21.0	24.0	27.0	30.0	33.0	36.0
25	21.9	25.1	28.1	31.4	34.5	37.6	40.9
30	24.6	28.0	31.2	34.6	37.9	41.2	44.6
35	26.5	30.0	33.5	37.0	40.5	44.0	47.5

The upperheights of all the plots and from all the line-strip cards were entered graphically over the age of the stand. The dots of successive measurements of each plot were connected by straight lines. In this way it was possible to construct a series of curves, each of which represents the trend of growth in upperheight for a different site quality class.
This construction follows the principles of OSBORNE & SCHUMACHER: a general average regression curve for upperheight on age is drawn, after which the standard deviation of height is computed for each age class and smoothed over age, after which finally the curves for the various site quality classes can be drawn by taking their deviation from the general average curve in proportion to the smoothed standard deviation. This method, however, is apt to result in anomalities of the current increment for the extreme, especially for the

lowest site classes. Therefore the current increment curves were smoothed again and the initial site quality curves corrected correspondingly.

It may be asked how many site classes will have to be distinguished. It appears that stands, differing three meters in height at the age of maturity, are generally recognizable as being of different site class. In the U.S.A. it has become a general practice to draw the lines through multiples of ten feet at an age somewhat under the probable rotation and to use these heights as indices for the corresponding site quality. The same method was followed by WOLFF VON WÜLFING for Java-teak. For *Pinus merkusii* we fixed the index-age at 20 years and the interval between the classes at 3 meters. Consequently curves for the growth of upperheight had to be drawn to cross multiples of three meters at the age of 20 years. Each curve represents a quality class.

Internationally it is a custom to call the best class the first quality, but in Indonesia the best site quality is indicated by the highest number, and number one quality is the lowest. To avoid misunderstanding the quality classes will always be called by their indices as well.

The wide variation in upperheight made it necessary to distinguish seven site classes; average quality (IV) has index 27. The curves for the best and the worst site classes, VII and I resp. (indices 36 and 18) as shown in table 1, are somewhat speculative.

These site classes differ somewhat from those published by the author in 1950. However, the discrepancy wil not seriously affect the previous work of the Forest Planning Division.

NUMBER OF TREES IN MAIN STAND AND THINNINGS; SPACING

The number of trees of the main stand varies with the age and, moreover, depends on original plant spacing and on intensity (grade) of thinning. In Indonesia the latter is expressed numerically by the "S %", the relative space:

$$S = 100\ Sm/Oh$$

in which Oh is the upperheight of the stand and Sm is the main distance of the trees thought in triangular position. Sm is computed from the number of trees per hectare (N):

$$Sm = 107.5/\sqrt{N}$$

In young stands in which the upperheight is still low S has high values. When the trees grow up the value of S decreases. Later on, weak trees die from suppression by stronger neighbours. If the stand is never thinned this mortality will keep balance with further growth of the stand and then the relative space will have reached a minimum value. In a former publication (FERGUSON, 1950) the author thought this minimum to amount to 19 %, dead and dying trees not included. Later data have shown, however, that narrower stands of *Pinus merkusii* may occur.

Various plant spacings have been tried and recommended and opinions differ, too, on the best grade of thinning. The yield tables added to this article, are based on the most frequently used spacing of 3 × 3 meters which gives rise to stands of fairly good appearance; 4 × 4 meters spaced stands generally result in a bad crooking and branching of the trees and narrower planting may be less economic. As for the intensity of thinning the tables are based on the assumption that every time when the S of a stand decreases to the value of 20 %, a thinning is performed, resulting in an S of 25 %.

Subsidiary tables (nrs. 2, 5 and 6) contain correction factors for deviating plant spacings and grades of thinning.

Average diameter at breast height of main stand

The average diameter at breast height is computed in the plots as the diameter corresponding with the average basal area at 1.30 m above ground.

The average diameter of the *main* stand depends on the intensity of the thinnings for two reasons: in the first place the average diameter increases as the thinning takes place owing to the fact that as a rule the smaller trees are felled and the bigger trees remain; in the second place the diameter growth proper of a heavily thinned stand exceeds the growth of a lightly thinned stand.

