STEM FORM AND VOLUME OF JAPANESE LARCH IN THE NETHERLANDS

J. VAN SOEST

STEM FORM AND VOLUME OF JAPANESE LARCH (*LARIX LEPTOLEPIS* GORD.) IN THE NETHERLANDS

SCHAFTFORM UND MASSE DER JAPANISCHEN LÄRCHE IN DEN NIEDERLANDEN

VORM EN INHOUD VAN DE JAPANSE LARIKS IN NEDERLAND

PROEFSCHRIFT

TER VERKRIJGING VAN DE GRAAD VAN
DOCTOR IN DE LANDBOUWKUNDE OP
GEZAG VAN DE RECTOR MAGNIFICUS
IR. W. DE JONG, HOOGLERAAR IN DE
VEETEELTWETENSCHAP, TE VERDEDIGEN
TEGEN DE BEDENKINGEN VAN EEN
COMMSSIE UIT DE SENAAT VAN DE
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TE 16 UUR

DOOR

J. VAN SOEST

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STELLINGEN

1. Voor het opstellen van inhoudstabellen verdient de vereffening van vormgetallen de voorkeur boven de vereffening van inhouden.

2. Bij de schatting van het vormgetal van een boom met behulp van sectiemetingen kan worden volstaan met het meten van één middellijn per sectie, mits daarbij in dezelfde richting wordt gemeten.

3. Verkoop van hout op stam is alleen verantwoord indien er naast een schatting van de inhoud bekend is, tot in welke mate er afwijkingen tussen schatting en werkelijkheid kunnen voorkomen.

4. Voor het groeionderzoek van bossen is de omtrekband doelmatiger dan de boomklem.

5. Internationale samenwerking zal bij het bosbouwkundig onderzoek eerst ten volle vruchtdragend kunnen worden indien daarbij wordt gestreefd naar een verdeling van taken welke moeten worden verricht om gemeenschappelijke vraagstukken op te lossen.

6. Bij boomsoorten welke in korte omlopen kunnen worden geteeld, hebben dunningsproeven alleen waarde indien van het eind der jonge fase af de te onderzoeken dunningsgraad en -wijze is toegepast.

7. De voordelen welke de vruchtwisseling als middel ter voorkoming van eenzijdig grondgebruik boven de menging van houtsoorten biedt, zijn in de houtteelt tot dusverre onvoldoende onderkend.

8. Bij de rationalisatie in de bosbouw behoort aan het leiding gevende werk evenzeer aandacht te worden geschonken als aan de zogenaamde directe produktieve arbeid.

9. De zo zeer gewenste standvastigheid van botanische namen kan met geringe veranderingen in de internationale regels voor de nomenclatuur aanzienlijk worden bevorderd.

10. Een algemeen marktonderzoek moet voor de Nederlandse bosbouw niet alleen als een nog ontbrekend onderdeel van het onderzoekingswerk worden beschouwd, doch als een onontbeerlijke grondslag voor de gehele bedrijfseconomische en bedrijfstechnische voorlichting.

11. Voor een doeltreffende vervanging van de Boswet 1922 is het nodig de Natuurschoonwet 1928 gelijktijdig te herzien.

12. Bij de vestiging van plantrechten verdient opstal de voorkeur boven erfdienstbaarheid.

13. De invloed van houtwallen op het klimaat ter plaatse is, mede in verband met wijzigingen in de vochthuishouding, belangrijker dan op grond van theoretische beschouwingen over de luchttemperatuur kan worden aangenomen.

Dissertatie J. van Soest,
Wageningen, april 1959

CONTENTS

Dit proefschrift verschijnt eveneens als band 4, nr. 1 in de reeks Uitvoerige Verslagen van de Stichting Bosbouwproefstation „De Dorschkamp".

en te verdiepen dat daaruit een proefschrift kon groeien. Ik ben mij ervan bewust dat dit niet mogelijk zou zijn geweest zonder de voorspraak van mijn directeur, dr. H. VAN VLOTEN, wiens vertrouwen en de grote mate van vrijheid, mij zowel bij dit onderzoek als bij mijn overige werkzaamheden geschonken, ik op hoge prijs stel.

Het is een voorrecht in een werkkring als de mijne nauwe betrekkingen te mogen onderhouden met de Landbouwhogeschool en talrijke instituten, ook buiten Nederland. Van een voortzetting van deze samenwerking stel ik mij veel voor.

Er rest mij nog een woord van bijzondere dank aan mijn vrouw voor de morele steun, de verleende hulp met typen en corrigeren en, mede aan de kinderen, voor de ruime mate van getoond begrip. Het werk bracht niet zozeer een vaak van huis zijn met zich mede, dan wel veelvuldige geestelijke afwezigheid, welke voor mijn naaste omgeving dikwijls een verschrikking moet zijn geweest. Ik beloof beterschap !

I. INTRODUCTION AND PROBLEM AT ISSUE

> *De waarschijnlijkheidsrekening is in staat de houtmeetkunde van het handwerk tot een wetenschap op te heffen.*
>
> *(Statistical technique is capable of raising forest mensuration from the level of handicraft to that of science.)*
>
> A. H. BERKHOUT

1. INTRODUCTION

One of the operations regularly recurring in forestry is the estimation of the volume of standing timber. The aim is to estimate the volume that will be found after felling by measuring the trees before they are felled. Such estimations are possible because the dimensions that are easily determined on the standing tree are correlated with the volume of the felled tree.

In forestry such estimates can only be made if this correlation is known. Forest research includes the study of the relationship between the volume of trees and the dimensions to be determined on their stems, as well as the presentation of the results in a form that will facilitate their application as much as possible. The tabulated form — the volume table — is the most suitable.

2. STATISTICAL NATURE OF PROBLEM

A table can be regarded as a function, for, it conforms to the definition given by KUIPER (1956): "a function of a variable is a collection of pairs of numbers (x; y) in which each number occurs at most once as the first of a pair". An example of such a function is the volume table with one entry (local volume table or tariff table). In this table the independent variable x is the diameter at breast height (by international agreement to be denoted by d or $d_{1.3}$, see Appendix 1) and the dependent variable y is the volume (v). The function can be written as:

$$y = F(x) \qquad \text{or} \qquad v = F(d_{1.3}).$$

Often the volume of a tree is estimated from two independent variables (the diameter at breast height and the height of the tree), so that

$$y = F(x_1,x_2).$$

It appears that trees of the same diameter and height have different volumes. In symbols:

$$(x_1,x_2) \mapsto \underline{y}.$$

The bar under y means that y is stochastic: at given x_1 and x_2 there are several values of y. Hence, between the variables there is not a functional, but a stochastic relationship. This implies that the regression function

$$\underline{y} = F(x_1,x_2)$$

must be determined empirically. For this purpose a number of representative observations (X_1,X_2,Y) must be available, which thus have to be collected first.

The next step is to make assumptions as regards the relation between $E(\underline{y})$, the expected value of the dependent variable, and the independent variables x_1 and x_2:

$$E(\underline{y}) = \varphi(x_1,x_2).$$

Subsequently, the estimates of the parameters can be derived from the observations.

After this an estimate (S) of the expected value of $\underline{y}$ can be found for any practical value of x_1 and x_2:

$$(x_1,x_2) \rightarrow S\ E\left\{\underline{y}(x_1,x_2)\right\}.$$

Finally, all the values of S can be listed in a table, the volume table.

The values included in the table being estimates of expected values it is desirable to have an idea of the precision of these estimates. To this end σ_y, the standard deviation of y, must be known:

$$(x_1,x_2) \rightarrow \sigma\left\{\underline{y}(x_1,x_2)\right\}.$$

Of this standard deviation σ, only an estimate can be obtained, which, for the sake of distinction, is denoted by s:

$$(x_1,x_2) \rightarrow s\ [S\ E\left\{\underline{y}(x_1,x_2)\right\}].$$

If the deviations from regression are normally distributed it is possible, with the aid of FISHER's t table — to be found in manuals and textbooks on statistics — to determine confidence intervals of the function. With the aid of these it can be predicted to what degree differences are to be expected between the actual values of the dependent variable and the values estimated by means of the regression function.

It is important to ascertain beforehand to what extent the deviations from regression are normally distributed. Fig. 1 shows the normal distribution as a graph. Fig. 2 gives the relationship between v and d for 125 observations; it will be seen that the standard deviation changes with the diameter:

$$s_v = F(d_{1.3}),$$

so that: $s_v = F(v)$ is also true.

Therefore, the frequency distribution of the differences between observed and regression volumes, taken over all classes of diameters together, deviates from the normal distribution. This is evident from a graph of the frequency distribution (Fig. 3).

In such a case there is little point in determining the standard deviation from the regression function. The deviation must then first be standardized. Sometimes this can be done with the aid of a simple transformation, for instance, by taking the logarithm of the dependent variable. It is also possible to use the relative deviation, which comes to practically the same thing:

$$\ln Y - \ln \overline{y} = \ln \frac{Y}{\overline{y}} = \ln \frac{\overline{y} + Y - \overline{y}}{\overline{y}} = \ln\left(1 + \frac{Y-\overline{y}}{\overline{y}}\right) \doteq \frac{Y-\overline{y}}{\overline{y}}.$$

Thus, it can be assumed that:

$$S\left(\sigma^2_{\ln\ y}\right) = \frac{1}{n-1}\,\Sigma\left(\frac{Y-\overline{y}}{\overline{y}}\right)^2, \text{ or:}$$

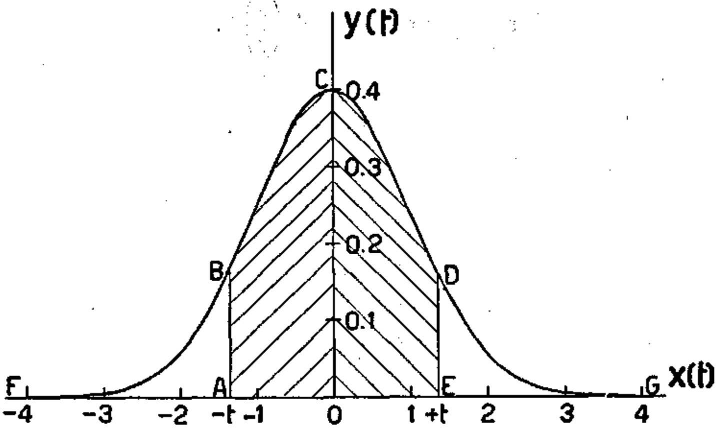

Figure 1. Normal frequency distribution
Abb. 1. Normale Häufigkeitsverteilung

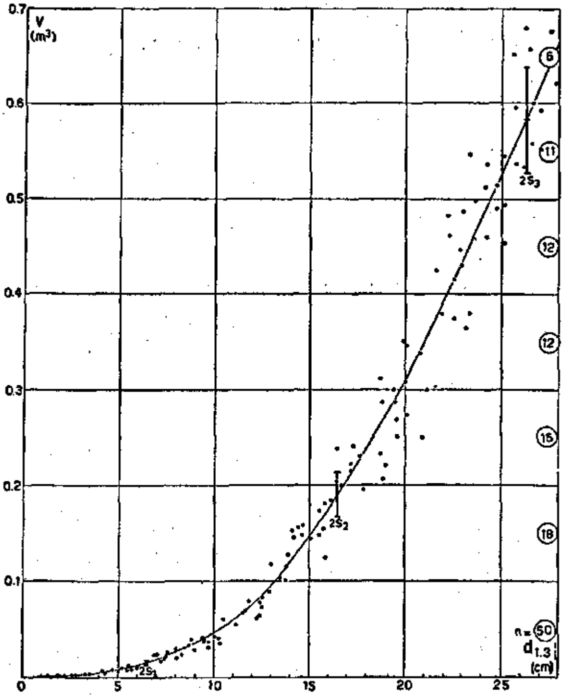

Figure 2. Relationship between the volume and the breast height diameter of 125 Japanese larch trees

Abb. 2. Zusammenhang zwischen v und $d_{1.3}$ bei 125 japanischen Lärchen.

$$s^{2}_{\ln\ y} = \frac{1}{n-1}\,\Sigma\left(\frac{y}{\bar{y}}\right)^{2}.$$

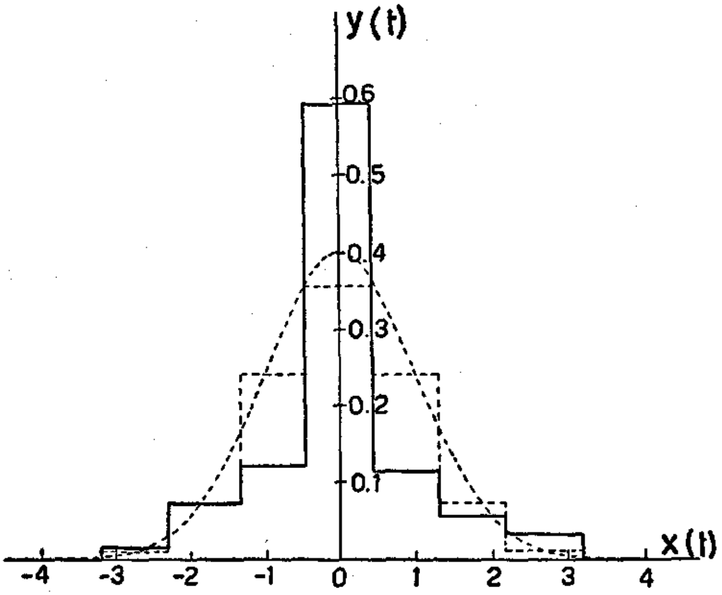

Figure 3. Actual frequency distribution of differences between observed and regression volumes (V—$\hat{V}$) of 125 Japanese larch trees

Abb. 3. Beobachtete Häufigkeitsverteilung von V—$\hat{V}$ *bei 125 japanischen Lärchen*

Often the relative deviation is multiplied by 100. The result is called the percentage deviation. An estimate is:

$$\frac{s_{100y}}{y} = \frac{100}{\sqrt{n-1}}\sqrt{\Sigma\left(\frac{y}{\bar{y}}\right)^{2}}\,.$$

The agreement with the coefficient of variation is evident if $\bar{y}$ is supposed to be constant. For, the coefficient of variation is calculated according to:

$$P_s = \frac{100\ s}{\bar{x}}.$$

3. Choice of function

A mathematical function can be represented by a formula (analytical equation), a graph, an alignment chart, or a table. The last two methods are more suited to present the results than for actual construction, for which either of the first two methods can be used.

The mathematical method with a formula offers the advantage that invariably the best estimate of y (indicated by $\hat{y}$) is obtained for the regression equation chosen. This best estimate is characterized by $\Sigma(Y-\hat{y}) = 0$ and $\Sigma(Y-\hat{y})^2 =$ minimum. On the other hand, the degree to which a statistical model will fit the observations depends on the choice of the analytical equation, in particular on the number of parameters occurring in it.

The graphical method grants the investigator considerable freedom in making the functions fit the observations, but, without an accurate specification of the procedure, there is no certainty whatever that the result will be independent of irrelevant conditions like „the research worker".

The literature gives a great many methods of volume table construction, but, as a rule, any indication of the efficiency of a given method compared with that of others is lacking. Without an experimental investigation into several methods, it is therefore impossible to make a justifiable choice from the procedures described in the literature. The variety of possibilities renders it necessary to restrict such investigations to a limited number of methods, but comparing a number of different methods enables a fairly impartial opinion to be obtained. Use has been made of data for Japanese larch, as these were available at an earlier date than those for the other species for which Dutch volume tables have to be made.

II. REQUIREMENTS TO BE MET BY TREE VOLUME RESEARCH

1. GENERAL

In tree volume research attention must be paid to the basic data being representative; to the units in which the data are to be expressed; the measuring procedure; the construction method; the method of tabulation; any additional data desirable for practical application.

2. SAMPLE TREE DATA

The best way of collecting sample tree data consists in unbiased sampling of the population, which in this case, comprises all stands of Japanese larch in the Netherlands. As details of these stands will not be known until the new census of Dutch woodlands will be ready, this would have involved too much delay.

Instead of a random selection of data from the Dutch woodlands, use has mainly been made of data obtained from permanent sample plots used for growth and yield research. The oldest plots for growth research (DE KONING, 1936) were taken over from the Committee for Exotic Tree Species in 1947, when the Forest Research Station at Wageningen was established; the newer plots date from after that time.

Another source of information was the sample plots for thinning research of the Forest Research Institute, Agricultural College, Wageningen, which furnished a welcome supplement to the observations in some classes of small dimensions. Finally, some forest owners, estate agents and timber merchants enabled the Forest Research Station to carry out measurements in felled stands where the trees were of large dimensions.

The main particulars of the sample tree groups investigated are given in Table 1. It will be seen that various parts of the country, various quality classes, various planting distances and both pure and mixed stands are included.

On the other hand, the material examined mainly originates from thinnings; in only five out of 27 plots, were the sample tree data obtained from clear-felled areas or selective fellings.

It thus remains to be proved that this circumstance does not lead to statistical bias. An indication of this can be found in plot JL 17. The first 13 trees, which were thinned in 1949/50, had a mean form factor of 0.476 ± 0.008. Two years later the stand was felled and another 30 trees were measured. These appeared to have a mean form factor of 0.474 ± 0.007. It should be taken into account that the trees thinned in 1949/50 had a somewhat smaller average diameter (22 cm) than those of the main crop in 1951/52 (25 cm), so that the differences in mean form factor, which are small anyhow, are certainly insignificant.

The supposition that thinnings furnish sufficiently representative data will be further confirmed by the comparative study of construction methods. This study has been carried out in two parts. The data listed in columns 11—13 of Table 1 have been used for the first investigation and they do not include clear-felled areas. The volume function definitely chosen after the second investigation has been based both on these data, and on those of column 15. The addition of the new data, obtained for the greater part from clear-felled areas, has not, in this case, led to a significant change of the parameters.

3. UNITS OF MEASUREMENT

For the Netherlands suitable units of measurement are the centimetre for diameter, the metre for height and the cubic metre for volume. The last-mentioned quantity should preferably be defined — at least for conifers — as total stem wood volume; consequently, the volume of the branches has not been taken into account, nor have allowances been made for top and stump wood. The volume of top and stump wood varies from forest to forest no less than from country to country, so that the stem wood volume is a better basis for comparison than the varying merchantable volume.

4. MEASURING PROCEDURE

A stem can be regarded as a solid of revolution. Its volume is described by:

$$v = \int_{x=0}^{x=h} \pi\, r^2\, dx,$$

where r is the radius of the supposedly circular cross-section at height x. The quantity r decreases from the bottom to the top of the tree by:

$$\lim_{x \to h} r = 0.$$

In practice this integral can be approximated in various ways, for instance, by drawing a stem form curve (longitudinal section of the tree) based on a limited number of diameter measurements at various heights and by measuring the area enclosed between the curve and the ordinates by means of a planimeter or a grid (REINEKE, 1926; SPURR, 1952). Another method is based on the idea that a reasonable approximation of the volume can be obtained by dividing the stem into a limited number of sections and considering each section as a cylinder, the diameter of which is measured at the mid-point of the section. After HOHENADL (1922) the stem can be divided into a fixed number of sections of equal length, this length varying from tree to tree. As a rule, however, a fixed section length and a varying number of sections per tree is preferred. This method was recommended by the International Union of Forest Research Organizations (FABRICIUS, GUILLEBAUD and OUDIN, 1936), using sections of 1 or 2 m in length, and has been adopted here. STOFFELS (1950) starts from the idea that the standard deviation of the measuring error is approximately proportional to the square root of the section length: $\sigma_v \doteq c\sqrt{\frac{\pi}{12}\, av}$, where a = section length and c = measuring interval. This presupposes, however, that all sections contribute to the volume of the stem to about the same degree. This is not the case, so that it cannot simply be concluded that the standard error of estimate of the tree volume would be halved if, for instance, the trees were measured in lengths of 0.5 metre instead of 2 metres.

Using a limited amount of observation data, given in detail in Table 2, the change of the volume estimate using sections of varying lengths has been examined. The results are expressed as form factors; $f = \frac{v}{gh}$, where v is the sum of the volumes of all the sections and g is the basal area. The use of the form factor eliminates, to a considerable extent, the effect of the variation in height and diameter at breast height of the trees.

The table shows that the influence of the section length is mainly restricted to the bottom part of the stem. If the bottom part of 2 metres is always measured in two sections of 1 metre and the rest of the stem in 2-metre sections the result is sufficiently accurate in the case of large- and medium-sized stems (JL 4). For very small trees, however, a section length of 1 metre is still rather large. For practical reasons it is not advisable to use sections of less than 1 metre. In the present investigation trees with a total length of less than 20 metres were measured in 1 metre sections; for trees with a length exceeding 20 metres the bottom part of the stem was measured in two 1 metre sections and the remainder of the stem in 2 metre sections.

In section measurements it is usual to derive the sectional area from the average of two diameter measurements made at right angles to each other. Another equally limited investigation showed that it is sufficient to determine one diameter per section. The figures leading to this conclusion are given in Table 3. It should be borne in mind, however, that this refers in particular to the form factor. If a felled tree, as is usually the case, lies on its flat side the diameters determined from a single measurement are larger than if the mean of two diameter measurements were obtained for each section. But this also applies to the diameter at breast height, so that nevertheless, the form factor determined from these measurements is approximately correct. This is not true for the volume (STOFFELS, 1948).

If for the determination of form factors — it will be shown later that the use of form factors in constructing volume tables offers advantages over using the volumes themselves — it is not necessary to average two diameters and to derive from this the sectional area this area can also be measured direct with the aid of special tree calipers. The normal linear d scale on these calipers has been replaced by a quadratic one; $g = \frac{1}{4}\pi\, d^2$.

An improvement can be obtained by constructing the scale so that the figures are rounded off automatically. The scale of the function then becomes:

$$d = \sqrt{\frac{4}{\pi}\left(g - \tfrac{1}{2}\Delta g\right)}, \qquad (1)$$

where Δg is the area interval.

If, however, this interval is supposed to be constant the distance between the marks becomes increasingly smaller, so that a variable interval — as found on the slide rule — is desirable. The automatic rounding, in going from one interval to another, leads to the difficulty that two adjacent classes with different intervals may overlap. This problem has been represented schematically in Fig. 4. Some-

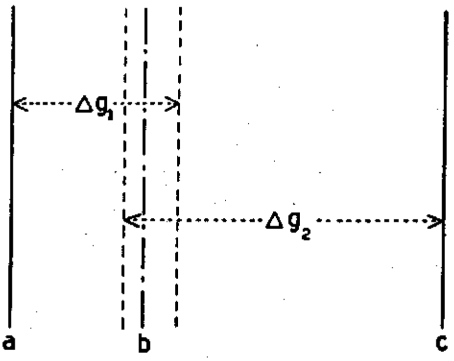

Figure 4. Diagram of changes in interval width of calipers with automatically rounding sectional area graduation

Abb. 4. Schematische Darstellung des Übergangs von Durchmesserklassen ungleicher Grösse

where within the overlap area a line b has to be fixed as common boundary line between the two classes. The distance x between this line b and the line a has been calculated from the equation:

$$\frac{a + c}{2} = x\,(a + \tfrac{1}{2}\,\Delta g_1) + (1 - x)\,(c - \tfrac{1}{2}\,\Delta g_2). \qquad (2)$$

With the aid of (1) and (2) the graduation of the scale of these calipers has been calculated; the results are given in Table 4, and the calipers are illustrated in Fig. 5. The graduation for the sectional area is on one side, the linear graduation for the diameter (which also rounds off automatically) is on the back of the calipers at right angles to the sectional area scale.

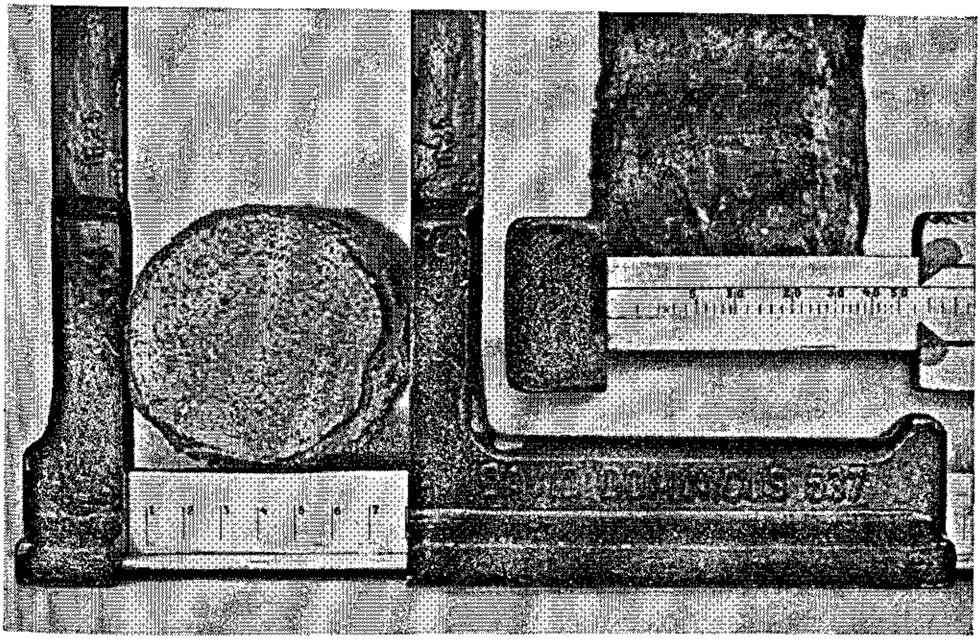

Figure 5. Automatically rounding calipers with a linear and a quadratic (sectional area) scale

Abb. 5. Kluppe mit selbstabrundender Durchmessereinteilung (links) und selbstabrundender Kreisflächeneinteilung (rechts)

In routine investigations the procedure is highly important for the efficiency of the instrument. The use of special calipers for measuring sectional areas as a means to save work shows to full advantage only if the sections are measured in the most efficient way. The results of a tentative time study carried out on two trees are given in Table 5. From this it may be concluded that a team of three is the most economical. Within the wage ratios chosen, this result is not influenced by the leader of the measuring team working with colleagues of the same wage bracket or with assistants receiving considerably lower salaries.

The objection may be raised that this experiment has not been carried out on a practical scale. It is not to be expected, however, that in measuring sample trees in actual practice the trend will change. This can be demonstrated, assuming an 8-hour working day, with 2 hours' travelling and 6 hours' measuring time. In practice the actual measuring time for a three-man team is about 3 minutes per tree, with 1 minute's walking time. Hence, a team of three can measure 90 trees a day. If two men should have to do the work, only $25/60 \times 90 = 38$ trees could be measured per day. Consequently, the day's work per man drops from 30 to 19 trees.

The tree calipers with sectional area graduation have been tried with the measuring team of three men. With this organization of the work, the leader exercises supervision and records the results of the measurements. One assistant fixes the steel measuring tape at the foot of the stem by means of an awl, so that the 1.3 m mark coincides with the mark at breast height on the stem, and the other assistant unrolls the tape along the stem. They then begin to measure starting from the bottom and the top, respectively, until they meet somewhere in the middle.

The actual measuring and calculating times for 10 trees for duplicate and single measurements of the diameter as well as for measurements using the special tree calipers are given in Table 6. The gain in time through measuring with the new calipers proves to be about 40%.

5. CONSTRUCTION METHOD

The literature[1] tells us that since 1800 numerous volume tables have been constructed by different methods, with different variables and for a variety of purposes. Most of them are intended for terrestrial (as opposed to aerial) determination of the volume of standing timber and to these we shall restrict ourselves.

Some authors have tried to formulate a mechanical theory for the form of the (straight) stem, but this has not led to the construction of volume tables. Attempts to describe the generating line of the geometric solid with the aid of an experimental function have been more successful.

Others have left the stem form out of account and have found experimental functions for the relationship between the volume and one or several dimensions of the tree. The form factor and the "form height" $fh = \frac{v}{g}$, are sometimes used

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[1] To be published elsewhere.

as dependent variables instead of the volume. With these variables, v, f and fh, both a graphical smoothing and a calculation according to the method of least squares have been used by the authors mentioned in the literature.

It was therefore decided to include in the comparative investigation both a stem form equation and some frequently used graphical solutions and mathematical methods, using d and h as independent variables and f and v, or in one case fh and fg, as dependent variables.

Table 7 gives a survey of the methods included in the preliminary investigation. Of the methods using *stem form equations* that of WOLFF VON WÜLFING (1933) has been chosen. It is based on the function:

$$y = ax + bx^2 + cx^3,$$

where x and y are proportional values, so that $y = 1$ if $x = 1$. Consequently, $a + b + c = 1$.

Hence, the equation can be solved if the ratio of any two diameters to a fixed third diameter is known. As the fixed diameter WOLFF VON WÜLFING has chosen the diameter at a quarter of the total height, $d_{\frac{1}{4}h}$. The other two diameters are also fixed, viz. at $\frac{1}{2}h$ and $\frac{1}{20}h$ (see Fig. 6).

A smooth taper curve is made of each tree measured. From this curve the three above-mentioned diameters are read. The ratios are then known as:

$$y_{\frac{1}{2}h} = \frac{d_{\frac{1}{2}h}}{d_{\frac{1}{4}h}} \text{ and } y_{\frac{1}{20}h} = \frac{d_{\frac{1}{20}h}}{d_{\frac{1}{4}h}}$$

These y values are stochastic, so that further smoothing is necessary.

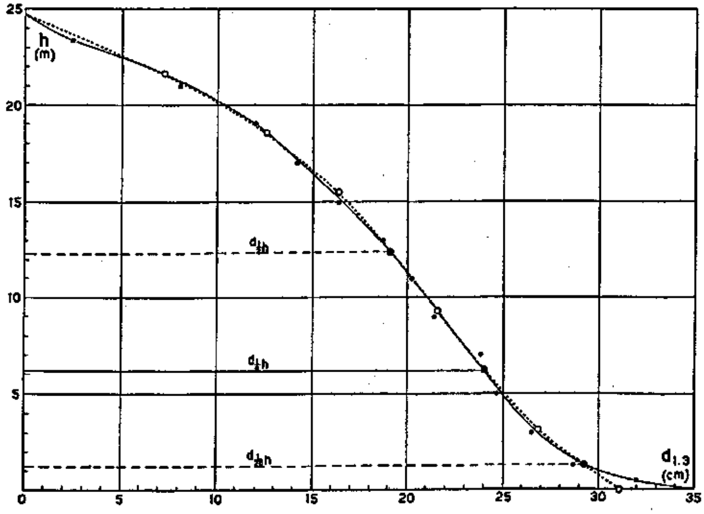

Figure 6. Stem form diagram of a Japanese larch (solid line) with the corresponding stem form curve obtained by Wolff von Wülfing's method (dotted line)

Abb. 6. Stammformkurve

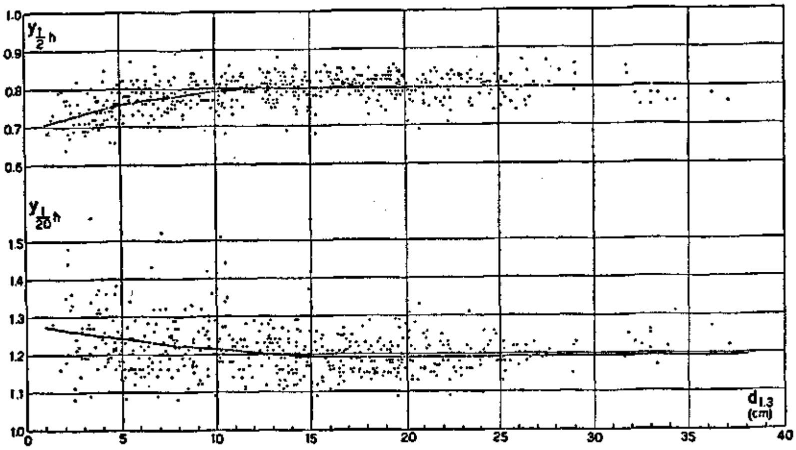

Figure 7. Relationship between $y_{\frac{1}{2}h}$ and $d_{1,3}$, and $y_{1/20h}$ and $d_{1,3}$ (Wolff von Wülfing/Ferguson)

Abb. 7. Zusammenhang zwischen $y_{\frac{1}{2}h}$ *und* $d_{1,3}$, *und* $y_{1/20 h}$ *und* $h_{1,3}$ *(Wolff von Wülfing-Ferguson)*

After FERGUSON (1949) these y values were first of all plotted against breast height diameter $d_{1.3}$, which resulted in the two asymptotic curves of Fig. 7.

For each $d_{1.3}$ the regression values $y_{\frac{1}{2}h}$ and $y_{\frac{1}{20}h}$ can be read from these curves. Thus, for the breast-height diameter class concerned, the parameters of the regression taper curve have been determined so that the true form factor $f_{\frac{1}{4}h}$ can easily be calculated using WOLFF VON WÜLFING's auxiliary tables (published by FERGUSON, 1949). The absolute form factors $f_{\frac{1}{4}h}$ thus obtained are collected in Table 8. With the aid of the same auxiliary tables it can also be determined what value of $d_{\frac{1}{4}h}$ belongs to given values of h and $d_{1.3}$, so that now for any combination of h and $d_{1.3}$ the regression volume can be calculated as $v = g_{\frac{1}{4}h} f_{\frac{1}{4}h} h$.

For the sake of comparison with the preceding method the values of $y_{\frac{1}{2}h}$ and $y_{\frac{1}{20}h}$ have also been plotted against *height*. As appears from Fig. 8 this also results in two asymptotic curves; they led to the absolute form factors given in Table 9, which deviate slightly from those in Table 8. These form factors were used to construct another volume table.

A third method to smooth out the stochastic variation was borrowed from BECKING (1950). The regression lines of $d_{\frac{1}{2}h}$ on $d_{\frac{1}{4}h}$ and of $d_{\frac{1}{20}h}$ on $d_{\frac{1}{4}h}$ were determined. For the data investigated these regression lines were found to be approximately straight and to pass through the origin (see Fig. 9), so that a single true form factor was found for all diameter and height classes: $f_{\frac{1}{4}h} = 0.6580$. This led to the third volume table of this type.

Of the methods employing *regression equations*, BERKHOUT's (1920) was the

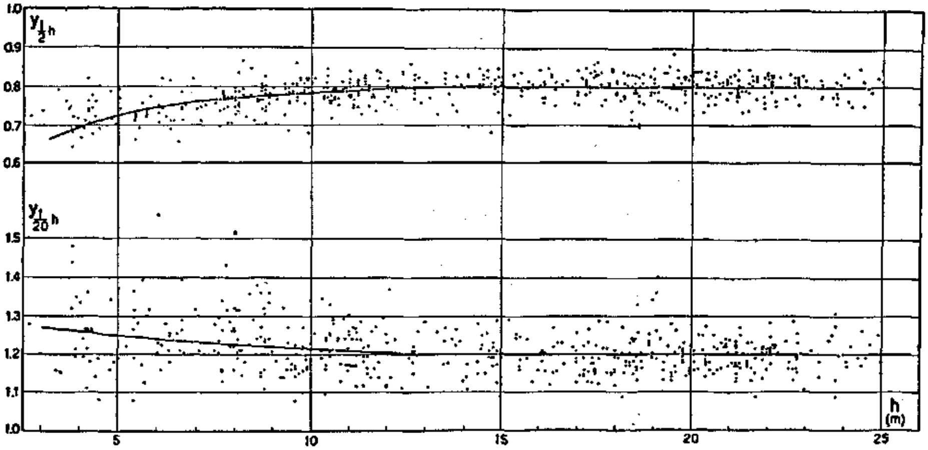

Figure 8. Relationship between $y_{\frac{1}{2}h}$ and h, and $y_{\frac{1}{20}h}$ and h (Wolff v. W./2nd modification)

Abb. 8. Zusammenhang zwischen $y_{\frac{1}{2}h}$ *und h, und* $y_{\frac{1}{20}h}$ *und h (Wolff von Wülfing-van Soest)*

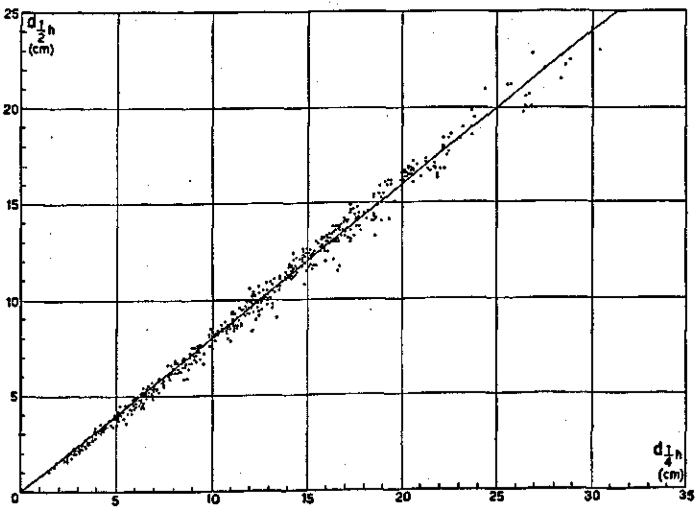

Figure 9. Relationship between $d_{\frac{1}{2}h}$ and $d_{\frac{1}{4}h}$ (Wolff von Wülfing/Becking)

Abb. 9. Zusammenhang zwischen $d_{\frac{1}{2}h}$ *und* $d_{\frac{1}{4}h}$ *(Wolff von Wülfing/Becking)* first to be examined. **Berkhout** applied the function:

$$\log v = \log a + b \log d_{1.3}$$

to the individual stand, but it might prove suitable also for constructing a local volume table if the sample is taken from a population. In addition, as a modification of this method, the *height* has been used as the independent variable:

$$\log v = \log a + b \log h.$$

The above construction methods, and the one suggested by **Schumacher** and **Hall** (1933) for volume tables with two entries, are closely related:

$$\log v = a + b_1 \log d_{1.3} + b_2 \log h.$$

Before them, **Bähler** and **Bosman** (1923) had arrived at the same independent variables when trying to find a regression equation for the form factor:

$$\log f = a + b_1 \log d_{1.3} + b_2 \log h.$$

In addition to the three above-mentioned methods the regression equation:

$$f = a + b_1 h + b_2 \frac{h}{d_{1.3}}$$

developed by **Näslund** (1940/41, 1947) for Scots pine in Sweden has been examined.

Of the *graphical solutions,* mention should first be made of two very simple functions intended for constructing volume tables with one entry:

$$fh = F(d) \text{ and } fg = F(h).$$

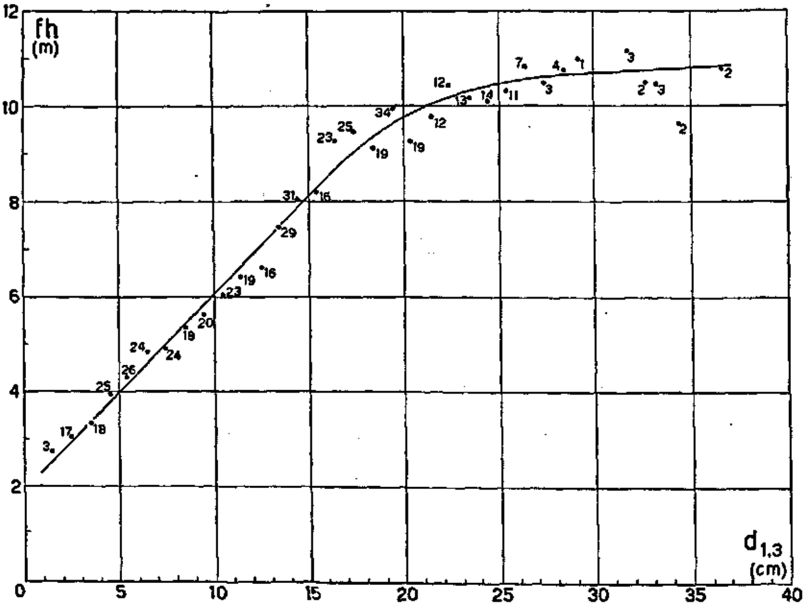

Figure 10. Relationship between "form height" (form factor times height: fh) and breast height diameter ($d_{1.3}$)

Abb. 10. Zusammenhang zwischen fh und $d_{1.3}$

The reason why it is not the volume, but the products of form factor and height and of form factor and basal area that have been used will be given later. Smoothing consists in plotting the weighted class averages and drawing a smooth curve through the points. Subsequently, the range of the independent variable is divided into a number of sections, e.g. three. The weighted distances from the observed points to the curve are measured in the direction of the dependent variable — usually in a vertical direction — and their sums are determined separately for each section. If these sums are not about equal to zero, the curve or portions of it must be shifted until they are. The functions for fg and fh thus estimated graphically are shown in Figs. 10 and 11.

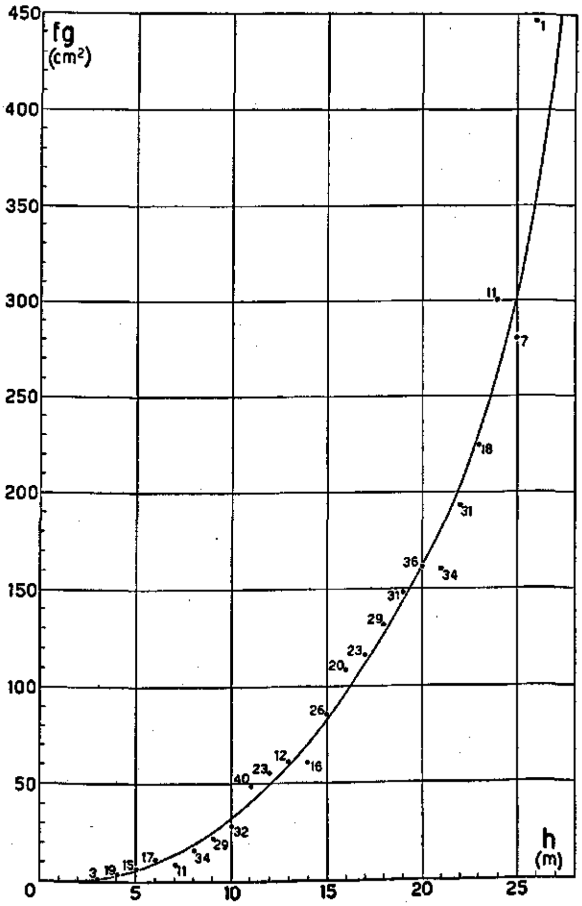

Figure 11. Relationship between "form basal area" (form factor times basal area: fg) and height (h)

Abb. 11. Zusammenhang zwischen fg und h

For the *graphical construction of regression functions with more than one independent variable* the choice fell on the methods of VISSER (1949) and of CHAPMAN and MEYER (1949), the latter being used for smoothing both the volume and the form factor.

VISSER's method does not determine the stochastic but the structural relationship. The difference is that the stochastic relationship is based on the assumption that

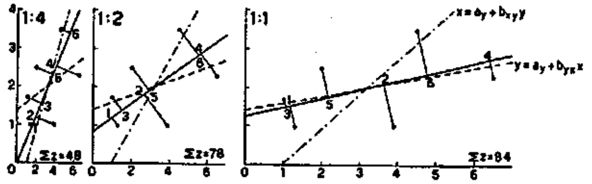

Figure 12. Diagram showing how the "structure line" depends on the ratio between the scales of x and y

Abb. 12. Einfluss des Massstabsverhältnisses auf den Strukturverband

the independent variables are without errors, whereas the idea underlying the structural relationship is that certain errors are inherent to both the independent variables and the dependent variable. In contrast to the regression curve, VISSER's method requires the measurement of the deviations from the average in the direction of the results of the elementary errors, which are restricted to 2 variables for each graph. However, this direction is dependent on the ratio between the scales on which the variables are plotted, see Fig. 12. d, h and $\sqrt[3]{v}$ have been chosen as variables, so that they are all of the same dimension and can be expressed in the same unit (metre).

If the ratio between the scales is empirically chosen, so that the elementary errors are on an equivalent scale the deviations from the average can be measured in a direction perpendicular to the curve. For the data investigated, however, it proved impossible to find such a ratio. The best approximation was the scale ratio:

$$\sqrt[3]{v} : d_{1.3} : h = 1 : 1 : 0.06,$$

the error $\sqrt[3]{v}$ being about 15% lower than that in d and h.