As a rule permanent sample plots for yield research are thinned according to a certain principle or a fixed scheme. In such cases the smoothed diameter growth curves may be found in an entirely empirical way corresponding directly with the diameters of the plots. If different schemes of thinning are applied a yield table may be composed for each of them.

Contrary to this general rule, many of our plots were thinned rather arbitrarily and not according to a previously fixed scheme. Most of them have suffered somewhat from uncontrolled fellings, as explained on page (199). Various plots were thinned only once, in 1952. A selection resulted in 21 plots fit for the present stage of investigation, 16 of which were thinned twice, in 1948/49 and 1952 respectively, and the others only once, in 1952. This furnished 37 sets of data, all referring to more or less normally thinned stands. The grades of thinning varied, however, from 21.4 % to 27.5 %. From these data a multiple regression was determined of the average diameter of the main stand dependent on the upperheight and on the relative space (S%) after thinning. A graphical method was applied. The partial diameter-upperheight regression appeared to be linear as far as the data reached. It is to be expected that in older stands the increment of the upperheight will slow down earlier than the diameter growth, but in our data this did not yet find expression. For most timber species it is the diameter-age regression which tends to be linear; consequently the diameter-height regression would be convex. But for a *Pinus* species a linear relation between diameter and height is not abnormal: see for instance Wiedemann (1950). The partial regression of diameter on relative space after the last thinning appeared to be curvilinear.

In applying this method it was possible to draw up the yield tables for a theoretical thinning intensity. This intensity was fixed on exactly 25 % which does not deviate much from the empirical average.

Table 2. Correction of Diameter Main Stand for different grades of thinning.

Relative Space, S %, after thinning	21 %	22 %	23 %	24 %	25 %	26 %	27 %	28 %
Correction for diameter, in cm	−1.4	−1.2	−0.9	−0.5	0	+0.6	+1.7	+2.9

For various grades of thinning corrections may be derived from Table 2. The corrections for S-values surpassing 26 % appear to be not quite consistent with those for lower values; it seems sensible to use these with due reserve.

Form factors

In the yield tables added to this paper the volume is defined as *"Thickwood volume without bark"*, i.e. the volume excluding trunk and bark of all timber measuring at least 7 cm over bark.

The bark volume of *Pinus merkusii* appears to average somewhat more than 20% of the total volume over bark which is more than most timbers have. With its thick bark this pine is able to stand fires.

The form factor of a tree is the quotient of its volume and the product of height and basal area (basal area is the surface of the cross section of the stem at breast height, i.e. 1.30 meter above ground). If the total volume of a stand is divided by the product of average height and total basal area (the sum of the basal areas) the quotient may be called the *"stand-formfactor"*.

The general trend of form factors derived from thickwood volumes is to rise initially with rising tree height until a maximum is attained, after which it decreases slowly again with increasing tree height. This trend can be explained theoretically and is well known. So we had to find a curvilinear regression for stand-formfactors over upperheight, the latter being the base of the construction of the yield tables. However, our difficulty was that the sample plots, as far as their volumes had been measured ranged in upperheight between 15 and 29 meters, so that the tables would have to be extrapolated not only for smaller upperheights, but also for larger values (up to about 45 meters). Fortunately for once the higher values do not render much risk as the form factor becomes rather constant there. The lower values would give more trouble, but again the corresponding volumes are still small and will not affect much the total timber production. Comparison with some other pine species for which tables have been published and with the results of not yet published investigations on the tree form and volume of the ujam pine, resulted in the relation laid down in Table 3.

Table 3. Stand-Formfactors for Thickwood volume inside bark, as dependent on upperheight (Abbreviated).

Upperheight	6	7	8	10	15	20	30	40
Form factor	0.30	0.336	0.348	0.354	0.349	0.343	0.334	0.333

We prefer to use this, not quite empirical, regression instead of a lump average form factor of 0.34.

Total basal area and volume of main stand

The total basal area is a function of the number of trees and the average diameter of the stand. After both factors had been worked out (pages (200) and (201)) the total basal area in square meters for the main stand was computed.

The volume of the main stand is the product of total basal area, average height, and stand-formfactor. The average height was derived from a simple regression on upperheight after which a relation of main stand volume and upperheight readily could be computed. This relation, nearly linear, is shown in figure 1 (dotted line).