With the aid of the scale ratio found a $\sqrt[3]{v}/d_{1.3}$ graph ²) is constructed, in which all the values measured are plotted individually after they have been grouped according to the third variable — in this case, h — into classes of equal numbers. A $\sqrt[3]{v}/h$ graph is constructed in a similar way. In these diagrams each individual group of data is smoothed independently by means of a "structure line". Subsequently, these lines have to be harmonized by effecting small changes in direction and location wherever this is necessary. This is done for both diagrams at the same time, in such a way that ultimately all lines are in one plane. In this "structure plane" as many vertical intersections in the direction of the d and h axes are made as there will be columns and rows in the volume table. The values of $\sqrt[3]{v}$ are read at the points of intersection. Fig. 13 gives the projections of the intersections of this plane for a number of d and h values.

CHAPMAN and MEYER's method, on the other hand, fits in with the first-mentioned graphical solutions using fh and fg. Use is made of weighted averages, and deviations are measured parallel to the (vertical) ordinate on which the dependent variable is plotted. As in VISSER's method, smoothing is three-dimensional, so that here too, the observation data have to be grouped into

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²) The stroke (/) is used to denote that in this graph $\sqrt[3]{v}$ is the dependent variable and $d_{1.3}$ the independent variable; the stroke (/) is similarly used for other notations in this paragraph.

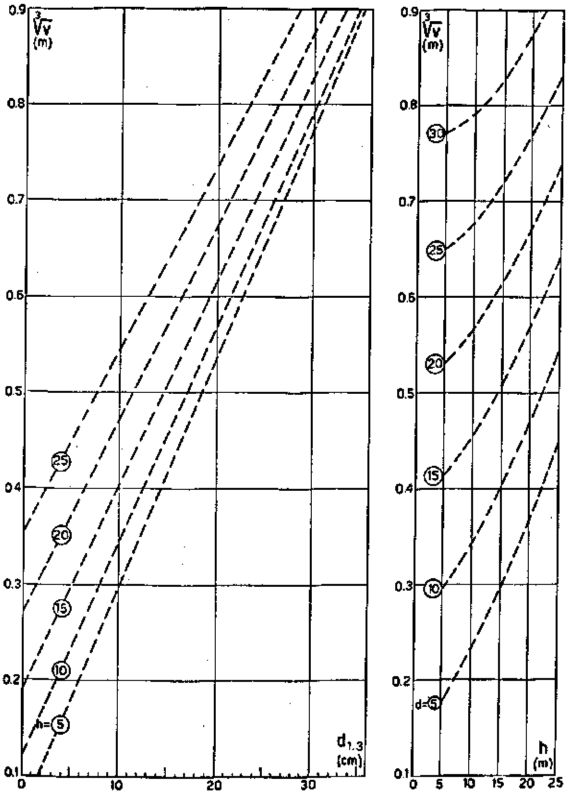

Figure 13. Simplified chart of the ultimate result of the Visser method

Abb. 13. Vereinfachtes Endergebnis nach der Methode Visser

h and $d_{1.3}$ classes. The class boundaries, however, are located at equal distances, so that the numbers within the classes vary and generally the averages are not exactly equal to the theoretical class averages (Table 10).

This method starts from a $v/d_{1.3}$ graph and the h classes are again smoothed independently (see Fig. 14). In the $h/d_{1.3}$ graph use is made of the harmonization of v already found in the $v/d_{1.3}$ graph read at the theoretical class averages, after which another harmonization on v is effected. The result is shown in Fig. 15. With the aid of the v values thus harmonized twice, another — final — $v/d_{1.3}$ graph is constructed, on which the table is based. Fig. 16 is an example of such a final $v/d_{1.3}$ graph and refers to the small trees plotted into a separate graph on a larger scale.

In addition to the harmonization of the volume on $d_{1.3}$ and on h the form factor was similarly harmonized according to the same method. It was found (Fig. 17) that the classification for height had much less effect than with harmonization of v. Therefore it was attempted to divide the material into only 4 height classes. It then appeared that within such wide height classes the height changes with the diameter (Fig. 18), so that DWIGHT's correction was applied to eliminate any consequent interfering influences. Nevertheless the f/h graph still showed irregularities before it had been brought in its final form (Fig. 19), which made the harmonization rather elaborate. The results are shown in Figs. 20 and 21.

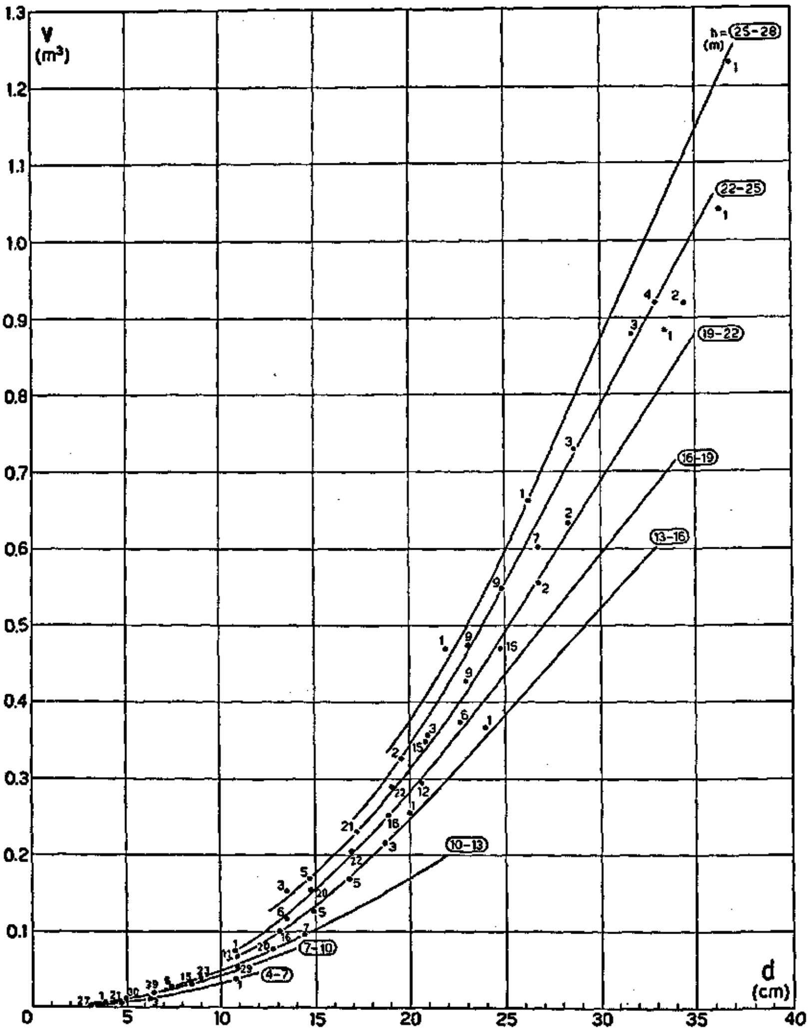

Figure 14. Harmonization of volume (v) on breast height diameter ($d_{1.3}$), according to Chapman and Meyer

Abb. 14. Ausgleichung von v auf $d_{1,3}$, nach Chapman und Meyer

There was then every reason to examine the relationship between *f and d* without a classification according to height, which led to Fig. 22.

Finally, as a counterpart of the last-mentioned method, the relationship between *f and h* (not shown in a figure) has been studied.

The results of all these different construction methods will be discussed in the next chapter.

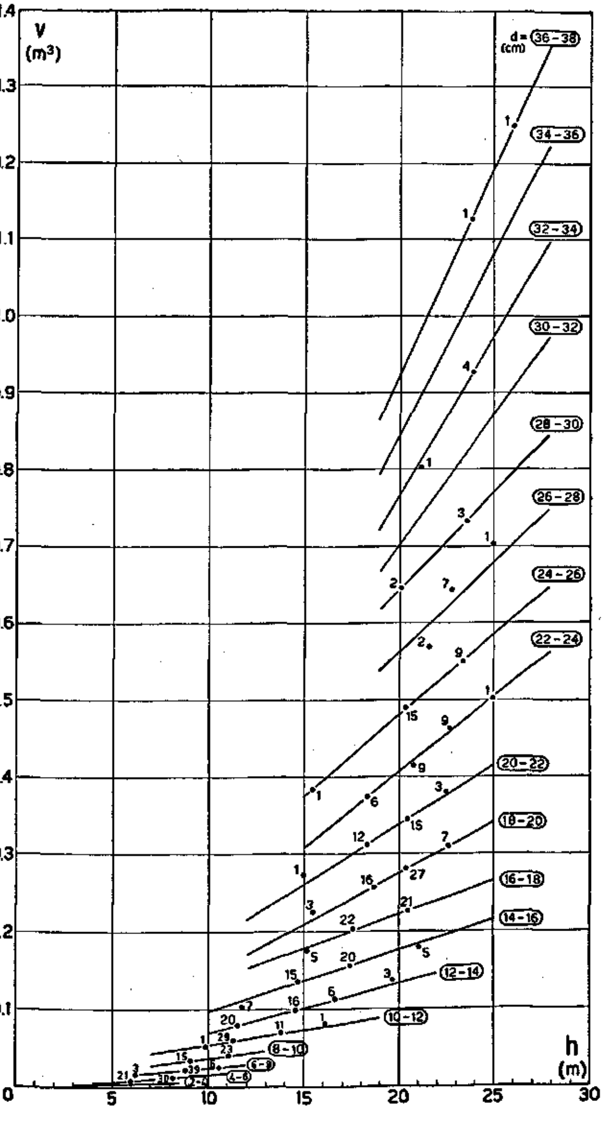

Figure 15. Harmonization of volume (v) on height (h), Chapman and Meyer

Abb. 15. Ausgleichung von v auf h, nach Chapman und Meyer

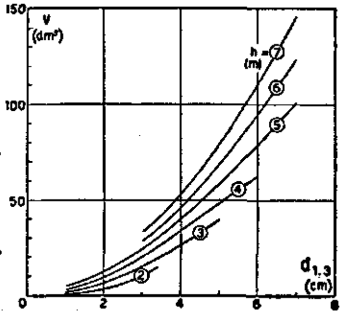

Figure 16. Final chart of the Chapman and Meyer method for the small trees which were treated separately

Abb. 16. Endgültiger Zusammenhang zwischen v und $d_{1.3}$ nach Chapman und Meyer, für kleine Bäume

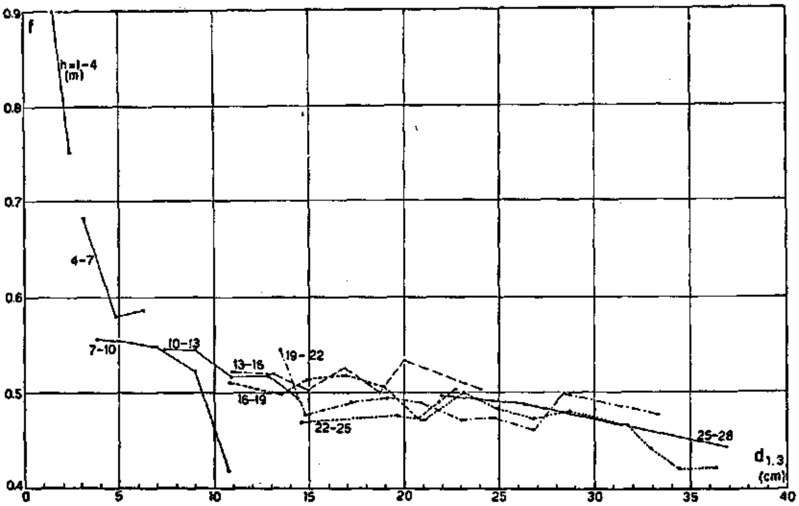

Figure 17. Chapman and Meyer modified for form factor harmonization. Relationship between form factor (f) and breast height diameter ($d_{1.3}$) before harmonization

Abb. 17. Nicht ausgeglichener Zusammenhang zwischen f und $d_{1.3}$; modifizierte Methode von Chapman und Meyer

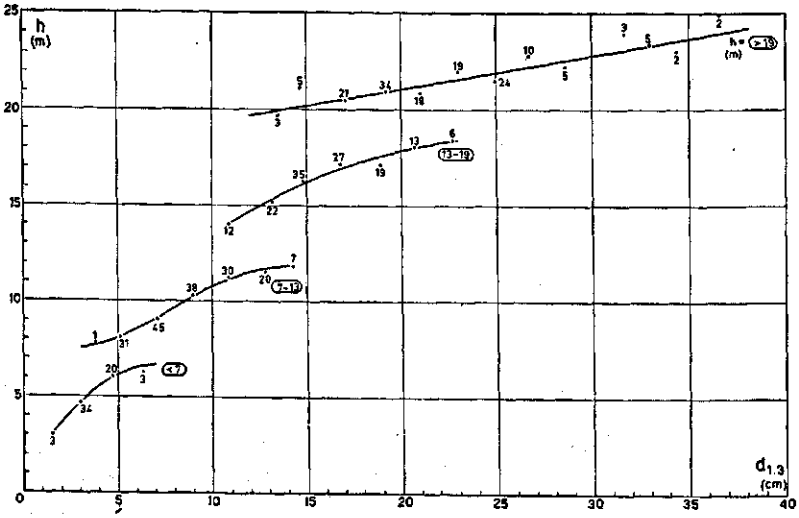

Figure 18. Dwight's correction, smoothing of height on breast height diameter ($d_{1.3}$)

Abb. 18. Korrektion nach Dwight, Ausgleichung zwischen h und $d_{1.3}$

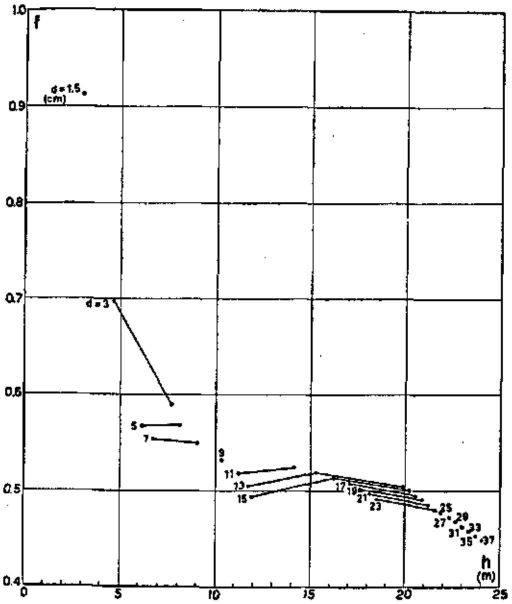

Figure 19. Chapman and Meyer (Dwight) modified for f, partially harmonized relation between form factor and height

Abb. 19. Modifizierte Methode von Chapman und Meyer (Dwight), teilweise ausgeglichener Zusammenhang zwischen f und h

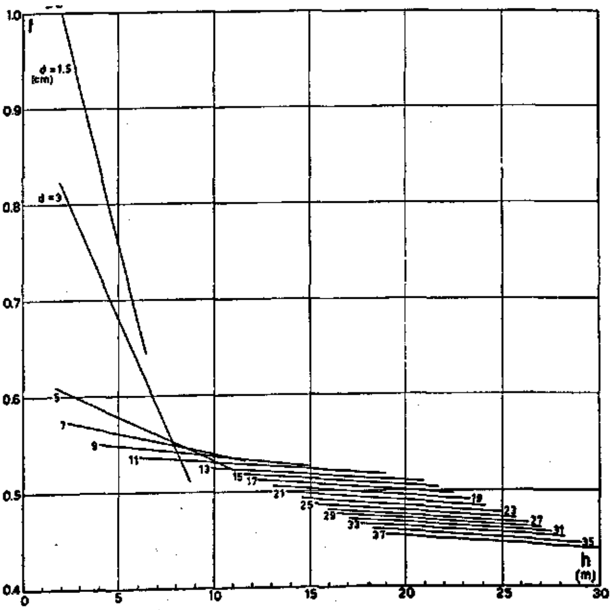

Figure 20. Chapman and Meyer (Dwight) modified for f, completely harmonized relation between f and h

Abb. 20. Chapman und Meyer (Dwight), völlig ausgeglichener Zusammenhang zwischen f und h

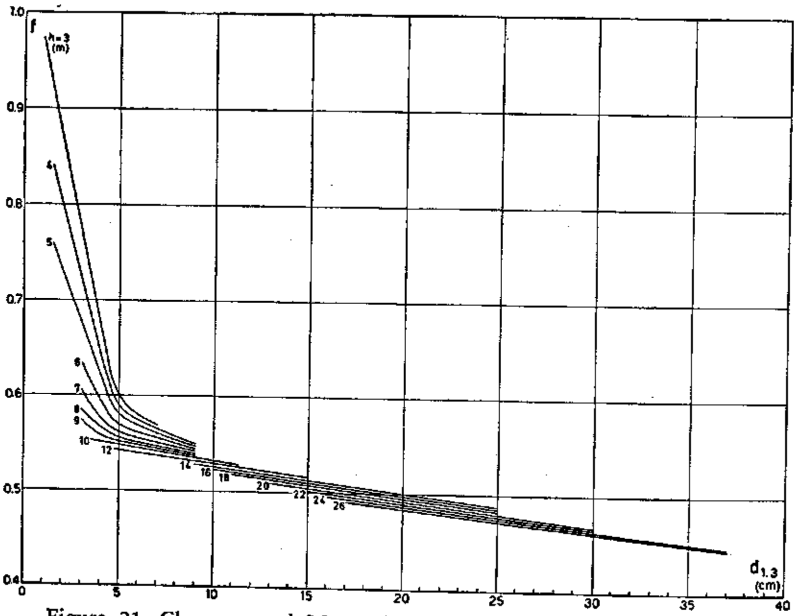

Figure 21. Chapman and Meyer (Dwight) modified for f, final chart

Abb. 21. Chapman und Meyer (Dwight), endgültiges Diagramm

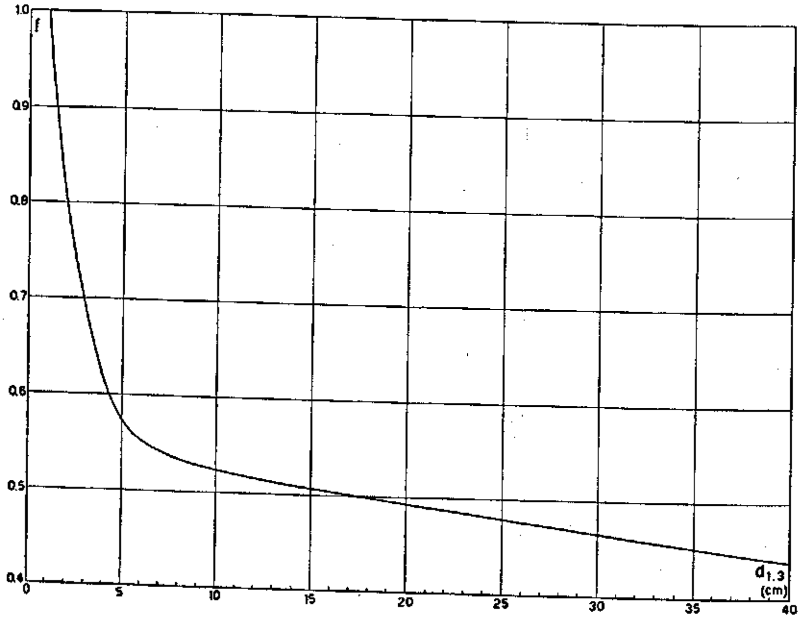

Figure 22. Harmonization of form factor on breast height diameter ($d_{1.3}$), regardless of height

Abb. 22. Ausgleichung von f, nur auf $d_{1.3}$

6. TABULATION

If there is only one independent variable — usually the diameter at breast height — it is obvious that it will be placed in the first column of a vertical table consisting of two columns of numbers. Correspondingly, in tables with two entries, it is desirable to arrange the diameters vertically and the heights horizontally. This is usually done, except in Germany and Denmark.

In forestry research it is, as a rule, sufficient (VAN SOEST, 1951) to measure the trees in 1-cm diameter classes. As greater accuracy is certainly not required in actual practice, a diameter interval of 1 cm can be chosen for the table.

Consequently, in the centre of the table the differences between trees of the same height and with diameters increasing progressively by 1 cm are of a certain order of magnitude. Preferably the height interval is given such a value that the corresponding differences in volume are of the same order. This is the case with a height interval of 1 m.

The table should be arranged for quick and easy reference without the risk of mistakes being made. It should be printed in a clear 8-point type which is to be preferred to typescript, although this is also suitable if done with proper care and, if necessary, reduced to about 2 mm height by photographic means.

Another important point is the grouping of the numbers. They can be conveniently arranged in groups of 5 both horizontally and vertically. The various columns can be separated by thin lines and by a heavy or double line after every fifth column. The horizontal rows, on the other hand, can better be separated by a space, with a double space or a line after every fifth row. Finally, it is advisable to repeat the entries on the right and at the bottom of the table.

Furthermore, it is desirable to add to each table some explanatory notes such as those suggested by CHAPMAN and MEYER (1949). They recommend the following form of presentation which might serve as a model for general use:

1. Enclose by heavy lines, the classes within which trees were actually found and measured.
2. The basis, or number of trees measured for each diameter class, on the right, and for each height class, below.
3. The region where the data were collected, and the class or age of the timber, such as old growth or second growth, with age limits, if possible.
4. The unit of volume and the portion of the tree included, such as total volume with or without bark, or merchantable volume; the standard height of stump; and the diameter limit or limits to which measurements have been taken.
5. Method of computing the tree volumes and of constructing the table.
6. Name of author and year.
7. Aggregate deviation of original data from the volume of the same trees as determined from the table, and the average deviation or the standard deviation of individual trees.

7. ADDITIONAL DATA

The volume of standing timber estimated with the aid of tables giving stem wood volumes will, in general, differ from the merchantable volume. After RICHTER, SCHAUER and THIELE (1954) it is possible to construct separate tables, but as the differences are due to several factors, it is better to determine them separately and collect them in auxiliary tables

III. COMPARATIVE INVESTIGATIONS

1. PRELIMINARY RESULTS AND CONCLUSIONS

The fifteen different solutions described under II.5 have all been worked out using the same data. These are denoted by n_1 in the 11th column of Table 1, the dimensions of the trees being specified in Table 11.