Both basal area and volume of main stand are given in the yield tables for a 25% relative space on the assumption that the stand had just been thinned. If a different scheme of thinning should have been used, for instance on a

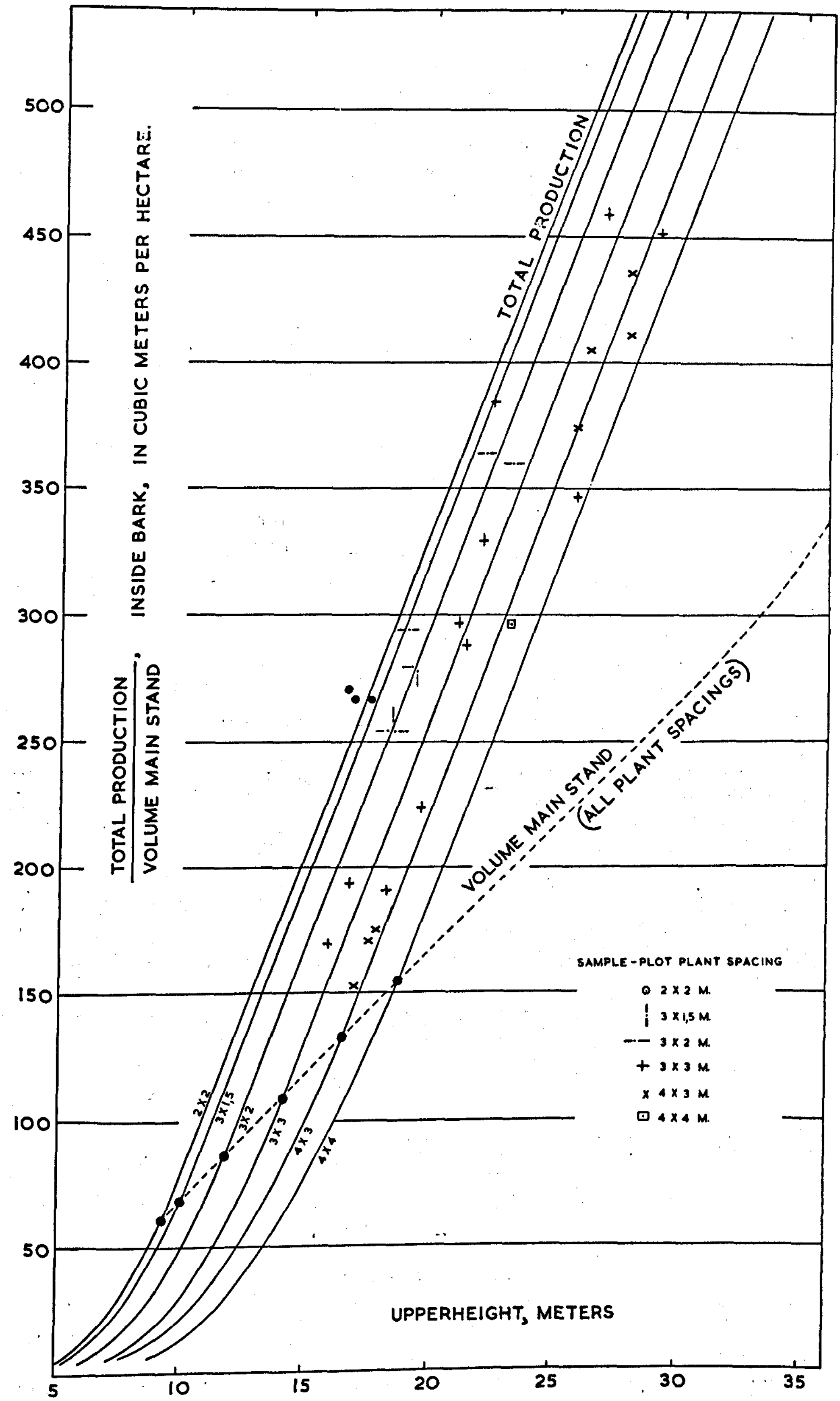

FIG. I. FOR EXTRAPOLATION: ADD 26 M.^{3} OF TOTAL PRODUCTION FOR EACH ADDITIONAL METER OF UPPERHEIGHT.