The deviation from regression is the best standard for comparing the volume functions found along different routes. Since the independent quantity is sometimes the volume, sometimes the form factor, the relative deviation seemed a suitable standard to compare these different quantities. In the first chapter it was already argued, referring to Fig. 2, that s changes with d. Replacing the absolute by the relative deviation results in a satisfactory improvement for the three d values chosen:

d	s	p_s
6.5	0.01	7
16.5	0.11	6
26.5	0.28	5

With the aid of Fig. 23 it is demonstrated that this also holds for the form factor, although after excluding the 10 observations with the highest form factors — originating from the smallest trees — the use of the absolute deviation in f (horizontal dashed line) must also be considered permissible.

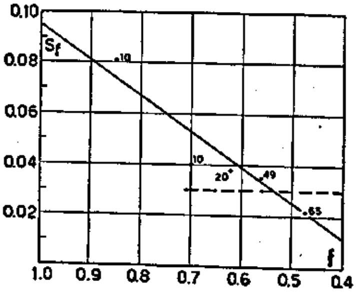

Figure 23. Relationship between average deviations from regression form factors and regression form factors themselves

Abb. 23. Zusammenhang zwischen den durchschnittlichen Abweichungen von Regressionsformzahlen und den Regressionsformzahlen selbst

Afterwards, it appeared that the results found by using the relative deviation as a measure of the differences in volume were quite different from those obtained using it as a measure of the differences in form factor. This is due to the fact that the effect of rounding off the observations in diameter classes of whole cm, and height classes of whole m, is much stronger for variable $\underline{v}$ than for variable $\underline{f}$. So ultimately, all values calculated in v had to be expressed in f before they could be tested according to $\Sigma\ (\frac{Y-\hat{y}}{\hat{y}})^2$. The results are given in Table 12.

The results of some construction methods do not satisfy the condition $\Sigma\ (Y-\hat{y}) = 0$. In this case the level of the regression function differs from the average level of the original observations. Consequently, in such cases the total sum of squares of deviations is larger than when this condition would have been entirely satisfied. For comparison, Table 12 gives both the original and the corrected sum of squares, so that an idea is gained of the extent to which the aggregate deviation, if it exists, has influenced the final result. It appears that there is no aggregate deviation with NÄSLUND's regression equation; in all the graphical solutions it is very small, which is also the case with the function of BÄHLER and BOSMAN. In the method of SCHUMACHER and HALL, the aggregate deviation is somewhat greater than that found according to the method of WOLFF VON WÜLFING. Finally, the largest differences between corrected and uncorrected residual variances occur in the two modifications of BERKHOUT's method.

In the graphical methods, the phenomenon is due to imperfect technique. With the calculated regression equations, disturbance of the original average level only occurs if the independent variable has been transformed beforehand, for, as is illustrated by table 13, the average of a number of transformed observations is not equal to the transform of the average of these observations. The greater the deviations from the independent variable, the more pronounced the effect of transformation: slight for BÄHLER and BOSMAN (log f, small deviation from f), considerable for BERKHOUT (log v only dependent on $d_{1.3}$ or h). For WOLFF VON WÜLFING the aggregate deviation is caused by a systematic underestimation of the volume amounting to ½—3%. This will be more clearly understood if, in Fig. 6, the observed stem curve (solid line) is compared with the calculated one (dotted line). The deviation is particularly evident at the base of the stem.

From the corrected sums of squares it can be deduced that the graphical solution according to CHAPMAN and MEYER, with the form factor as the dependent variable, gives the best results. However, the simpler graphical solution of smoothing f on $d_{1.3}$ only is hardly less suitable and the graphical function $f = F(h)$ also gives very satisfactory results. After these come the regression calculations of NÄSLUND, BÄHLER and BOSMAN and SCHUMACHER and HALL. VISSER's graphical method involves slightly greater deviations of the residual variances, but this may be due to the essentially different basis of this method, which is certainly open to doubt. CHAPMAN and MEYER's ranks last among the methods for the construction of normal volume tables.

The four methods for the construction of tables with one entry show considerably larger deviations than the previous methods. Besides, the difference between harmonizations on $d_{1.3}$ and on h is striking. In both cases the harmonizations of fh and fg give better results than the mathematical solutions with log v. This corresponds with the conclusion given under 1 below, which was taken into account when choosing fh and fg as dependent variables.

The principal conclusions from this comparative investigation are as follows:

1. If the form factor — instead of the volume — is used as the dependent variable, better results are obtained.
2. It matters little whether the form factor is estimated from the diameter only or from diameter and height together.
3. Estimating the volume (or, if more convenient, the so-called form height, fh) from the diameter only, on the other hand, leads to much greater inaccuracies.
4. Estimating v or fg from the height only is most inaccurate.
5. The graphical method should be considered slightly preferable.

The second conclusion is substantiated by the figures of Table 14, which shows the changes of the form factor with diameter and height according to the methods of Wolff von Wülfing, Schumacher and Hall and Näslund as compared with the graphical function $f = F\ (d_{1.3})$ which is independent of height. Within the same diameter class f drops with increasing h according to Wolff von Wülfing, it increases according to Schumacher and Hall; it decreases in the first and increases in the second half according to Näslund. These discrepancies are only due to the differences in the method of harmonizing, the qualities of the material being represented incorrectly. This is a further justification of harmonizing f only on d and, moreover, explains why this method produces such good results.

2. CONTINUATION OF THE INVESTIGATION

The fifth conclusion is not yet very satisfactory. The differences between the results of the best graphical and the best mathematical method — Näslund's, using 3 parameters — justify the question whether a better mathematical solution is possible. Two possibilities have been considered: Näslund's function with 4 parameters, and a mathematical expression for the graphically determined relation between f and d.

The first-mentioned possibility has been tested with the aid of the method of regression diagrams developed by Frisch (1934) — see also Anonym (1942) —, which is also known as the bunch map analysis. The aim of this method is to find out whether the addition of another — in this case a fourth — independent variable is of any use. By interchanging the dependent and independent variables in a regression equation different estimates of the same relationship are obtained, which are plotted as rays emanating from the origin of a system of coordinates. The increase in density of the "bunch" when another independent variable is added indicates an improvement, a decrease ("explosion") means the opposite.

The bunch map analysis comprises the estimates of both the regression coefficients of the complete equation and those which can be derived from it by omitting one or several variables. In the case under consideration Näslund's expanded function:

$$f = b_0 + b_1 \frac{1}{h} + b_2 \frac{h}{d_{1.3}} + b_3 \frac{h}{d^2_{1.3}}$$

was taken as a basis, simplified to:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3.$$

Omitting one or several variables leads to considering the following sets of variables:

$y\ ;\ x_1;\ x_2$
$y\ ;\ x_1;\ x_3$
$y\ ;\ x_2;\ x_3$
$x_1;\ x_2;\ x_3$
$y\ ;\ x_1$

$y\ ;\ x_2$
$y\ ;\ x_3$
$x_1;\ x_2$
$x_1;\ x_3$
$x_2;\ x_3$

The estimates resulting from the simplest equations are first plotted. Thus each time two rays are obtained which enclose a certain angle (see Fig. 24, top row of 6). Subsequently, the diagrams of the regression equations with one more variable are given (Fig. 24, 2nd and 3rd rows). This change is attained in various ways by adding one variable to one of the simplest regression equations. In the last stage (Fig. 24, 4th row) the last variable is added.

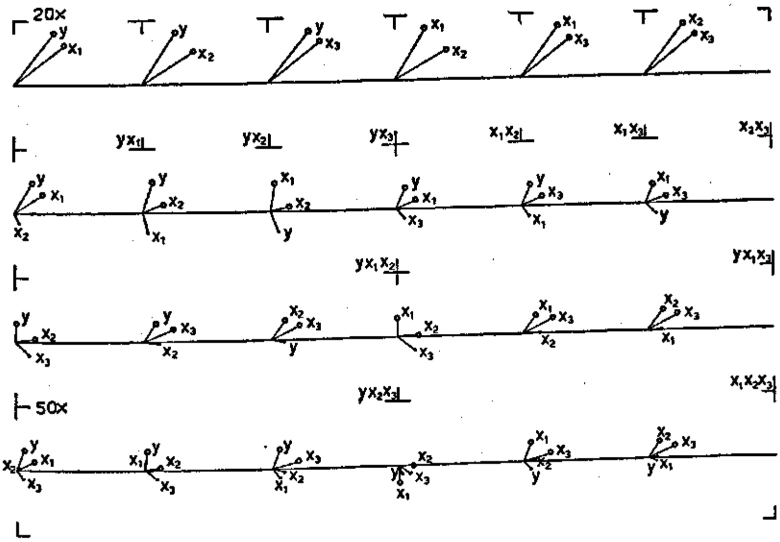

Figure 24. Regression diagrams (bunch map) according to Frisch, as obtained by testing Näslund's form factor equations

Abb. 24. Regressionsdiagramme (bunch map) nach Frisch, erhalten bei der Prüfung der Näslund'schen Formzahlgleichungen

As appears from Fig. 24, the 4th term of NÄSLUND's function not only fails to effect an improvement, but "explosion" occurs even with 3 independent variables. This confirms the conclusion based on Table 14, viz. that it is sufficient to estimate f from $d_{1.3}$ only.

Thus, a regression equation for this function $f = F(d_{1.3})$ had still to be found. The idea that the height would have some influence was not dismissed beforehand. It might be imagined that true form factors are only dependent on the diameter, but that breast-height form factors are also influenced by a relative shifting of the measuring height. It was then decided to choose the function $f = a + b \log x$, taking in one case $x = \frac{h - 1.3}{d_{1.3}h}$, in the other $x = d_{1.3}$.

The choice of the simple function $f = a + b \log x$ proved to be correct if the trees with $d_{1.3} < 5$ cm were discounted (see Fig. 25). In addition, it can be deduced from Table 15 that the correction factor $\frac{h - 1.3}{h}$ is of no importance.

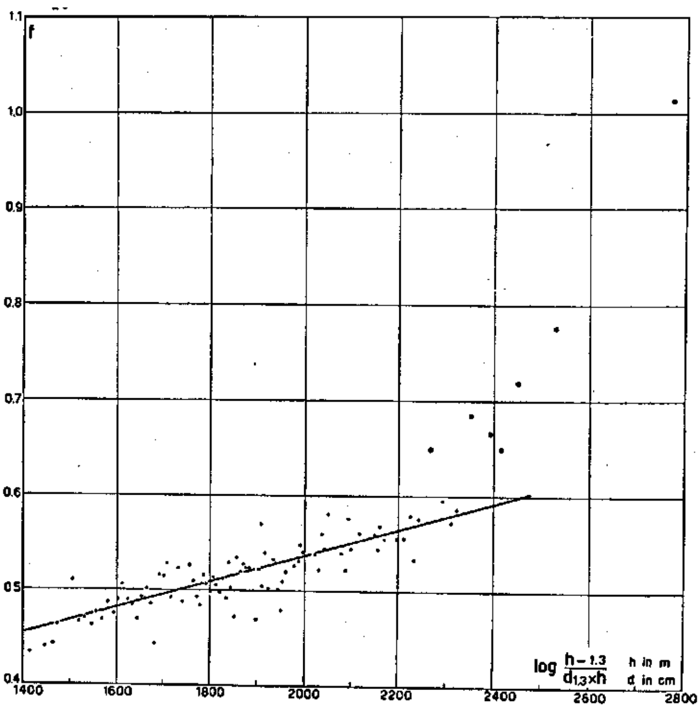

Figure 25. Relationship between f and log $\frac{h-1.3}{d_{1.3}\,h}$

Abb. 25. Zusammenhang zwischen f und log $\frac{h-1.3}{d_{1.3}\,h}$

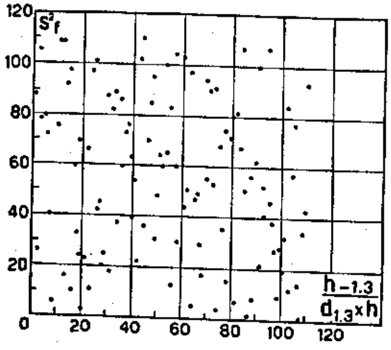

Figure 26. Diagram showing the absence of rank correlation between $\overline{s}^2_f$ and log $\frac{h-1.3}{d_{1.3}\,h}$

Abb. 26. Graphische Darstellung, welche zeigt dass keine Rangkorrelation zwischen $\overline{s}^2_f$ *und* $\log \frac{h-1.3}{d_{1.3}\,h}$ *besteht*

Now that the smallest trees (with the greatest deviations from f) had been eliminated, a comparison on the basis of percentage deviations was no longer necessary. As is shown by Fig. 26, there is no rank correlation between the mean variance of the form factor per diameter class and the diameter [3]). For the sake of simplicity the function $f = a + b \log d_{1.3}$ is to be preferred. The linearity test showed this to be sufficiently linear ($P = 0.50$!) for the range of $d_{1.3} \geqq 5$ cm, which comprised 466 of the 518 trees. When the standard deviation of the graphical solution was estimated once more for the 466 trees with $d \geqq 5$ cm a value of $s_{\hat{f}} = 0.036$ was found, the same as for the two functions of Table 15. In this way, a further substantiation of the 5th conclusion had been obtained, which implies that the results of graphical methods and mathematical solutions are equivalent.

Hence, the answer to the question as to which method of constructing a volume table is to be preferred depends on other factors, such as the investigator's equipment. A calculation of the regression offers the advantage that the accuracy of the function can be determined at the same time, and that with a simple function the calculation work can be done by assistants of secondary education. However, the graph is indispensable for orientation, if one does not want to resort to an "emergency formula" with the risk that the properties of the material have not sufficiently been taken into account (HAMMING, 1949).

For Japanese larch, use was made of the function $f = a + b \log d_{1.3}$ to construct the final volume table as far as trees with $d_{1.3} > 5$ cm were concerned; for smaller trees, the results of the graphical method were used. This solution is, perhaps, somewhat less elegant, but NÄSLUND, too, had to treat the group of very small trees separately. In this respect, the graphical solution seems to have the advantage over calculation, but this is only a seeming advantage, for here, too, it appeared necessary to treat the small trees separately and to use 0.5 cm diameter classes to avoid irregularities. The form factors so calculated are given in table 16.

3. TESTING THE TABLE

It is estimated that the 518 trees used to test the volume functions constitute about 1/6000 part of the Japanese larch population in the Netherlands. It had, therefore, to be ascertained to what extent this "sample" could be considered representative of Japanese larch in the Dutch forests. To this end, the parameters of the regression equation $f = a + b \log d_{1.3}$ were determined once more with the aid of another "sample". This consisted of 273 trees, of which more than half were obtained from clear-felled areas (Table 1, group n_4, column 14). The parameters of the new data are given in Table 17. The results of an analysis of covariance of the two groups of trees are given in Table 18 and demonstrate that the groups may be considered equivalent. In order to use all the observation data the final volume table (Table 19) was based on the two groups of trees combined, i.e. 791 trees.

The table was further tested using data published by TUTEIN NOLTHENIUS

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[3]) For the function $f = a + b \log \frac{h-1.3}{d_{1.3}h}$.

(1946) — see Table 20 — and additional data from two lots of 100 trees, kindly measured by the *"Dienst der Landelijke Eigendommen"* (Department of Rural Properties) of the Municipality of Apeldoorn. The deviations of these Apeldoorn lots were — 2.9% and + 7.3%, respectively. A final check was carried out on 261 trees measured by the Department for Forest Mensuration and Management of the Forest Research Institute; the actual total volume of these trees differed from the calculated volume by — 0.5%. Unlike the control data collected by us the data collected by others referred to small trees, so that the test was made on a sufficiently broad basis.

The calculated standard error of the table ($s_{\bar{f}}$) was 0.0013, which, at a mean form factor of 0.5, is about $\frac{1}{4}$ %. For a volume table this standard error is acceptable.

The results have also been compared with Japanese data. Thanks to the kind cooperation of professor dr. SCHOBER, Hann. Münden, it was possible to compare the results of the Japanese authors TERAZAKI, SARUYA, NAKAJIMA and MINE with the Dutch ones. As appears from the stand form factors, illustrated in figure 27, the Dutch data are in no respect inferior to the, otherwise rather heterogeneous, Japanese ones.

In addition, the European volume tables for Japanese larch constructed by the investigators ANDERSEN (Denmark), HUMMEL, IRVINE and JEFFERS (Great Britain) and SCHOBER (Germany) have also been compared with the Dutch table on the basis of total stem wood volume for which an estimated allowance has been made where necessary. See Table 21, which also includes data of the Japanese volume table of TAKAHASHI. The agreement is, on the whole, satisfactory, especially if it is taken into account that there are considerable differences in the treatment of stands and the methods of measuring trees between

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27

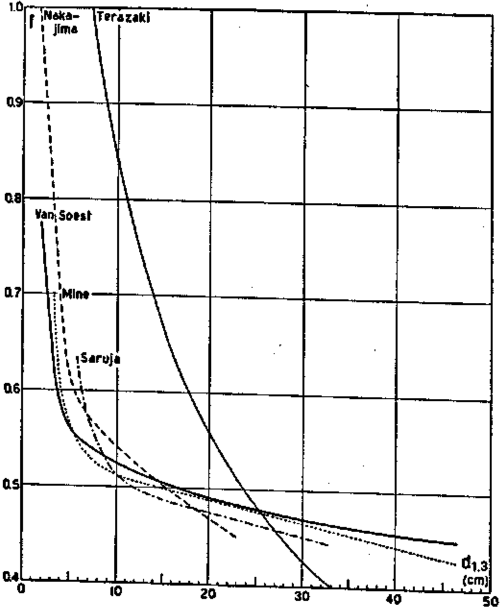


Figure 27. Comparison between stand form factors according to some Japanese research workers and those found by the author

Abb. 27. Vergleich zwischen Bestandesformzahlen für Japanlärche nach einigen japanischen Autoren und den vom Verfasser errechneten Bestandesformzahlen.

the countries concerned. The contrast between TAKAHASHI and SCHOBER regarding the relationship between form factor and height is remarkable.

A final test was carried out using the original numerical data of professor SCHOBER's volume investigation, which he kindly placed at the author's disposal.

For all 769 trees the differences between the actual (German) form factors and the (Dutch) regression form factors were determined. The cumulative frequencies of these data are presented in Fig. 28; the average difference is 0.0015, i.e. about once the standard error.

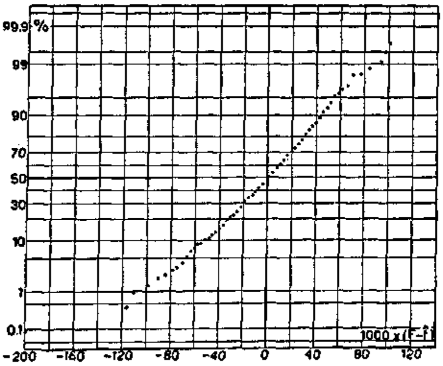


Figure 28. Results of testing the Dutch standard volume table with German observation data kindly provided by prof. Schober

Abb. 28. Ergebnis der Prüfung der holländischen Massentafel mit Beobachtungsdaten welche dem Verfasser freundlicherweise von Prof. Schober zur Verfügung gestellt wurden. Die Abweichungen sind im Wahrscheinlichkeitsnetz aufgetragen

IV. ACCURACY OF VOLUME ESTIMATES

1. VOLUME ESTIMATES WITH THE AID OF THE FUNCTION FOUND (TABLE WITH TWO ENTRIES)

In measuring standing timber the basal area is determined with some degree of precision and is converted into an estimate of the actual volume with the aid of a volume function, generally a standard volume table. If the diameter of all the trees of a stand and the height of 25 of them are measured once, it may be assumed that the basal area can be determined with an accuracy of within 1% (see Van Soest, 1951) and the cylinder volume of the stand with an accuracy of within 2% (see Fig. 29). As is shown in Fig. 30, the form factor level of the individual stand may display a deviation from the general level of the function of up to 10%. If a reliable estimate of the total volume of a large area is required, still greater individual deviations are quite acceptable, provided that they are normally distributed. It is therefore important to analyse the consequences of the use of tables with one entry. On the other hand, for an accurate estimate of the volume of a single stand, the use of a standard volume table may be a serious drawback. Consequently, it must also be ascertained to what extent the accuracy of volume estimates can be enhanced if use is made of tables with more than two entries.

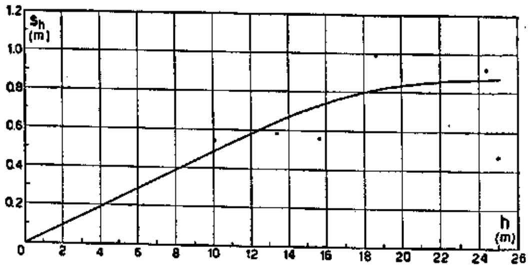


Figure 29. Relationship between the standard deviation of the height measurement (deviation from regression) and the mean stand height

Abb. 29. Zusammenhang zwischen mittlerer Abweichung der Höhenmessung (Abweichung von Regression) und mittlerer Bestandeshöhe

2. VOLUME ESTIMATES WITH A TARIFF TABLE (TABLE WITH ONE ENTRY)

Among the methods included in the comparative investigation of the volume of Japanese larch there are four general tariff tables. Of these, Berkhout's logarithmic function (Table 12, no. 4) and the harmonization of form height on diameter (Table 12, no. 14) have the lowest sum of squares of deviations, which amounts to about four times that of the related functions with two variables (nos. 7 and 12, respectively).

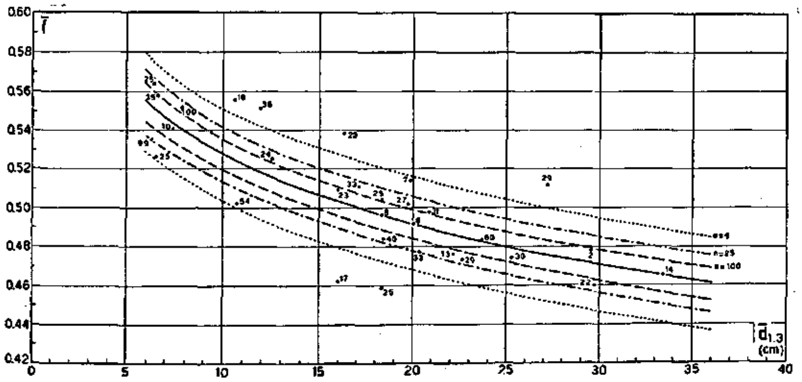


Figure 30. Diagram showing variation in form factor between stands. The drawn curve represents the regression equation of the standard volume table, the dashed and dotted curves represent the 95% confidence interval for means of 9, 25 and 100 observations, respectively. The figures refer to numbers of observations

Abb. 30. Graphische Darstellung der Variation in Schaftformzahlen zwischen Beständen. Die gezogene Kurve stellt die Regressionsgleichung der Massentafel dar, die gebrochenen Linien geben den Streuungsbereich bei 95% Wahrscheinlichkeit für Mittelwerte von bezw. 9, 25 und 100 Beobachtungen an. Die Nummern beziehen sich auf die Anzahl der Beobachtungen

If the deviations are normally distributed, the volume of the standing crop of a forest area could, therefore, be estimated with the same accuracy by applying a tariff table and taking four times as many samples as when a normal volume table is used. Local differences in establishment and treatment of stands may, however, lead to systematic deviations from the tariff table. If, therefore, the volume of a unit of management (forest range) is estimated with the aid of a general tariff table on the basis of measured diameters only, it is improbable that the deviations will be balanced to a sufficient degree. Even for an estimation of the standing crop of an entire country, the use of a tariff table constructed on the basis of the test measurements made in this investigation is not to be recommended. For, a general tariff must be based on proportionally the same numbers of short, medium and tall trees occurring in the population and a general survey of the latter is not known.

A local volume table can be derived from a standard volume table if the average height of each diameter class for each individual area is known. It should, if possible, first be ascertained by means of experimental measurements whether the local volume level differs from the general one.

The objection that general tariffs are so much less accurate than tables with two entries can be met to some extent by constructing a number of tariff tables, say three, for relatively short, normal and tall trees. Such a multiple general tariff table for Japanese larch is given in Table 43. It has been constructed in a slightly different form; the starting point is the normal tree according to the yield table for Japanese larch (VAN SOEST, 1954), and for every metre's difference in height the corresponding change in volume has been stated.

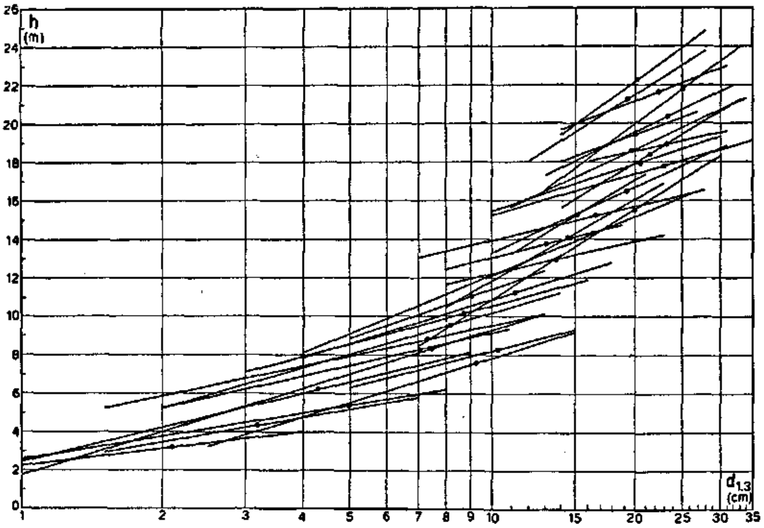


Figure 31. A number of (semi-logarithmically transformed) height curves for Japanese larch stands

Abb. 31. Eine Anzahl (halblogarithmisch transformierte) Höhenkurven für jap. Lärchenbestände

3. VOLUME ESTIMATES BASED ON NORMAL HEIGHT CURVES

If the best possible estimate of the volume of a stand must be made with the aid of a normal volume table the regression volume must be estimated for every diameter class measured separately, so that the regression height of each diameter class must be known. The estimation of the regression of height on diameter requires a fairly large number of height measurements, which must be distributed over all diameter classes.

If, however, normal height curves can be used a calculation of the volume per diameter class can also be made on the basis of a limited number of height measurements. For Japanese larch these curves have been traced by harmonization of 175 height curves of sample plots with in all 11,927 height measurements. These height measurements were smoothed according to HENRIKSEN's method (1950) : $h = a + b \log d_{1.3}$. The 175 height curves were then normalized according to the equation:

$$\tan \vartheta = a + b \log d_g,$$

where ϑ is the angle of the normalized height curve and d_g the diameter corresponding with the mean basal area. Hence, the slope changes with d_g, and is, at a given d_g, independent of the stand height, h_g. In figs. 31 and 34 a number of original and normalized height curves are illustrated. Figs. 32 and 33 demonstrate that it matters little whether the independent variable is log d_g or log h_g. For the function $\tan \vartheta = a + b \log d_g$ a value of

$$\tan \vartheta = -0.1305 + 0.53373 \log d$$

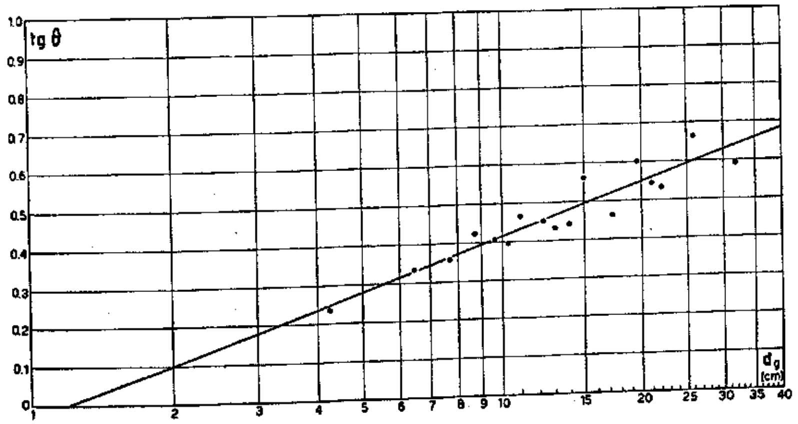


Figure 32. Relationship between gradient of regression line $h = a + b \log d_{1.3}$ and mean diameter of the stand

Abb. 32. Zusammenhang zwischen Neigungswinkel der Regressionslinie $h = a + b \log d_{1,3}$ und mittlerem Bestandsdurchmesser

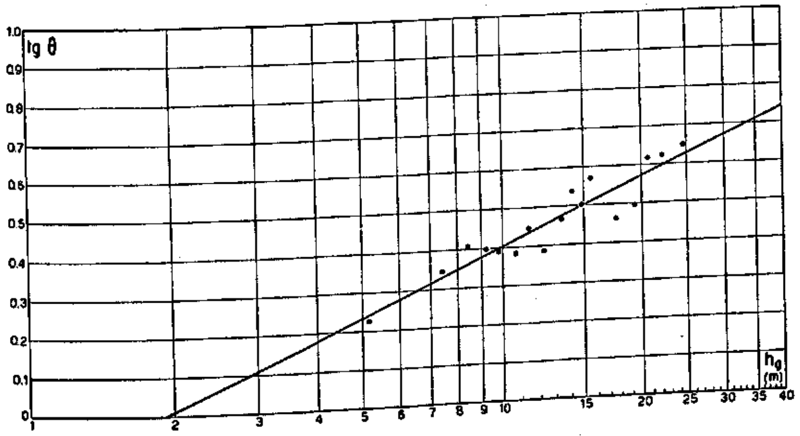


Figure 33. Relationship between gradient of regression line $h = a + b \log d_{1.3}$ and mean height of the stand

Abb. 33. Veränderung des Neigungswinkels der Höhenregressionslinie mit mittlerer Bestandeshöhe

was found. It should be noted that these parameters only hold for paper with the same scale ratio as that used in this investigation (Fig. 31).

The normalized height curves have been used to construct Table 22. The regression volumes it contains are derived from the normal volume table (Table 19). As far as accuracy is concerned Table 22 is only slightly inferior to Table 19, as the two sources of errors now introduced (normalized height curves and stand heights rounded off to whole metres) are comparatively unimportant and, moreover, are not of a systematic character. As a rule, when using normal height

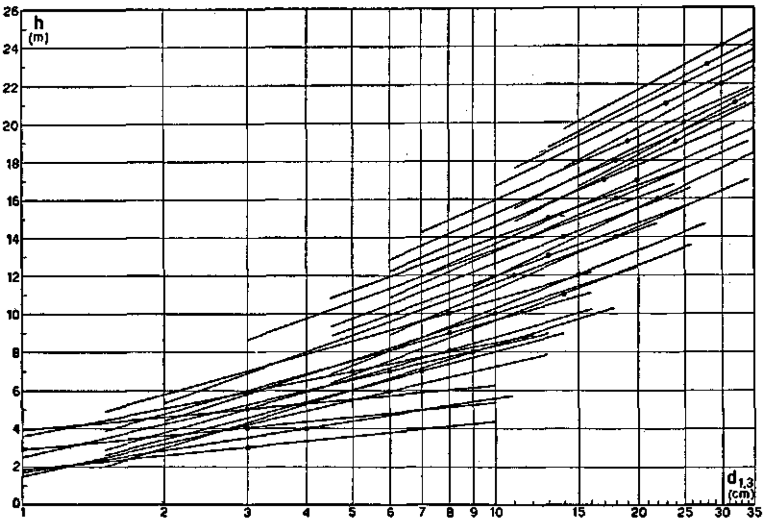


Figure 34. A number of normalized (transformed) height curves for Japanese larch

Abb. 34. Eine Anzahl (transformierte) Einheitshöhenkurven für japanische Lärche

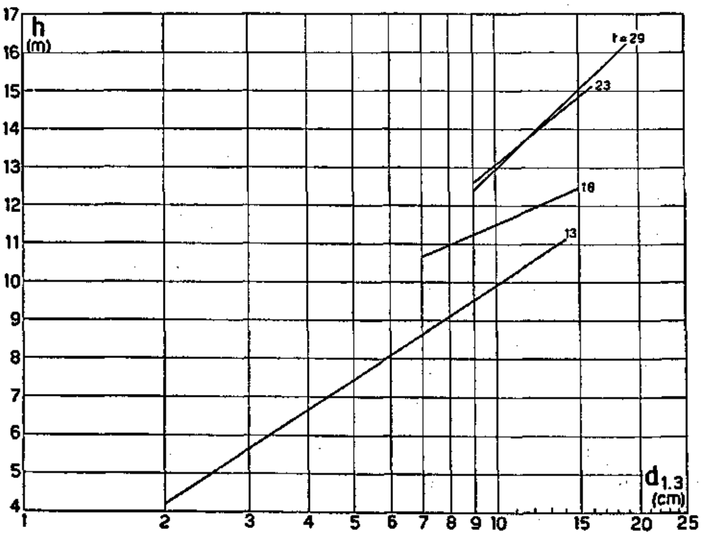


Figure 35. Transformed height curves of a young sample plot in Japanese larch (JL 3) at different ages (t)

Abb. 35. Transformierte Höhenkurven einer jungen Versuchsfläche (JL 3) in japanischer Lärche in verschiedenen Alter.

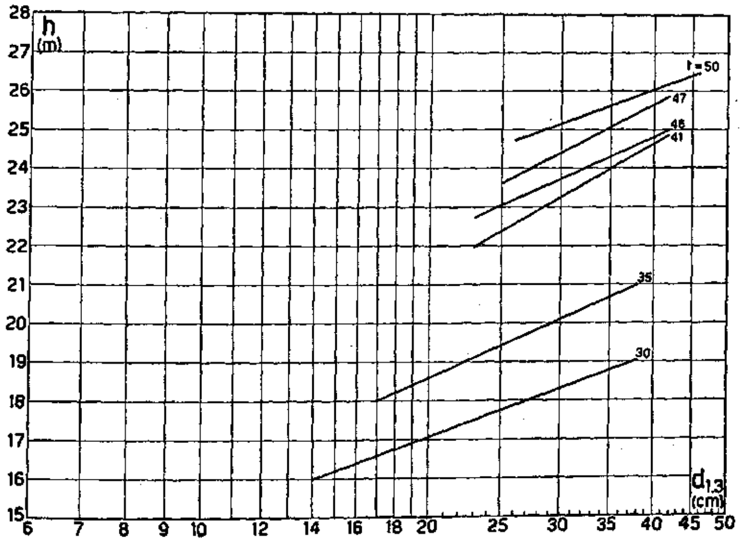


Figure 36. Transformed height curves of an older sample plot (JL 1) at different ages

Abb. 36. Höhenkurven einer älteren Versuchsfläche (JL 1) in verschiedenen Alter

curves for Japanese larch there is no advantage to be gained by carrying out more than four height measurements per stand.

Figs. 35 and 36 demonstrate that the height curve of a stand changes with its age, so that if the measurements are repeated, d_g and h_g must be determined again. Accurate determination of the diameter with the average basal area is not strictly necessary; this can be approximated by means of WEISE's counting rule and as far as Japanese larch is concerned it must be borne in mind that d_g lies at 45% from the highest observed value of the cumulative frequency distribution of the diameter. The percentage location of d_g was determined on 128 objects, an average value of 45.15 ± 0.35 being found (standard deviation of the individual determination: 3.9).

4. VOLUME FUNCTION WITH SEVERAL PARAMETERS

To find out how a volume table with a smaller residual variance than that of $f = a + b \log d$ could be constructed it was first ascertained, by means of correlation calculations, what diameter of the tree is most characteristic of the volume. To this end the HOHENADL diameters $d_{0.1h}$, $d_{0.3h}$, $d_{0.5h}$, $d_{0.7h}$ and $d_{0.9h}$ as well as $d_{0.05h}$ and $d_{1.3}$ were chosen. The correlation of these diameters with the "theoretical" diameter d_t of a cylinder of the same volume (calculated according to HOHENADL's method) and height as the tree was determined. It can be concluded from Table 24 and Fig. 37 that $d_{0.3h}$ is the most representative of the volume of the tree. In combination with the diameter at breast height, which is known in any case, $d_{0.5h}$ gave better results; the multiple correlation coefficients were 0.881 and 0.894, respectively.

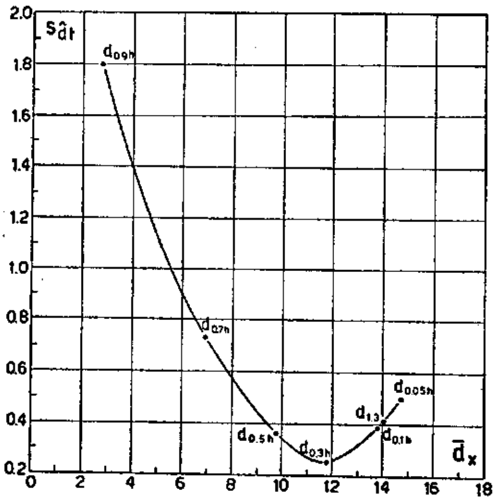


Figure 37. Relationship between the standard deviation from the regression line $d_t = a + bd_x$ and the mean value of d_x

Abb. 37. Zusammenhang zwischen der mittleren Abweichung von der Regressionsgeraden $d_t = a + bd_x$ *und dem durchschnittlichen Wert von* d_x

Compared with a second measuring point at a fixed height, say at 6 m above the ground, $d_{0.3h}$ and $d_{0.5h}$ have the drawback that they are more difficult to measure. In spite of the circumstance that d_6, as the second independent variable, produces less accurate estimates of d_t ($R = 0.787$) than $d_{0.3h}$ or $d_{0.5h}$ it has been chosen as a starting point for the regression equation $f = a + b_1 \log d_{1.3} + b_2 \log d_6$ with $R = 0.77$ (for $f = a + b \log d_{1.3}$ a value of $r = 0.58$ had been found). A test revealed that f was also dependent on height (see Fig. 38), so that — as was also shown by the bunch map analysis — expansion of the function to

$$f = a + b_1 \log d_{1.3} + b_2 \log d_6 + b_3 \log h \quad (R = 0.90)$$

is justified. With this function the differences between stands are considerably reduced (see Table 25) : with one exception they become insignificant (Table 26).

The new function, initially calculated from the observation material indicated by n_3 in Table 1 (251 trees), was tested with the 290 trees of group n_4. Although — as shown by Table 27 and 28 — not all the remaining differences between stands are insignificant there is, on the whole, good agreement. The two groups of data, with the exception of the extreme values of JL 14, have therefore been combined to n_6 with 524 trees, with the result that for the final function the following values were found:

$a = 1.245$
$b_1 = -1.749$
$b_2 = +1.692$
$b_3 = -0.415$
$s_{\hat{f}} = 0.016$

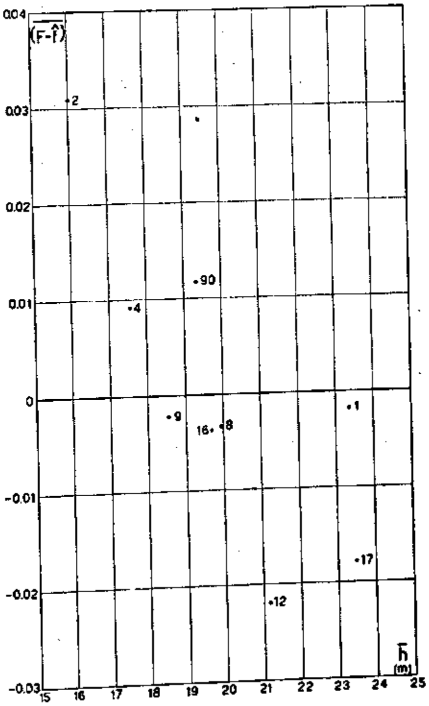
$R = 0.90$
$s_{b1} = 0.04$
$s_{b2} = 0.04$
$s_{b3} = 0.02$

Figure 38. Relationship between deviations from regression with the equation

$$f = a + b_1 \log d_{1,3} + b_2 \log d_6,$$

and height

Abb. 38. Zusammenhang zwischen Abweichungen von der Regression bei der Gleichung $f = a + b_1 \ \log \ d._{1,3} \ + b_2 \log d_6$ *und Höhe*



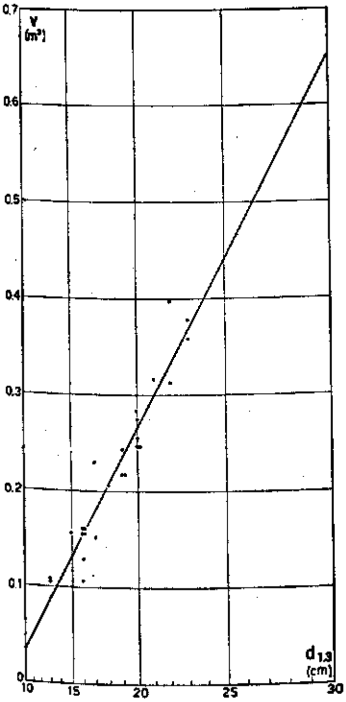


Figure 39. Smoothing of v on d^2 according to Kopezky-Gehrhardt. The d-scale on the graph is a quadratic one

Abb. 39. Ausgleichung von v auf d2 nach Kopezky-Gehrhardt. Die d-Achse hat eine kwadratische Einteilung.

Subsequently, Table 29 was constructed. This table consists of two parts. Table 29a gives the partial form factors f_1 derived from the two diameters. Table 29b contains the partial form factors f_2, which are dependent on height. The total regression form factor is found by addition: $f = f_1 + f_2$.

The use of the tables is illustrated by an example given in table 30. The breast height diameters of all trees in a stand are measured (column 2, Table 30) and in addition, d_6 and h are measured on a sample of say, 25 trees. With the aid of Tables 29 a and b and an ordinary basal area or a cylinder volume table, the volumes of the sample trees are derived from these data as shown in Table 31. Subsequently, a regression line must be constructed from the sample tree data, for instance, the volume - basal area line of KOPEZKY - GEHRHARDT (Fig. 39). Finally, the regression volume for each diameter is entered in the diameter frequency distribution (Table 30) and the calculation completed. It may be assumed that the volume thus calculated will differ from the actual volume by at most 3%.

V. SILVICULTURAL ASPECTS OF THE DIFFERENCES IN FORM FACTOR BETWEEN STANDS

The differences in form factor level between stands discussed in the preceding chapter are due to a difference in taper. This is one of the factors determining the quality of the wood. For poles this taper is of decisive importance for the assortment, and it is also partly responsible for the value of saw logs. For the silviculturists it is, therefore, important to know whether any silvicultural measures are conducive to a slight taper.

To answer this question the data would have to be subjected to a statistical study. The number of stands (28) is, however, too small for this purpose, but the available data do allow some preliminary conclusions to be drawn.

The observed differences are not likely to be of genetic origin. It must be assumed that the stands examined have originated from commercial seed and that any differences in hereditary properties between parent stands have been obliterated by seed mixing.

An attempt to attribute the differences observed to environmental factors will, therefore, probably be more successful. These influences may be due to treatment or to natural causes such as site factors, diseases, etc.

In general, the literature does not provide information on the degree to which a disease may influence the development of each of the three volume components diameter, height and form factor separately. An exception is a publication of Vité (1953) from which it appears that *Taeniothrips laricivorus* Krat. checks the height growth but does not interfere with the diameter growth. Consequently, the top does not increase in length, but in diameter, which leads to a less tapered stem. The author's own observations seem to indicate that *Coleophora laricella* Hbn., on the contrary, checks the diameter growth in particular, but it was not possible to ascertain at the same time whether these attacks also have an influence on the development of the form factor as well.

It may be imagined that chronic diseases and annually recurring insect pests may lead to significant differences in form factor level. Although notes concerning diseases occurring in the sample plots included in the investigation have not been taken regularly, sufficient data are known for this pathological explanation to be rejected as being not very acceptable. For, stands of slow growth, which are attacked by pests more frequently, and to a greater degree than stands developing rapidly, would have to have generally lower form factors. Fortunately, this is not the case, otherwise it would not be permissible to use general volume tables.