23 % base, the main stand will show other values for basal area and volume; these values may be derived from the number of trees corresponding with the other S %, applying the corrections for diameter as mentioned in Table 2.

In young stands not yet fully closed, the relative space still being over 25 %, the basal area and volume are smaller than indicated by the relations mentioned above. This will be worked out in the next section.

Total production

The total volume is the sum of the volume of the main stand and the volume of all previous thinnings. From investigations with different species in various countries it has become clear that in a pure, even-aged forest stand the total production expressed in terms of volume of solid wood is practically independent of the grade of thinning, provided that the thinnings were executed sufficiently frequently so as to prevent the canopy to be too seriously opened. This result is not unexpected. The production of wood is the result of assimilation and as long as the combined canopies and roots profit fully from light and soil this production is independent of the number of trees.

Another feature of the total production is that it is generally found to correlate linearly with the height of the stand. In overmature stands where height growth has ceased but volume still increases by further diameter growth this relation is not continued, but in a regulated forest the crop should be felled long before that stage is reached.

In order to compute the total production of the permanent sample plots it was necessary to estimate and account for the volumes of the uncontrolled thinnings and the disappeared trees. Plots in which these fellings amounted to more than a 100 trees per hectare had to be discarded. On the other hand some plots not suitable for investigations on the main stand owing to inconsistent thinnings could be used now.

It soon became clear that the total production depends on the initial plant spacing too. Some plots in which the remaining number of trees deviated too much from the original number, had to be discarded again. A fair criterion for a normal plantation appears to be the presence of 85 % of the plants corresponding with the due plant spacing.

The number of plots available for this step may be read from table 4.

Table 4. Number of plots used for research of total production.

Plant spacing (m)	2 × 2	3 × 1½	3 × 2	3 × 3	4 × 3	4 × 4
	Number of permanent plots used					
LEMBANG district	1	2	5	4	7	(1)
AEK NA ULI forest	2	0	0	7	0	0
Total	3	2	5	11	7	(1)

The 4 × 4 plot was discarded because it was not comparable with the other stands: trees are crooked and branched and the stand does not possess a satisfactory appearance. Consequently 28 plots remain for a regression study with upperheight and plant spacing as independent variables and total production as the dependent factor. This number would probably have been quite unsufficient had the regression been curvilinear; but as mentioned before, from general experience a linear regression may be expected to be quite adequate.

There is, however, one more important consideration. In a young stand which has never been thinned the total production is identical with the volume present. As the plantation grows up this holds true until the moment when the relative space has diminished below 25%. From that moment there is a latent thinning present in the stand, as it was stated before that the volume of the main stand was defined as the volume of the stand just thinned on a 25% relative space base. For different plant spacings the 25% relative space is reached at different upperheights; this has been computed in table 5 showing respectively:

a the plant spacing in meters,
b the corresponding theoretical number of trees,
c the actual number of trees, i.e. 85% of the theoretical number,
d the mean distance of the trees for the latter number per hectare ($Sm = 1.075 : \sqrt{N}$),
e the value of the upperheight (Oh) that corresponds with a relative spacing of 25% ($Oh = 100Sm : 25$), and finally,
f the volume at that moment.

Table 5. Various data for different plant spacings.

a Plant spacing	2 × 2	3 × 1½	3 × 2	3 × 3	4 × 3	4 × 4
b Theoretical N	2500	2222	1667	1111	833	625
c Actual N	2125	1888	1420	945	708	531
d Distance, Sm	2.33	2.47	2.85	3.50	4.04	4.66
e Oh for S = 25%	9.3	9.9	11.4	14.0	16.2	18.6
f Volume, m^3	61	67	82	108	130	154

The volumes from line (f) have been derived from the relation between volume of main stand and upperheight, as mentioned on page (203). As stated before, this relation was based on the assumption that the stand exactly has been thinned on a 25% relative space. Of course, in younger stands the number of trees is the same as indicated in line (c) of Table 5. The upperheight, however, is less than indicated in line (e) and consequently the S exceeds the 25% value. The volume at this younger stage may be computed by reducing the volumes from the upperheight-volume regression by the ratio of the initial number of trees (from line c) and the number of trees which would correspond with the relative space of 25% of the given upperheight.