Of the silvicultural aspects spacing, mixing and thinning may be mentioned as possible causes. It appears that widely spaced plantations (D 19, JL 14, JL 41 and, to a lesser degree, JL 12, JL 16, JL 8 and JL 17) have low form factors, whereas in dense plantations (JL 2, to a lesser degree also JL 39, JL 4 and JL 3) higher form factors occur. The form factor in JL 1, however, is of normal level, although this stand is very widely spaced, whilst in JL 25, which was planted at a normal spacing of 4000 trees per ha, the deviation is much greater than would be expected.

Upon closer inspection it appears that among the old permanent sample plots (JL 1 to JL 25 incl.) there are only three in which the trees have always had sufficient space: JL 1, JL 2 and JL 25. The slow growing JL 25 was heavily thinned about 1930 for underplanting with Douglas fir and has subsequently been kept at a low density. In JL 2 the district officer has personally marked all the thinnings, in a way that can still serve as a perfect model. JL 1 did not need any thinning for 30 years on account of its wide initial spacing; after that time heavy thinnings have been regularly carried out.

On the other hand, there are widely spaced plantations which were lightly thinned, if at all, and whose form factors are below the normal level, as well as plantations with normal and high degrees of density which were lightly thinned and also had rather low form factors. All this provides sound ground for supposing that, in the first instance, spacing determines the level of the form factor, but that it also depends on the subsequent thinning treatment as to what extent the variance thus brought about is enhanced or reduced. ZIMMERLE's observations (1951) that silver fir in selection forests has higher form factors than in even-aged forests point in the same direction.

The impression is conveyed that the tree is most active as regards wood formation in the neighbourhood of the living crown and that the diameter growth of the lower part of the stem only takes place in view of a minimum requisite reinforcement. The extent of this growth is governed by external conditions, so that changes of these call forth reactions. For instance, NYSSÖNEN (1952) found that after a selective thinning of Scots pine there is first increased diameter growth at the foot of the stem, which does not occur higher up the stem until a few years later.

The observations have not shown that an essentially different development of form factors occurs in mixed stands; obviously the influence of spacing is more important than that of mixing.

From the differences in form factor level between stands it can be deduced that in the first place a sufficient density is necessary to prevent the trees from exhibiting too rapid a diameter growth in the lower part of the stem in their first years, which will lead to too considerable a taper.

As soon as the canopy has begun to close, however, the stands must be thinned to such a degree that crowns of sufficient dimensions are maintained in order that the diameter growth may proceed unchecked, particularly in the upper part of the stem. Comparatively narrow spacing reduces, not only the relative, but also the absolute taper and this is the main factor in determining the suitability of a stem as a pole. For the production of poles, it is therefore desirable to only carry out moderate thinnings.

VI. ADDITIONAL DATA FOR PRACTICAL APPLICATION

In actual practice the merchantable volume differs from the volume measured on standing trees because of the allowances that have to be made for stump and top-wood and because the volume is derived from only one diameter (at half the merchantable height). To these regularly occurring differences, must sometimes be added losses due to defects, differences on account of under bark measurements as well as differences due to rounding down and shrinkage due to seasoning.

According to Fig. 40 stump wood losses increase with the diameter at breast

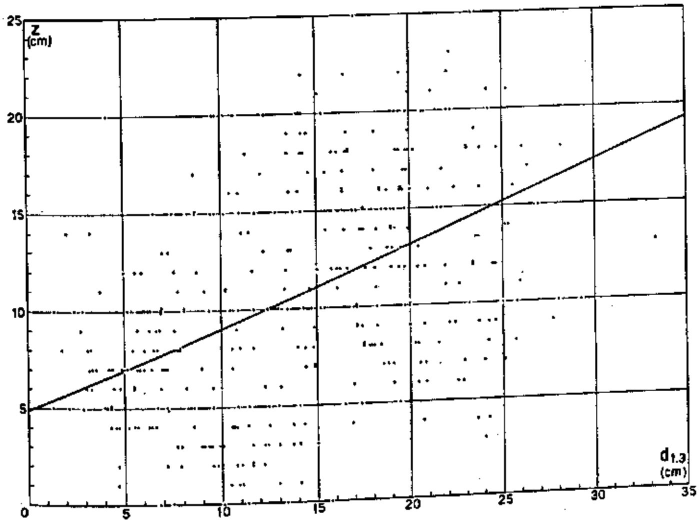


Figure 40. Relationship between stump height (z) and breast height diameter

Abb. 40. Zusammenhang zwischen Stockhöhe (z) und Brusthöhendurchmesser

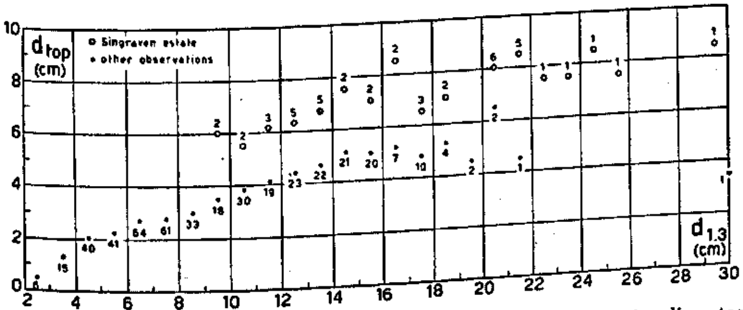


Figure 41. Relationship between top diameter and breast height diameter

Abb. 41. Zusammenhang zwischen Zopfdurchmesser und Brusthöhendurchmesser height and amount to about 0.1 or 0.2 m depending on whether the diameter at breast height is more or less than 25 cm. As shown by Fig. 41 the minimum top diameter (as observed in forestry practice) also increases with the diameter at breast height and, for Japanese larch, is about equal to that of Scots pine (Fig. 42). The 621 observations for this top diameter function of Japanese larch have been made on trees other than those used for the main investigation.

Table 33 shows that lower form factors are found if the trees are measured in

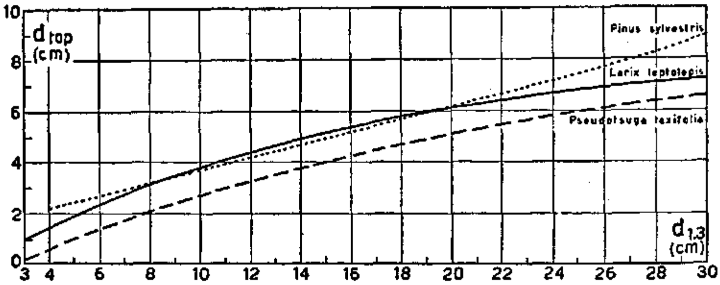


Figure 42. Regression chart for estimating top diameter from diameter at breast height, for Japanese larch, Scots pine and Douglas fir

Abb. 42. Ableitung des Zopfdurchmessers aus dem Brusthöhendurchmesser, für japanische Lärche, Kiefer und Douglasie

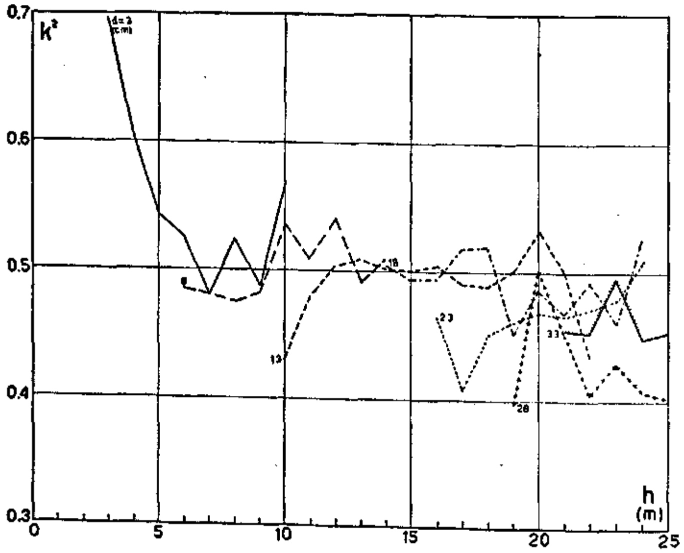


Figure 43. Relationship between form factor based on diameter at half the total height only (k^2) and height (h), for different diameter classes .

Abb. 43. Zusammenhang zwischen Schaftformzahl, bezogen auf Durchmesser in halber Höhe (k^2) und Scheitelhöhe (h), für verschiedene Durchmesserklassen one section only; the differences between these and the form factors determined in the conventional way are, however, not constant. Hence, the trend of the form factors based on $d_{0.5h}$ and $d_{1.3}$ differs from that of the stem wood form factor, but can — as appears from Fig. 43 — be regarded as a function of the diameter at breast height only. The influence of measuring the trees in a single section on the result of the volume calculation is greater than that of reductions for stump and top wood. Table 34 gives the percentages by which the measurements of standing timber may be reduced to obtain the equivalent commercial volumes of felled trees measured in a single section. Thanks to the kind co-operation of Mr. W. BRANTSMA, the then deputy-surveyor of the Royal Forest at Het Loo, these figures were checked and the results are summarized in Table 35.

With regard to the percentage of bark, Tables 36 and 37 contain the relevant data of SCHOBER and of HUMMEL, IRVINE and JEFFERS. The bark thickness is a factor that varies considerably, but, as appears from tentative observations, it is not necessary to take a large number of measurements per tree to determine it (Table 38). The under and over bark diameters measured at 0.3h are a suitable starting point for estimating the total bark percentage of the tree (Table 39). Owing to the great differences in bark percentage between any two trees, however, it is desirable to measure the bark thickness at breast height and to derive from this the bark percentage in order to arrive at a reasonably accurate estimate. Table 40 fills this requirement. It has been drawn up on the basis of the regression equation $y = a + bx$, where y is the bark percentage at 0.3h and x the bark percentage at 1.3 m. Using 319 trees the following values were found:

$\bar{x} = 0.1757$ $\quad s_{\hat{y}} = 0.0267$
$\bar{y} = 0.1773$ $\quad r = +0.860$
$a = 0.0153$ $\quad s_a = 0.0056$
$b = 0.922$ $\quad s_b = 0.0308$

If there is no opportunity to carry out bark measurements, Table 41 can be used to give a rough estimate of the bark percentage, or else a general bark percentage of 18 can serve as a starting point.

In actual practice only part of the bark is removed in peeling, so that it is better to determine the differences for each forest enterprise than to take the general (and thus rough) reduction percentages into account.

In order to gain an idea of the differences that may occur between estimates of volume obtained from the measurements of standing trees and the merchantable volume as determined on felled trees, we take the measurements of the trees given in Table 30 and assume that the standing volume of 93.7 m³ so obtained is exactly right. In addition, we assume that no allowances for cull need be made. First of all a reduction is made on account of measuring according to commercial usage amounting to 4% (Table 34). We then assume the wood to be barked as usual in practice. This means that the bark is removed in strips and that between them parts of the bark are left. What proportion is removed depends on circumstances. According to the "*Sorteringslijst*" 1950 (official Dutch list of assortments; ANONYM, 1950) the standard is 20% for fully barked wood and

10% for stripped wood, i.e. half the former percentage. In our case, therefore, the bark loss may be supposed to be half of 18, which is 9%.

If the trees are measured immediately after felling and according to normal forestry practice, these losses are the only ones. If the volume has decreased due to seasoning, a further reduction has to be made. This is also necessary if the measuring results are rounded down. According to the „*Houtjaarboek*" (SCHARROO, 1956) a radial shrinkage of 3.2% from unseasoned to air-dry larch wood is to be expected. Assuming a shrinkage to half of this amount before the wood is measured the radial loss is about $1\frac{1}{2}$ %, i.e. a volume loss of about 3%. Rounding down the measurements means approximately, that for an average diameter of the stand of 22 cm a value of 21.5 cm is taken, so that the sectional area is reduced by:

$$\frac{22^2 - 21.5^2}{22^2} \times 100 \doteqdot 4.5\ {}^0/_0.$$

Summarizing we have:

error of measurement on standing timber		p. m.
defects		p. m.
allowances for:		
measurement in one section only and stump wood	—4 %	96 %
bark	—9 %	87.4%
shrinkage, if any	—3 %	84.8%
rounding down, if any	—4.5%	81.0%

The above percentages of about —13 for normal and —19 for special cases apply to medium size larch wood. For big assortments the percentage of —13 remains unchanged, but that of —19 drops slightly, because the effects of rounding down decrease with increasing diameter. Conversely, the reduction values for small assortments are higher, because measuring in a single section leads to greater deviations.

In measuring standing timber it is often assumed that v_g, the tree with the average basal area, $\bar{g}$, represents the average volume of the stand, $\bar{v}$. By definition $v_g = \bar{g}\, h_g\, f_g$ and $\bar{v} = \frac{\Sigma v}{n} = \bar{g}\, \bar{\bar{h}}\, \bar{\bar{f}}$, where h_g = regression height at average basal area $\bar{g}$; f_g = regression form factor at $\bar{g}$; $\bar{\bar{h}}$ = "average" stand height; and $\bar{\bar{f}}$ = "average" stand form factor. The quantities $\bar{\bar{h}}$ and $\bar{\bar{f}}$ are defined as follows:

$$\bar{\bar{h}} = \frac{\Sigma (gh)}{\Sigma g} \text{ and } \bar{\bar{f}} = \frac{\Sigma v}{\Sigma (gh)}.$$

Thus, the supposition $v_g = \bar{v}$ is correct if $h_g\, f_g = \bar{\bar{h}}\, \bar{\bar{f}}$, or (1) $h_g = \bar{\bar{h}}$ and (2) $f_g = \bar{\bar{f}}$.

When the relative location of d_g on the cumulative frequency distribution was determined it was at the same time ascertained on the 128 trees mentioned under

IV.3 to what extent h_g deviates from $\bar{\bar{h}}$ and f_g from $\bar{\bar{f}}$. The positive difference between f_g and $\bar{\bar{f}}$ proved to be extremely small, whereas h_g and $\bar{\bar{h}}$ differ, on an average, by —1%. The total deviation of the product fh thus remains below —1%. In the volume tariff table discussed under IV.2, however, this has been taken into account, Table 43 being based on corrected stand form factors.

For volume estimates, use is sometimes also made of BITTERLICH's method of counting basal areas per ha. As is known, with this procedure, it is theoretically not necessary to measure diameters, but in practice it usually is, because d_g as an entry of a volume table is indispensable. This difficulty is remedied by Table 44, which gives the regression volume per ha of the stand if basal area per ha and *arithmetic* mean height are known. Hence, after counting G one need only measure the height of some randomly chosen trees to be able to use the table. Like Table 43, this table is based on the data of the sample plots of the Forest Research Station.

Felled trees are sometimes classified (e.g. into 2 inch or 5 cm classes) according to the diameter at the mid-point of commercial length ($d_{\frac{1}{2}l}$). If one wants to make an estimate of the frequency distribution of these mid diameters, the relationship between $d_{1.3}$ and $d_{\frac{1}{2}l}$ should be known. This relationship is presented in Table 45.

VII. FURTHER CONCLUSIONS

The 5th conclusion, formulated after discussing the preliminary investigation, was rendered incorrect by subsequent work, and other points have also emerged. Accordingly, to conclusions 1—4 incl. (p. 25) can now be added :

5. From an accuracy point of view graphical and mathematical methods must be considered equivalent.
6. In actual practice, the form factor of Japanese larch can, for most measurements of standing timber, be derived with sufficient accuracy from a smoothing of f on d or from a mathematical solution with the aid of $f = a + b \log d_{1.3}$. One should, however, expect deviations of the average form factor of a stand from the regression line, of up to 10%.
7. A considerably better estimate of f is obtained using the regression equation $f = a + b_1 \log d_{1.3} + b_2 \log d_6 + b_3 \log h$. With this function the deviations of stands remain below 3%.
8. The data investigated indicate that close initial spacings and medium to heavy thinnings lead to relatively high form factors.
9. The error caused by using the form factor of the tree with the average basal area as the stand form factor is negligible.

In conclusion it may be asked whether the regression equations found may be used — applying different parameters — to construct volume tables for other tree species. To this question a negative answer must be given. The literature provides several indications that not all tree species obey the same rules of growth, nor do they correspond as regards the way in which the stems are built up. Hence, it must certainly not be precluded that other form factor functions may produce better results for other species. Invariably, therefore, a preliminary survey will have to be made beforehand, preferably with the aid of a graphical test, and this "craft of the artisan" prepares the ground for mathematical analysis ...... by the same artisan, who is then called a statistician.

SUMMARY

Constructing a volume table is, in fact, trying to find a function with the aid of which the stochastic variable $\underline{v}$ or $\underline{f}$ can be derived from one or several dimensions of the tree. An example is $\underline{v} = F\ (d_{1.3}, h)$. With the aid of such a function — this may be an analytical equation or a graph — a number of observation data are harmonized, after which the results can be presented in tabular form (Chapter I).

The observation data (Table 1) can be considered representative of the population (Japanese larch in the Netherlands) to which the table will be applied. The stem-wood volume was determined by measuring the trees in sections without allowance being made for stump and top wood. In order to determine the most suitable length of section some experimental measurements were carried out, the results of which are given in Table 2. From these, it was decided to measure trees with a total length of less than 20 metres in 1 metre sections; for trees with a length exceeding 20 metres the bottom part of the stem was measured in two 1 metre sections and the remainder of the stem in 2 metre sections.

As is shown by the results given in Table 3, it is for form factor estimation not necessary to determine the diameter of each section in more than one direction so that, in order to save time, use can be made of a pair of tree calipers with a graduation for the sectional area which automatically rounds off the results (Table 4, Fig. 5). Moreover in this way, less time is required than if graphical methods using a planimeter (REINEKE, 1926) or a grid (SPURR, 1952) are applied. The saving in time is given in Table 6, and is based on the work being done by a measuring team of three, which, according to Table 5, is the best organization (Chapter II).

In the literature numerous construction methods are described, but hardly any remarks are made as to their suitability. It was therefore decided to compare the methods listed in Table 7. All these were applied to the group of 518 Japanese larch trees denoted by n_1 in the 11th column of Table 1. The frequency distribution of this group is given in Table 11.

As a standard for judging the results the relative deviation from regression has been adopted. For functions with $\underline{v}$ as the dependent variable the absolute deviation is unsuitable because it changes with the dimensions of the trees (Fig. 2). For functions with the dependent variable $\underline{f}$, the desirability of using this relative deviation as a standard is mainly determined by the very small trees. If this limited group is left out the absolute deviation of f is also acceptable as a standard (Fig. 23).

Owing to the trees being classified according to height and diameter there are rounding-off effects which lead to quite different results of smoothing on $\underline{v}$ and on $\underline{f}$. It was therefore necessary to express the relative deviation in f for all the methods examined. The results are given in Table 12.

With regard to this table, it should be added that, after harmonization the original average level may be disturbed. As this has an adverse influence on the deviation, both the total uncorrected relative deviation from regression, and also the corrected one are given. The correction appears to be superfluous for regression calculations in f; it is small for the applied graphical solutions and may be fairly considerable if a transformed dependent variable (log f, log v) is used.

Of the mathematical methods NÄSLUND's is the best, but the graphical ones using $f = F(d_{13}, h)$ and $f = F(d_{1.3})$ are considerably better. The omission of the second independent variable h, appears to have hardly any significance when the form factor is taken as the dependent variable. This is further illustrated in Table 14.

Thus, it can be stated that for Japanese larch there is no advantage to be gained by estimating the form factors from more than one independent variable and it matters little whether this independent variable is the diameter or the height. Estimating the volume from the height, on the other hand, gives much poorer results than estimating it from the diameter. Smoothing of the dependent variable $\underline{f}$ leads to better results than smoothing of $\underline{v}$.

In addition, an attempt has been made to find a regression equation producing equally good results as the graphical method using f as the dependent variable. Since NÄSLUND, in addition to the function examined:

$$f = a + b_1 \frac{1}{h} + b_2 \frac{h}{d_{1.3}},$$

has also described the equation:

$$f = a + b_1 \frac{1}{h} + b_2 \frac{h}{d_{1.3}} + b_3 \frac{h}{d^2_{1.3}}$$

it has first been ascertained whether the latter is more suitable for Japanese larch. To this end use has been made of the bunch map analysis (FRISCH 's method using regression diagrams) and it has been found that even the introduction of a parameter b_2 must be considered undesirable (Fig. 24).

Subsequently, it has been ascertained whether or not for the function $f = F(d)$ — see Fig. 22 — a regression equation could be calculated. This proved to be $f = a + b \log d$, provided $d \geq 5$ cm (see Fig. 25).

For the last calculation 466 trees were included, the 52 trees out of the 518 with a diameter of less than 5 cm being omitted. As these 466 trees mainly originated from thinnings it was considered desirable to check the function with 273 new trees, mainly from clear-felled areas. Table 17 and 18 show that the results of this test give every satisfaction, so that the final volume table no. 19 is based on the entire group of 739 trees with $d \geq 5$ cm and 52 trees with $d < 5$ cm. The particulars of this table are given according to the recommendations made by CHAPMAN and MEYER (1949).

In addition, a further test was made, both with Dutch and with foreign data. Table 20 compares the form factors of Table 19 with form factors of Japanese larch published by TUTEIN NOLTHENIUS. Two lots of 100 trees each, measured by the *Dienst der Landelijke Eigendommen* (Department of Rural Properties) of the Municipality of Apeldoorn, showed deviations of —2.9% and +7.3%, respectively; 261 trees measured by the Department for Forest Mensuration and

Management of the Forest Research Institute gave a total deviation of —0.5%.

Fig. 27 compares the stand form factors obtained by some Japanese investigators with the Dutch ones. The form factors from the volume tables of a few European authors are compared in table 21 with those of the Netherlands and of the Japanese research worker TAKAHASHI.

Professor SCHOBER was kind enough to place his original observation data (769 section measurements) at the author's disposal, so that a frequency distribution of the differences in respect of the Dutch table could be calculated. The results have been presented in Fig. 28 (Chapter III).

With the aid of the new table and of data from permanent and temporary sample plots a volume tariff table for Japanese larch was constructed (Table 43). In addition, 175 height curves were harmonized according to $h = a + b \log d_{1.3}$ (HENRIKSEN, 1950) to normal height curves (Figs. 31—34) and with the aid of these a volume table for normal height curves (Table 22) was constructed. If this table is used in regular stands it is sufficient to determine the height of 4 trees with the average basal area. As illustrated by Figs. 35 and 36, however, it is necessary to carry out height measurements each time a stand is measured.

The total deviation from the regression function

$$f = a + b \log d_{1.3}$$

is caused both by deviations within the individual stand and by differences between stands. Fig. 29 demonstrates that the mean form factor of a stand may display a deviation from the general level of a volume table of up to 10%. This deviation — and thus the significance of differences between stands — can perhaps be reduced by introducing a third independent variable. This might be a diameter at greater height than 1.3 m. Correlation calculations (see Table 24 and Fig. 27) have shown that $d_{0.3h}$ is most characteristic of the volume of a tree, but that at a given $d_{1.3}$ it is better to choose $d_{0.5h}$ as the second independent variable. However, both $d_{0.3h}$ and $d_{0.5h}$ have the drawback of being at a variable measuring height, so that a second diameter at a fixed height, viz. d_6, is preferred. It was found that the differences between stands could be considerably reduced by using the function $f = a + b_1 \log d_{1.3} + b_2 \log d_6 + b_3 \log h$ ($R = 0.90$), as demonstrated in Tables 25 and 26. The function was first calculated for the group n_3 with 251 trees, then tested with n_4 consisting of 290 trees and subsequently brought to its final form for the two groups together, omitting the trees of sample plot JL 14.

The result, which is thus based on $n_6 = 524$ trees, is given in Tables 29a and 29b, their use being explained with the aid of Tables 30 and 31 and Fig. 39 (Chapter IV).

Although the data are insufficient for statistical treatment it may be assumed that the differences in form factor between stands are influenced by original density and subsequent thinning. A narrow initial spacing (4000—6000 trees per ha) and moderate to heavy thinnings might be conducive to a high form factor level (Chapter V).

For the sale of felled trees the volume of the tree without top and stump wood is measured in a single section. The approximate differences caused by this method of measurement are given in Table 34. In addition, the sale is often based on the

WOORD VOORAF

Indien een publikatie in een vreemde taal wordt gesteld, ligt het voor de hand de erkentelijkheid voor verleende hulp in diezelfde taal uit te drukken, vandaar de „Acknowledgements" op blz. 54. Het bijzondere karakter van deze verhandeling geeft daarnaast echter een welkome aanleiding tot een voorwoord. Hierin wil ik allereerst mijn waardering uitspreken jegens mijn promotor, prof. dr. J. H. Becking, door wiens toedoen dit geschrift een proefschrift kon worden.

In weerwil van het feit, dat de opvoeding van de mens alleen maar een duidelijk beginpunt heeft — de wieg — en het zelfs de vraag is of opvoeding en opleiding ooit bij leven als geëindigd kunnen worden beschouwd, rechtvaardigt het tot stand komen van een proefschrift een blik terug, naar die wieg en de tijdvakken welke daarop volgden.

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Het bestuur van het Bosbouwproefstation ben ik erkentelijk voor de mij geboden gelegenheid, een onderdeel van mijn taak op zodanige wijze uit te werken under bark volume, so that bark percentages must be known as well if the volume of the standing timber is to be recalculated as merchantable volume. The bark percentage is highly variable, therefore, an estimation of this percentage with the aid of bark thickness measurements at breast height is to be preferred to the use of general regression values for the bark percentage. To this end Table 34 has been drawn up, based on a linear regression between the bark percentages at 0.3 h and at breast height.

Other factors that may influence the difference between the volume of standing timber and the merchantable volume are shrinkage owing to seasoning and rounding down in measuring.

In actual practice, for rough measurements of standing timber, use is often made of the tree with the average basal area. It is then assumed that the volume of this tree is also representative of the average volume of the stand. The investigation has shown that this leads to the introduction of a small systematic error which, on the average, causes a deviation of less than 1%. Nevertheless, in constructing Table 43 a correction for this systematic error has been made by starting from stand form factors instead of tree form factors.

With the aid of Table 44 it is possible to obtain directly the volume per ha of a stand by applying BITTERLICH's counting method, without previous determination of V_g with the aid of d_g, for this table gives directly the volume per ha of a stand based on the mean arithmetic height $(\bar{h})$ and basal area per ha (G).

Finally, Table 45 serves to estimate the frequency distribution of diameter classes measured at mid of commercial length from the frequency distribution of diameters at breast height (Chapter VI).

The investigation has led to the following conclusions:

1. If for volume table construction, the form factor, instead of the volume, is used as the dependent variable better results are obtained.
2. It matters little whether the form factor is estimated from the diameter only, or from diameter and height together.
3. Estimating the volume (or, if more convenient, the so-called form height, fh) from the diameter only, on the other hand, leads to much greater inaccuracies.
4. Estimating v or fg from the height only is most inaccurate.
5. From an accuracy point of view graphical and mathematical methods must be considered equivalent.
6. In actual practice, the form factor of Japanese larch can, for most measurements of standing timber be derived with sufficient accuracy from a smoothing of f on d or from a mathematical solution with the aid of $f = a + b \log d_{1.3}$. One should, however, expect deviations of the average form factor of a stand from the regression line, of up to 10%.
7. A considerably better estimate of f is obtained with the aid of the regression equation:

$$f = a + b_1 \log d_{1.3} + b_2 \log d_6 + b_3 \log h.$$

With this function, the deviations of stands remain below 3%.

8. The data investigated indicate that close initial spacings and medium to heavy thinnings lead to relatively high form factors.

9. The error caused by using the form factor of the tree with the average basal area as the stand form factor, is negligible.

The literature supports the contention that it is not likely that the functions found for Japanese larch will also apply to other tree species. For each species, therefore, a tentative (graphical) survey will invariably have to precede the construction of final volume tables.

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This investigation would not have been possible without the assistance and co-operation of several people.

Many practical foresters and some timber merchants enabled the research assistants to take section measurements. Besides Mr. W. Brantsma and Mr. D. Bouman and their forest staff were kind enough to measure sample trees in behalf of the present investigation. Prof. dr. R. Schober willingly provided his sample tree data for testing purposes, rendered assistance with German and Japanese literature references and corrected the German summary. Ir. A. van Laar placed other data for research and testing at the author's disposal and provided the results presented in Table 45. The Kamerlingh Onnes Laboratory of the University of Leiden engraved the special scales in the tree calipers.

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Ir. D. J. Maltha and ir. A. W. Keijzer of the Section Documentation and Publications of the Ministry of Agriculture, Fisheries and Food prepared the book for the press and the printing was in the hands of Messrs. Ponsen & Looijen at Wageningen.

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ZUSAMMENFASSUNG

SCHAFTFORM UND MASSE DER JAPANISCHEN LÄRCHE IN DEN NIEDERLANDEN

Die Aufstellung einer Massentafel besteht im Suchen einer Funktion mit der die stochastische Variable $\underline{v}$ oder $\underline{f}$ aus einer oder mehreren Dimensionen des Baumes abgeleitet werden kann. Z.B. $\underline{v} = F\ (d_{1.3},\ h)$. Mit Hilfe einer solchen Funktion — sie kann eine analytische Gleichung oder eine graphische Darstellung sein — wird eine Anzahl von Beobachtungsdaten ausgeglichen, und nachher können die Ergebnisse in der Form einer Tafel dargestellt werden (Kapittel I).

Man kann annehmen, dass die Beobachtungsdaten (Tabelle 1) repräsentativ sind für die Population (japanische Lärche im Wachstumsgebiet der Niederlande), auf welche die Tafel angewandt werden soll. An den gemessenen Probestämmen wurde die Schaftholzmasse in Sektionen bestimmt, ohne dabei etwaige Hauungsverluste zu berücksichtigen. Zur Bestimmung der erwünschten Sektionslänge sind zunächst einige Probemessungen ausgeführt worden, deren Ergebnisse in Tabelle 2 dargestellt sind. Auf Grund dieser Beobachtungen wurde beschlossen, Stämme mit einer Gesamtlänge von weniger als 20 m in 1 m-Sektionen zu messen. Bei Stämmen ab 20 m Länge wurde der untere 2 m-Abschnitt in 2 Sektionen von je 1 m, der Teil über 2 m Höhe in 2 m-Sektionen gemessen.

Wie Tabelle 3 zeigt, ist es für die Bestimmung der Formzahl nicht nötig je Sektion mehr als einen Durchmesser zu bestimmen, so dass man auf Kluppung übers Kreuz verzichten kann. Um die Arbeit zu beschleunigen, kann man deshalb eine Kluppe mit selbstabrundender Kreisflächeneinteilung (Tabelle 4, Abb. 5) benutzen. Eine derartige Kluppe arbeitet auch schneller als die graphische Massenermittlung mit Hilfe eines Planimeters (REINEKE, 1926) oder Quadratnetzes (SPURR, 1952). Der Zeitgewinn ist ersichtlich aus Tabelle 6. Die dort erwähnten Zahlen gründen sich auf eine aus 3 Personen zusammengestellten Messgruppe, welche nach Tabelle 5 für diese Arbeit am besten geeignet ist (Kapitel II).

In der Literatur begegnet man zahlreichen Methoden für die Aufstellung von Massentafeln. Meistens fehlen dabei aber Angaben, inwieweit eine bestimmte Methode mehr oder weniger geeignet ist als eine andere. Es wurde deshalb beschlossen, eine grössere Anzahl solcher Methoden, welche in Tabelle 7 dargestellt sind, miteinander zu vergleichen. Dazu wurden in jedem einzelnen Fall dieselben 518 Probestämme — mit n_1 bezeichnet in Spalte 11 der Tabelle 1 — benutzt. Die Häufigkeitsverteilung dieser Probestämme ist in Tabelle 11 dargestellt.

Die relative Streuung um die Regressionsfunktion ist als Beurteilungsmassstab für die Ergebnisse benutzt worden. Für Funktionen in denen $\underline{v}$ als abhängige Variable vorkommt, ist das absolute Streuungsmass (die Standardabweichung) nicht geeignet, weil es sich mit den Dimensionen des Baumes ändert (Abb. 2). Für Funktionen, in denen $\underline{f}$ die abhängige Variable ist, ist auch das relative

Streuungsmass, insbesondere wegen der kleinsten Stämmen vorzuziehen. Wenn diese ausser Betracht gelassen werden, kann man auch das absolute Streuungsmass verwenden (Abb. 23).

Infolge der Gliederung der Stämme nach Durchmesser- und Höhenstufen treten Abrundungseffekte auf, welche ganz verschieden sind, je nachdem Massen oder Formzahlen ausgeglichen werden. Deshalb war es nötig, bei allen probierten Ausgleichsmethoden die relative Streuung in f auszudrücken. Die Ergebnisse sind in Tabelle 12 dargestellt.

Bei dieser Tabelle kann man bemerken, dass bei bestimmten Ausgleichsmethoden Differenzen zwischen der Regressionsfunktion und dem ursprünglichen allgemeinen Niveau entstehen. Weil die Gesamtstreuung von dieser Tatsache ungünstig beeinflusst wird, ist neben der nichtkorrigierten Gesamtstreuung um die Regressionsfunktion auch die korrigierte Gesamtstreuung erwähnt. Dabei ergibt sich, dass keine Abweichungen auftreten bei Regressionsrechnungen mit f als abhängige Variable; sie sind gering bei den graphischen Ausgleichsmethoden, können aber erheblich sein wenn die abhängige Variable transformiert wird (log f, log v).

Von den rechnerischen Methoden hat die Methode-NÄSLUND zu den besten Ergebnissen geführt; jedoch haben sich die graphischen Ausgleichungen $f = F(d_{1.3}, h)$ und $f = F(d_{1.3})$ erheblich besser bewährt.

Es ist dabei praktisch ohne Bedeutung, ob bei der graphischen Ausgleichung der Formzahl die zweite unabhängige Variable h berücksichtigt wird oder nicht. Mit Hilfe von Tabelle 14 wird das noch näher beleuchtet.

Dementsprechend hat es bei der japanischen Lärche keinen Zweck, die Formzahl aus mehr als einer unabhängigen Variablen zu erklären. Dabei macht es nur wenig aus, ob man dazu den Durchmesser oder die Höhe auswählt. Die Ableitung der Masse von der Höhe gibt dagegen viel schlechtere Ergebnisse, als wenn sie vom Durchmesser abgeleitet wird. Übrigens zeigt sich noch, dass Ausgleichungen der abhängigen Variablen $\underline{f}$ zu besseren Ergebnissen führen als Ausgleichungen von $\underline{v}$.

Weiter ist versucht worden eine Regressionsgleichung mit gleich guten Ergebnissen als die der graphischen Ausgleichung von f zu finden. Da NÄSLUND neben der schon untersuchten Funktion $f = a + b_1 \frac{1}{h} + b_2 \frac{h}{d_{1.3}}$ auch die Gleichung

$$f = a + b_1 \frac{1}{h} + b_2 \frac{h}{d_{1.3}} + b_3 \frac{h}{d_{1.3}^2}$$

beschrieben hat, wurde zunächst untersucht, ob die zweite Funktion für die Japanlärche besser passen würde. Hierzu wurde das Verfahren der Regressionsdiagramme nach FRISCH (*"bunch map analysis"*) angewandt und daraus ergab sich dass die Einführung eines Parameters b_2 schon als unerwünscht betrachtet werden muss (Abb. 24).

Es blieb deshalb nur die Möglichkeit übrig, für die graphische Funktion $f = F(d_{1.3})$ — siehe Abb. 22 — einen mathematischen Ausdruck zu finden. Dies ist gelungen mittels der Regressionsgleichung $f = a + b \log d_{1.3}$, vorausgesetzt dass $d_{1.3} \geqq 5$ cm (siehe Abb. 25).

Bei dieser Berechnung konnten von den 518 Probestämmen 52 nicht benutzt werden, weil ihre Stärke in Brusthöhe geringer als 5 cm ist. Die Ausgleichsrechnung stützt sich also auf 466 Probestämmen, und diese sind hauptsächlich Durchforstungsstämme. Es war deshalb erwünscht, die gefundene Funktion mit 273 neuen Beobachtungsdaten, vorwiegend aus Kahlschlägen und Lichtungshieben, zu überprüfen. Wie die Tabelle 17 und 18 zeigen, sind die Ergebnisse dieser Prüfung sehr befriedigend. Es konnte also aus den gesamten Beobachtungen, d.h. 739 ab 5 cm Brusthöhendurchmesser und 52 darunter, die endgültige Tabelle 19 aufgestellt werden. Den Empfehlungen von CHAPMAN und MEYER (1949) entsprechend ist die Tafel mit den wichtigsten Einzelheiten erläutert.

Ausserdem ist noch eine weitere Überprüfung ausgeführt worden und zwar mit anderen holländischen wie auch mit ausländischen Daten. In Tabelle 20 ist eine Vergleichung mit Formzahlen der japanischen Lärche nach TUTEIN NOLTHENIUS dargestellt. Weiter zeigten zwei, je aus 100 Stämmen bestehende Gruppen, welche von der Stadtwaldverwaltung in Apeldoorn gemessen wurden, eine Abweichung von bezw. —2,9% und +7,3%. 261 Probestämme, welche von der Abt. Holzmesskunde des Forstlichen Forschungsinstituts vermessen wurden, hatten eine Gesamtabweichung von —0,5%.

In Abb. 27 sind Bestandesformzahlen nach einigen japanischen Forschern, welche mir freundlicherweise von Herrn Prof. SCHOBER zur Verfügung gestellt wurden, neben den vom Verfasser gefundenen dargestellt. Die Tabelle 21 ermöglicht es, die Massentafel des japanischen Verfassers TAKAHASHI und verschiedene europäische Massentafeln für Japanlärche zu vergleichen.

Ferner war Prof. SCHOBER so liebenswürdig, mir alle Daten seiner eigenen 769 Probestämme zuzusenden, so dass deren individuelle Differenzen hinsichtlich der Tafelwerte berechnet und in einer kumulativen Häufigkeitsverteilung dargestellt werden konnten (Abb. 38) (Kapitel III).

Mit Hilfe der neuen Tafel und der Daten von Dauerversuchsflächen und einmalig aufgenommenen Probeflächen ist ein Massentarif für die japanische Lärche aufgestellt worden (Tabelle 43). Weiter wurden auf der Grundlage von Regressionsgeraden nach der Formel $h = a + b \log d_{1.3}$ (HENRIKSEN, 1950) Einheitshöhenkurven aufgestellt (Abbn. 31—34 einschl.) und auf diese gründet sich die Massentafel für Einheitshöhenkurven (Tabelle 22). In gleichmässigen Beständen ist es zur Massenabschätzung mittels dieser Tafel ausreichend, 4 Höhenmessungen an Grundflächenmittelstämmen auszuführen. Wie die Abb. 35 und 36 zeigen, ist es aber nötig, bei jeder Wiederaufnahme aufs neue Höhenmessungen zu machen.

Die Gesamtstreuung um die Regressionsfunktion $f = a + b \log d_{1.3}$ ist das Ergebnis von zweierlei Ursachen; der Streuung innerhalb des Bestandes und der Streuung zwischen Beständen. Durch Abb. 29 wird gezeigt, dass die mittlere Formzahl eines Bestandes bis zu 10% vom Niveau einer allgemeinen Massentafel abweichen kann. Es ist sinnvoll, zu versuchen diese Streuung durch Einführung einer dritten unabhängigen Variablen zu verringern. Hierzu kommt ein Durchmesser in einer grösseren Höhe als 1,3 m in Betracht. Aus Korrelationsberechnungen (Siehe Tabelle 24 und Abb. 37) hat sich ergeben, dass $d_{0,3h}$ am meisten charakteristisch für die Schaftholzmasse ist. In Zusammenhang mit dem an sich schon bekannten Durchmesser in Brusthöhe kann aber als zweiter bezeichnender

Durchmesser besser $d_{0.5h}$ gewählt werden. Gegen $d_{0,3h}$ wie auch gegen $d_{0,5h}$ kann man jedoch aus praktischen Erwägungen einwenden, dass die Messhöhe von Stamm zu Stamm variiert. Deshalb wurde einem zweiten Durchmesser in konstanter Höhe, und zwar d_6 Vorzug gegeben.

Es stellte sich heraus, dass die Streuung zwischen Beständen erheblich reduziert werden konnte bei Anwendung der Funktion

$$f = a + b_1 \log d_{1,3} + b_2 \log d_6 + b_3 \log h \ (R = 0{,}90),$$

wie in den Tabellen 25 und 26 dargelegt wird. Die Funktion wurde zunächst berechnet für die Probestammgruppe n_3 mit 251 Stämmen und anschliessend überprüft mit der Gruppe n_4, welche aus 290 Stämmen besteht. Schliesslich wurden die Funktionen endgültig ausgearbeitet für beide Gruppen zusammen und zwar unter weglassen der abnormen Probestämme der Versuchsfläche JL 14. Deshalb gründet sich das Ergebnis auf $n_6 = 524$ Probestämmen und ist in ausgearbeiteter Form in den Tabellen 29a und 29b dargestellt. Mit Hilfe der Tabelle 30 und 31 und Abb. 39 ist die Anwendung dieser Tafel 29 erläutert (Kapitel IV).

Obgleich die Anzahl der Bestände, aus welchen Probestämme entnommen sind, zu einer statistischen Bearbeitung nicht ausreicht, darf man wohl annehmen, dass die bestandsweisen Abweichungen vom allgemeinen Formzahlniveau vom Pflanzverband bei der Bestandesbegründung und vom Durchforstungsgrad beeinflusst werden. Ein hohes Formzahlniveau wäre durch Pflanzung in dichtem Verband (4000—6000 Stück pro ha) und durch ziemlich starke Durchforstungen zu fördern (Kapitel V).

Wenn man gefällte Stämme verkauft, so wird der in Stockhöhe abgesägte und abgezopfte Stamm nach der Mittenfläche kubiert. Die Differenzen zwischen diesen Vermessungsergebnissen und den Tafelwerten sind annähernd dargestellt in Tabelle 34. Ausserdem wird liegendes Holz beim Verkauf oft ohne Rinde gemessen, so dass Rindenprozente bekannt sein müssen, wenn man stehendes Holz ohne Rinde verkaufen will. Das Rindenprozent zeigt eine grosse Variation. Es empfiehlt sich, statt allgemeine Regressionswerte anzuwenden, das Rindenprozent aus Rindenstärkemessungen in Brusthöhe abzuleiten. Zu diesem Zweck ist Tabelle 40 aufgestellt worden. Diese Tabelle gründet sich auf eine geradlinige Regression zwischen dem für den ganzen Stamm repräsentativen Rindenprozent in der Höhe 0,3h und dem Rindenprozent in Brusthöhe.

Andere Faktoren, welche Differenzen zwischen stehenden Holzmassen und Verkaufsmassen verursachen können, sind das Schwinden des Hölzes infolge Austrocknung im Walde und eventuelle handelsübliche einseitige Abrundungen bei der Vermessung.

In der Praxis benutzt man bei Messungen stehender Holzvorräte, an welche nicht besonders hohe Genauigkeitsansprüche gestellt werden, oft den Grundflächenmittelstamm und nimmt dabei an, dass dieser dem Massenmittelstamm gleich ist. Bei der vorliegenden Untersuchung hat sich gezeigt, dass man dabei einen kleinen systematischen Fehler macht, welche aber durchschnittlich unter einen Wert von 1% liegt. Bei der Aufstellung der Tabelle 43 ist jedoch auf diese systematische Abweichung Rücksicht genommen durch Benutzung von Bestandesformzahlen an Stelle von Formzahlen für Einzelstämme.

Mit Hilfe von Tabelle 44 ist es möglich, das Winkelzählverfahren von BITTERLICH auszuführen ohne eine zusätzliche Schätzung von v_g mit Hilfe von d_g. Die Tabelle 44 gründet sich nämlich auf der arithmetischen Mittelhöhe.

Zum Schluss ist Tabelle 45 hinzugefügt, um die Häufigkeitsverteilung der Mittendurchmesser, also die Sortenverteilung des liegenden Holzes aus der Häufigkeitsverteilung der Brusthöhendurchmesser abschätzen zu können (Kapitel VI).