Consequently, from the moment that a 25% relative space has been attained the regression lines for total production and main-stand-volume diverge; until that moment they are identical. The values of the upperheight and the volume at these moments are mentioned in lines (e) and (f) of Table 5. These values (one for each of the six plant spacings) are represented in the graph by firm dots, and have been used as starting points for the straight lines of Total Production. In this graph are plotted the total productions of the 29 sample plots mentioned in Table 4 on the corresponding upperheight values; the planting distances are indicated by different signs. The lower curved parts of the lines give the volumes for the not yet closed stands (relative space still over 25%) for six different plant spacings. The dotted line represents the volume of the main stand with a 25% relative space, one line for all spacings. Finally six steep straight lines represent the regression of Total Production on Upperheight, one line for each of the plant spacings. The line for 4 × 4 spacing has been added for completeness' sake but it is not reliable, as stated before. The general direction of the lines for Total Production have been derived mainly from the 4 × 3 and 3 × 3 spacings. The intervals between the lines are based on the theoretical "starting points" on the main-standvolume curves. Further empirical analyses made it clear that if computed without taking notice of the "startings points" the intervals between the lines might undergo only minute alterations, in the order of 5 cubic meters to the total production. This discrepancy appears to be insignificant.

The total production is a most important feature. The accuracy of this total production is expressed in terms of the Standard Error of Estimate, $s_{y.x}$; calculated from:

$$s_{y.x}^2 = \frac{\Sigma\,(y - y^*)^2}{(n - 3)}$$

in which y is the observed value of the total production, y^* is the estimated value, and n the number of observations. For 28 plots this standard error is 26.4 m^3. Of course, the extrapolated values are less reliable.

In the yield tables (table 7) the total production has been mentioned for 3 × 3 plant spacings. The corrections to be applied for other spacings as read from the graph are shown in Table 6.

Table 6. Corrections for Total Production for divergent plant spacings.

Plant spacing (m)	2 × 2	3 × 1½	3 × 2	3 × 3	4 × 3	4 × 4
Correction (m^3)	+75	+66	+42	0	−35	(−74)

Final composition of the yield tables; conclusions

From the data collected up till now it is possible to compose a traditional yield table. Table 7, added to this text, has been worked out for 5 site quality classes, with the indices 21, 24, 27, 30 and 33, and with intervals of 5 years, from 5 to 35 years. The upperheights were derived from the site quality table 1; the other data were read or computed from regressions on upperheight. The cumulative thinnings were computed as the difference of the total production and the volume of the main stand, whereas the volume of the thinning in the last 5-years period is the difference of two successive cumulative thinnings. The average annual increment was found by dividing the total production by the age.

In Table 8, finally, a compilation is given of the total production and the average annual increment for three plant spacings.

It is to be stressed again that all data for stands with upperheights surpassing 30 meter are the result of extrapolation and consequently have to be used with due reserve; for this reason these tables are still to be considered as being provisional. The main features, however, the total production and the average annual increment have been derived from a linear regression on upperheight which by general experience may be trusted to remain linear up to any economic rotation.

Table 7. Yield table for thickwood-volume inside bark.

Plant-spacing 3 × 3 meters. Thinnings on Relative Space of 25 %.

Age	Upper-height m	Main stand: Number of trees per ha	Main stand: Average diameter cm	Main stand: Average height m	Main stand: Total basal area m^2/ha	Main stand: Volume m^3/ha	Volume: Thinnings m^3/ha	Volume: Cumulative thinnings m^3/ha	Volume: Total production m^3/ha	Volume: Average annual increment m^3/ha
Site quality class 2 – Site index 21										
5	4.6	945	4.3	4.0	1.4	0	–	–	–	–
10	10.2	945	12.6	9.0	11.8	37	–	–	37	3.7
15	15.8	740	20.9	14.3	25.4	126	28	28	154	10.3
20	21.9	417	28.6	19.4	26.9	178	83	111	289	14.4
25	25.1	293	34.6	23.5	27.6	219	66	177	396	*15.8*
30	28.0	236	38.9	26.4	28.1	248	46	223	471	15.7
35	30.0	205	41.9	28.5	28.3	270	30	253	523	14.9
Site quality class 3 – Site index 24										
5	6.0	945	6.4	5.1	3.0	0	–	–	–	–
10	12.3	945	15.7	11.0	18.3	71	–	–	71	7.1
15	18.6	535	25.0	17.0	26.3	154	73	73	227	15.1
20	24.0	321	33.0	22.4	27.4	208	86	159	367	18.4
25	28.1	234	39.1	26.5	28.1	249	66	225	474	*18.9*
30	31.2	189	43.7	29.8	28.4	283	46	271	554	18.5
35	33.5	165	47.1	32.3	28.7	309	34	305	614	17.5
Site quality class 4 – Site index 27										
5	7.4	945	8.5	6.4	5.5	11	–	–	11	2.2
10	14.7	857	19.3	13.2	25.1	115	10	10	125	12.5
15	21.4	403	29.1	19.8	26.8	182	107	117	299	19.9
20	27.0	253	37.5	25.4	27.9	238	90	207	445	22.2
25	31.4	187	44.0	30.0	28.4	286	66	273	559	*22.4*
30	34.6	154	48.7	33.5	28.7	322	48	321	643	21.4
35	37.0	135	52.3	36.2	29.0	349	35	356	705	20.1
Site quality class 5 – Site index 30										
5	8.6	945	10.2	7.5	7.7	20	–	–	20	4.0
10	17.0	639	22.7	15.4	25.8	138	47	47	185	13.8
15	24.1	318	33.2	22.5	27.5	209	114	161	370	24.7
20	30.0	205	41.9	28.5	28.3	270	92	253	523	*26.2*
25	34.5	155	48.6	33.4	28.8	321	66	319	640	25.6
30	37.9	129	53.6	37.2	29.0	360	49	368	728	24.3
35	40.5	113	57.4	40.4	29.2	389	39	407	796	22.7
Site quality class 6 – Site index 33										
5	10.1	945	12.4	8.9	11.4	36	–	–	36	7.2
10	19.6	481	26.5	18.0	26.6	164	89	89	253	25.3
15	27.0	253	37.4	25.4	27.8	238	118	207	445	29.7
20	33.0	170	46.3	31.7	28.6	303	91	298	601	*30.0*
25	37.6	131	53.1	36.9	28.9	356	67	365	721	28.8
30	41.2	109	58.5	41.1	29.2	397	52	417	814	27.1
35	44.0	95	62.6	44.0	29.4	429	41	458	887	25.3

Table 8. Total Production (P) and Average Annual Increment (A.A.I.) for different plant spacings (m³ per ha).

Age	Site class: 2 / Site index: 21		Site class: 3 / Site index: 24		Site class: 4 / Site index: 27		Site class: 5 / Site index: 30		Site class: 6 / Site index: 33	
	P	A.A.I.	P	A.A.I.	P	A.A.I.	P	A.A.I.	P	A.A.I.
Plant spacing 2 × 2 meters										
10	80	8	136	14	200	20	260	26	328	33
15	229	15	302	20	374	25	445	30	510	*34*
20	364	18	442	*22*	520	*26*	598	*30*	676	34
25	471	*19*	549	22	634	25	715	29	796	32
30	546	18	629	21	718	24	803	27	889	30
35	598	17	689	20	780	22	871	25	962	28
Plant spacing 3 × 3 meters										
10	37	4	71	7	125	12	185	14	253	25
15	154	10	227	15	299	20	370	25	445	30
20	289	14	367	18	445	22	523	*26*	601	*30*
25	396	*16*	474	*19*	559	22	640	26	721	29
30	471	16	554	18	643	21	728	24	814	27
35	523	15	614	18	705	20	796	23	887	25
Plant spacing 4 × 4 meters										
10	21	2	40	4	72	7	114	11	179	18
15	90	6	154	10	225	15	296	20	371	25
20	215	11	293	15	371	18	449	22	527	*26*
25	322	13	400	*16*	485	*19*	566	23	647	26
30	397	*13*	480	*16*	569	19	654	22	740	25
35	449	13	540	15	631	18	722	21	813	23

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