Die vorliegende Untersuchung hat zu folgenden Schlussfolgerungen geführt:

1. Ausgleichungen von Schaftformzahlen führen zu besseren Ergebnissen als Ausgleichungen der Massen;
2. Es macht dabei nur wenig aus, ob man die Formzahl aus dem Brusthöhendurchmesser allein oder aus Durchmesser und Höhe zusammen herleitet;
3. Ableitung der Masse (eventuell ausgeglichen als die Formhöhe fh) vom Durchmesser allein führt dagegen zu einer erheblich grösseren Ungenauigkeit;
4. Herleitung von v oder fg aus der Höhe allein ist am ungenauesten;
5. Hinsichtlich der Genauigkeit sind graphische und rechnerische Ausgleichsverfahren als gleichwertig zu betrachten;
6. Die Schaftformzahl der japanischen Lärche kann für die meisten praktischen Vermessungen stehender Holzmassen mit einer ausreichenden Genauigkeit aus einer graphischen Ausgleichung von f über d oder aus einer rechnerischen Ausgleichung nach $f = a + b \log d_{1,3}$ hergeleitet werden. Man muss aber darauf bedacht sein, dass die Bestandesmittelwerte bis zu 10% von der allgemeinen Regressionslinie abweichen können;
7. Eine erheblich bessere Schätzung von f bekommt man mit Hilfe der Regressionsgleichung:

$$f = a + b_1 \log d_{1,3} + b_2 \log d_6 + b_3 \log h.$$

   Die bestandesweise Streuung bleibt bei dieser Funktion unter 3%;
8. Aus den Beobachtungsdaten bekommt man den Eindruck, dass ein dichter Pflanzverband und ziemlich starke Durchforstungen die Höhe der Schaftformzahl fördern;
9. Der Fehler welche entsteht, wenn die Stammformzahl statt der Bestandesformzahl bei der Holzmassenermittlung mittels des Grundflächenmittelstammes angewandt wird, ist ohne praktische Bedeutung.

Auch auf Grund der Literatur ist es nicht wahrscheinlich, dass die für die japanische Lärche gefundenen Funktionen auf andere Baumarten angewandt werden können. Für jede Baumart wird es nötig sein, der endgültigen Ausgleichung eine orientierende (graphische) Erkundung vorangehen zu lassen.

Neben den zahlreichen wissenschaftlichen und praktischen holländischen Kollegen und Mitarbeitern ist der Verfasser Herrn Prof. Dr. R. SCHOBER, Hann.-Münden, Deutschland und Herrn J. M. CHRISTIE, *Forest Research Station* Alice Holt, England, besonders dankbar für die Überprüfung der Übersetzungen.

SAMENVATTING

VORM EN INHOUD VAN DE JAPANSE LARIKS IN NEDERLAND

Het vervaardigen van een inhoudstabel komt neer op het zoeken van een functie waarmee de stochastische variabele $\underline{v}$ of $\underline{f}$ kan worden verklaard uit één of meer afmetingen van de boom. Bijvoorbeeld $\underline{v} = F\ (d_{1,3}, h)$. Met behulp van zo'n functie — dit kan een analytische vergelijking of een grafiek zijn — vereffent men een hoeveelheid waarnemingen, waarna de resultaten in tabelvorm kunnen worden weergegeven (hoofdstuk I).

Het waarnemingsmateriaal (tabel 1) kan geacht worden representatief te zijn voor de populatie (Japanse lariks in Nederland) waarop de tabel zal worden toegepast. Aan de gemeten stammen werd de spilinhoud bepaald in secties, zonder rekening te houden met zaagverliezen. Voor het bepalen van de lengte van de secties werden enige proefmetingen gedaan, waarvan de resultaten zijn weergegeven in tabel 2. Op grond daarvan werd besloten, bomen met een totale lengte van minder dan 20 m in secties van 1 m lengte op te meten. Stammen met een lengte van 20 m en meer werden gemeten als volgt: de onderste 2 m in 2 secties van 1 m, het gedeelte daarboven in secties van 2 m.

Blijkens de uitkomsten van tabel 3 is het voor bepaling van het vormgetal niet nodig per sectie meer dan één diameter te bepalen, zodat ter besparing van tijd gebruik kan worden gemaakt van een boomklem met automatisch afrondende cirkelvlak-verdeling (tabel 4, fig. 5). Een dergelijke klem werkt ook sneller dan de grafische inhoudsbepaling met een planimeter (REINEKE, 1926) of een ruitennet (SPURR, 1952). De tijdwinst blijkt uit tabel 6. Hierbij is uitgegaan van een meetploeg van 3 personen, welke blijkens tabel 5 de beste personeelsbezetting is (hoofdstuk II).

In de literatuur worden talrijke vereffeningswijzen beschreven, doch mededelingen over de mate van bruikbaarheid van deze vereffeningswijzen ontbreken vrijwel geheel. Er werd daarom besloten de in tabel 7 weergegeven werkwijzen aan een vergelijkend onderzoek te onderwerpen. Al deze vereffeningswijzen werden toegepast op de 518 Japanse lariksen, aangeduid als n_1 in de 11e kolom van tabel 1. De frequentieverdeling van dit materiaal is weergeven in tabel 11.

Als maatstaf voor de beoordeling van de uitkomsten is gebruik gemaakt van de relatieve spreiding om de regressiefunctie. Voor functies met $\underline{v}$ als afhankelijke variabele is de absolute spreiding niet bruikbaar, omdat deze met de afmetingen van het materiaal verandert (fig. 2). Voor functies met de afhankelijke variabele $\underline{f}$ wordt de wenselijkheid van deze relatieve spreidingsmaat voornamelijk bepaald door de zeer kleine bomen. Als men deze beperkte groep weglaat is ook de absolute spreiding in f als maatstaf aanvaardbaar (fig. 23).

Ten gevolge van de indeling der bomen in diameter- en hoogteklassen treden afrondingseffecten op, welke bij vereffening op $\underline{v}$ tot geheel andere uitkomsten leiden dan bij vereffening in f. Daarom was het noodzakelijk, van alle onderzochte vereffeningswijzen de relatieve spreiding in f uit te drukken. De resultaten zijn weergegeven in tabel 12.

Bij deze tabel kan worden opgemerkt, dat er na sommige vereffeningen een algemene afwijking van het niveau optreedt. Daar hierdoor de spreiding ongunstig wordt beïnvloed, is naast de totale ongecorrigeerde relatieve spreiding om de regressiefunctie ook de gecorrigeerde spreiding vermeld. De correctie blijkt overbodig te zijn bij regressieberekeningen in f; zij is gering bij grafische vereffeningen en kan bij gebruik van een getransformeerde afhankelijke variabele (log f, log v) vrij belangrijk zijn.

Van de rekenkundige vereffeningen is die van NÄSLUND het beste, maar de grafische vereffeningen $f = F\ (d_{1.3}, h)$ en $f = F\ (d_{1.3})$ zijn aanzienlijk beter. Het weglaten van de tweede onafhankelijke variabele h blijkt bij de grafische vereffening van het vormgetal nauwelijks van betekenis te zijn. Met behulp van tabel 14 wordt dit nog nader geïllustreerd.

Men kan dus zeggen dat het bij de Japanse lariks geen zin heeft het vormgetal uit meer dan één onafhankelijke variabele te verklaren en daarbij maakt het slechts weinig verschil uit of men hiervoor de diameter dan wel de hoogte kiest.

Verklaring van de inhoud uit de hoogte geeft daarentegen veel slechtere uitkomsten dan vereffening van de inhoud op de diameter. Voorts blijkt dat vereffeningen van de afhankelijke variabele $\underline{f}$ tot betere resultaten leiden dan de vereffeningen van $\underline{v}$.

Er is voorts nog gezocht naar een regressievergelijking met even goede uitkomsten als de grafische vereffening in f. Aangezien NÄSLUND naast de onderzochte functie

$$f = a + b_1 \frac{1}{h} + b_2 \frac{h}{d_{1.3}}$$

ook nog de vergelijking

$$f = a + b_1 \frac{1}{h} + b_2 \frac{h}{d_{1.3}} + b_3 \frac{h}{d_{1.3}}$$

heeft geschreven, is eerst nagegaan of laatstgenoemde bij de Japanse lariks beter past. Hiervoor is gebruik gemaakt van de bunch-map analyse (methode der regressie-diagrammen van FRISCH) en daarbij bleek dat reeds de invoering van een parameter b_2 als een ongewenste uitbreiding moet worden beschouwd (fig. 24).

Daarna is nagegaan of voor de grafische functie $f = F\ (d_{1.3})$ — zie fig. 22 — een regressievergelijking kon worden opgesteld. Dit gelukte met

$$f = a + b \log d_{1.3} \quad \text{mits } d \geqq 5 \text{ cm (zie fig. 25).}$$

Bij de laatste berekening werden 466 waarnemingen gebruikt, daar 52 van de 518 bomen een diameter van minder dan 5 cm bezaten. Aangezien deze 466 bomen in hoofdzaak uit dunningen afkomstig zijn werd het wenselijk geacht de functie te controleren met 273 nieuwe waarnemingen, in hoofdzaak van voor de voet gevelde opstanden afkomstig. Blijkens de tabellen 17 en 18 zijn de uitkomsten van deze toets alleszins bevredigend, zodat de definitieve inhoudstabel (tabel 19) berust op het gezamenlijke materiaal van 739 bomen, waarvan $d_{1.3} \geqq 5$ cm en 52 bomen met $d_{1.3} < 5$ cm. Overeenkomstig de aanbevelingen van CHAPMAN and MEYER (1949) is deze tabel met de voornaamste bijzonderheden toegelicht.

Daarnaast heeft nog een verdere controle plaats gevonden, zowel met Nederlands materiaal als met buitenlandse gegevens. In tabel 20 is weergegeven een vergelijking met vormgetallen van Japanse lariks, welke TUTEIN NOLTHENIUS (1946) heeft gepubliceerd. Twee partijen elk van 100 bomen, gemeten door de Dienst der Landelijke Eigendommen van de gemeente Apeldoorn, bleken achtereenvolgens —2,9% en +7,3% af te wijken, terwijl tenslotte 261 bomen, gemeten door de afdeling houtmeetkunde van het Instituut voor Bosbouwkundig Onderzoek, een gezamenlijke afwijking van —0,5% opleverden.

Dank zij de medewerking van prof. SCHOBER konden in fig. 27 opstandsvormgetallen van enkele Japanse onderzoekers samen met die van Nederland worden weergegeven. Tabel 21 maakt een vergelijking mogelijk tussen inhoudstabellen van enkele Europese auteurs en van de Japanner TAKAHASHI.

Prof. SCHOBER was zo bereidwillig, mij bovendien zijn oorspronkelijke waarnemingsmateriaal (769 sectiemetingen) ter beschikking te stellen, zodat daarvan een frequentieverdeling van de verschillen ten opzichte van de Nederlandse tabel kon worden berekend. De uitkomsten zijn weergegeven in fig. 28 (hoofdstuk III).

Met behulp van de nieuwe tabel en gegevens van permanente en tijdelijke proefperken is een inhoudstarief voor de Japanse lariks opgesteld, weergegeven in tabel 43. Voorts zijn van 175 regressielijnen van hoogte op diameter volgens $h = a + b \log d_{1.3}$ (HENRIKSEN, 1950) standaardhoogtekrommen opgesteld (fig. 31—34) en met behulp hiervan is een inhoudstabel voor standaardhoogtekrommen (tabel 22) geconstrueerd. Bij gebruik van deze tabel is het in regelmatige opstanden voldoende van 4 bomen met het gemiddelde grondvlak de hoogte te bepalen. Zoals de figuren 35 en 36 illustreren is het echter wel nodig bij iedere hermeting van een opstand opnieuw hoogtemetingen te doen.

De totale spreiding van de regressiefunctie $f = a + b \log d_{1.3}$ wordt zowel veroorzaakt door een spreiding binnen de opstand als door de spreiding tussen opstanden. In fig. 29 wordt aangetoond dat het gemiddelde vormgetal van een opstand tot 10% van het niveau van een algemene inhoudstabel kan afwijken. Deze spreiding — en daarmede de significantie van opstandsgewijze verschillen — kan wellicht worden verminderd door invoering van een derde onafhankelijke variabele. Hiervoor komt een diameter op grotere hoogte dan 1,3 m in aanmerking. Uit correlatieberekeningen (zie tabel 24 en fig. 37), is gebleken dat $d_{0.3h}$ het meest kenmerkend is voor de inhoud van de boom, doch dat bij gegeven $d_{1.3}$ als tweede verklarende diameter beter $d_{0.5h}$ kan worden gekozen. Zowel $d_{0.3h}$ als $d_{0.5h}$ hebben echter het bezwaar van een variabele meethoogte, zodat de voorkeur werd gegeven aan een tweede diameter op vaste hoogte en wel d_6. Het bleek dat de opstandsgewijze spreiding aanzienlijk kon worden gereduceerd door gebruik te maken van de functie

$$f = a + b_1 \log d_{1.3} + b_2 \log d_6 + b_3 \log h \quad (R = 0{,}90),$$

zoals wordt aangetoond in de tabellen 25 en 26. De functie werd eerst berekend voor de materiaalgroep n_3 met 251 bomen, vervolgens getoetst met n_4 bestaande uit 290 bomen en daarna definitief opgesteld voor beide groepen gezamenlijk, onder weglating van de bomen van het proefperk JL 14. Het resultaat, derhalve gebaseerd op $n_6 = 524$ bomen, is weergegeven in de tabellen 29a en 29b, waarvan het gebruik is toegelicht met behulp van de tabellen 30 en 31 en fig. 39 (hoofdstuk IV).

Hoewel de gegevens voor een statistische bewerking ontoereikend zijn, mag worden aangenomen, dat de opstandsgewijze afwijkingen van het algemene vormgetal-niveau worden beïnvloed door het plantverband bij aanleg en de wijze van dunnen. Een hoog vormgetal-niveau zou door een dicht plantverband (4000—6000 per ha) en matig sterke dunningen kunnen worden bevorderd (hoofdstuk V).

Bij verkoop van gevelde bomen meet men de inhoud van de afgezaagde en afgetopte boom in één sectie. De verschillen welke ten gevolge van deze meetwijze ontstaan, zijn bij benadering opgegeven in tabel 34. Daarnaast gaat men bij verkoop dikwijls uit van het volume zonder schors, zodat ook schorspercentages bekend moeten zijn indien men de staande tot de verkoopbare inhoud wil herleiden. Het blijkt dat het schorspercentage sterk variabel is. Boven het gebruik van algemene regressiewaarden voor het schorspercentage verdient de schatting daarvan met behulp van gemeten schorsdikten op borsthoogte de voorkeur. Voor dit doel is tabel 40 ontworpen, waaraan een lineaire regressie tussen schorspercentage op 0,3h en schorspercentage op borsthoogte ten grondslag ligt.

Andere faktoren welke het verschil tussen houtvoorraden op stam en handelsvolumina kunnen beïnvloeden zijn het krimpen van het hout ten gevolge van uitdrogen en de eventuele toepassing van eenzijdige afronding bij het meten.

In de praktijk maakt men bij globale metingen van hout op stam dikwijls gebruik van de boom met het gemiddelde grondvlak. Men neemt daarbij aan dat deze boom ook de gemiddelde inhoud van de opstand representeert. Bij het onderzoek is gebleken, dat men hierbij een kleine systematische fout maakt, welke echter gemiddeld slechts tot een afwijking van minder dan 1% leidt. Bij het opstellen van tabel 43 is deze systematische fout nochtans gecorrigeerd, door uit te gaan van opstandsvormgetallen in plaats van boomvormgetallen.

Met behulp van tabel 44 is het mogelijk de inventarisatiemethode van BITTERLICH toe te passen zonder daarnaast afzonderlijk v_g met behulp van d_g te moeten bepalen. Deze tabel geeft namelijk opstandsvormgetallen weer, welke gebaseerd zijn op aritmetisch gemiddelde hoogten.

Ten slotte dient tabel 45 om de frequentieverdeling van diameterklassen volgens middenvlak gesorteerd te kunnen schatten uit een frequentieverdeling van borsthoogtediameters (hoofdstuk VI).

Het onderzoek heeft geleid tot de volgende conclusies:

1. vereffeningen van het vormgetal leiden tot betere uitkomsten dan vereffening van de inhoud;
2. het maakt daarbij slechts weinig verschil uit, of men het vormgetal alleen uit de diameter dan wel uit diameter en hoogte gezamenlijk verklaart;
3. verklaring van de inhoud (eventueel vereffend als de zogenaamde vormhoogte, fh) uit de diameter alleen leidt daarentegen tot een veel grotere onnauwkeurigheid;
4. verklaring van v of fg uit de hoogte alleen is het meest onnauwkeurig;

5. uit een oogpunt van nauwkeurigheid zijn grafische en rekenkundige vereffeningen gelijkwaardig te achten;
6. het vormgetal van de Japanse lariks kan voor de meeste praktische metingen van hout op stam voldoende nauwkeurig worden verklaard uit een grafische vereffening van f op $d_{1.3}$ of uit een rekenkundige bewerking volgens $f = a + b \log d_{1.3}$. Men moet echter bedacht zijn op opstandsgewijze afwijkingen van de regressielijn, welke tot 10% kunnen gaan;
7. een aanzienlijke betere schatting van f verkrijgt men met de regressievergelijking

$$f = a + b_1 \log d_{1.3} + b_2 \log d_6 + b_3 \log h.$$

De opstandsgewijze spreiding van deze functie blijft daarbij beneden 3%.

8. het onderzochte materiaal geeft aanwijzingen, dat een dicht plantverband en matig sterke dunningen het vormgetalniveau gunstig beïnvloeden;
9. de fout, welke men maakt door het vormgetal van de boom met het gemiddelde grondvlak als opstandsvormgetal te gebruiken, is zonder praktische betekenis.

Mede op grond van gegevens uit de literatuur is het niet waarschijnlijk dat de voor de Japanse lariks gevonden functies ook voor andere boomsoorten zullen gelden. Voor elke houtsoort zal dus steeds een oriënterend (grafisch) onderzoek aan de definitieve vereffening moeten voorafgaan.

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APPENDIX 1: SYMBOLS
ANHANG 1: SYMBOLE

APPENDIX 2: TABLES
ANHANG 2: TABELLEN

The tables are combined as follows:
Die Tabellen sind kombiniert wie folgt:

(1) T. 1 — 13 incl.
(2) T. 14 — 18 incl., 20 — 28 incl.,
30 — 39 incl., 41
(3) T. 19
(4) T. 29
(5) T. 40
(6) T. 42 — 45 incl.

APPENDIX 1 : SYMBOLS

SYMBOLS	SYMBOLE	SYMBOLEN
1. *Greek letters*	*Griechische Buchstaben*	*Griekse letters*
α expected (population) value of a regression constant	Erwartungswert (Populationswert) einer Regressionskonstante	verwachtingswaarde van een regressieconstante
β expected value of a regression coefficient	Erwartungswert einer Regressionskoeffizient	verwachtingswaarde van een regressiecoefficiënt
Δ difference	Differenz	verschil
E expected value	Erwartungswert	verwachtingswaarde
η diameter quotient according to Hohenadl	Durchmesserverhältnis nach Hohenadl	diameterquotiënt volgens Hohenadl
θ angle measured from the horizontal	Winkel von der Horizontalachse gemessen	hoek ten opzichte van de horizontale as
λ true form quotient according to Hohenadl	echter Formquotient nach Hohenadl	echt vormquotiënt volgens Hohenadl
μ expected value of a mean	Erwartungswert eines Mittels	verwachtingswaarde van een gemiddelde
π a constant ($\pi \doteq 3.14159$)	eine Konstante	een constante
Σ sum	Summe	som
σ expected value of a standard deviation	Erwartungswert einer Standardabweichung	verwachtingswaarde van een standaardafwijking
ϕ (expected) function	(erwartete) Funktion	(verwachte) functie
2. *Roman letters*	*Lateinische Buchstaben*	*Gewone letters*
a, a_0, a_1, etc. b, b_0, b_1, etc. c, etc. algebraic constants and parameters in regression equations	algebraische Konstanten und Parameter in Regressionsgleichungen	algebraische constanten en parameters in regressie-vergelijkingen
c girth	Umfang	omtrek
d diameter	Durchmesser	middellijn
d_0 diameter at base of tree	Durchmesser am Stammfuss	middellijn aan de voet van de stam
$d_{1.3}$ diameter at breast height	Durchmesser in Brusthöhe ($d_{1,3}$)	middellijn op borsthoogte ($d_{1,3}$)
d_6 diameter at 6 metres from ground	Durchmesser in 6 m Höhe	middellijn op 6 m hoogte
d_x diameter at a height x from ground	Durchmesser in der Höhe x vom Boden	middellijn op hoogte x boven de grond
$d_{0.1h}$ diameter at 0.1 of total height from ground	Durchmesser in ein Zehntel der Scheitelhöhe	middellijn op $\frac{1}{10}$ der totale hoogte
d_g diameter corresponding to mean basal area	Durchmesser des Grundflächenmittelstammes	middellijn, behorende bij het gemiddelde grondvlak
d_t "theoretical mean" diameter of a tree, defined as the diameter of a cylinder with same height and volume of the tree	"theoretischer mittlerer" Durchmesser eines Stammes, definiert als der Durchmesser einer Walze, mit derselben Höhe und Masse als der Stamm	"theoretische gemiddelde" diameter van een stam, gedefiniëerd als de diameter van een cilinder met *dezelfde* hoogte en inhoud als de stam
d_{top} top diameter	Zopfdurchmesser (Derbholzgrenze)	topdiameter
e base of natural logs ($e \doteq 2.71828$)	Grundzahl der natürlichen Logarithmen	grondtal van de natuurlijke logaritmen
f form factor	Formzahl	vormgetal
F (1) in equations: function	(1) in Gleichungen: Funktion	(1) in vergelijkingen: functie
(2) in analyses of variance: test of statistical significance according to Snedecor	(2) in Variationsanalysen: Testwert für statistische Signifikanz nach Snedecor	(2) in variatie-analyses: toetsingsnorm voor de beoordeling van verschillen, volgens Snedecor
g basal, or sectional area	Grundfläche oder Kreisfläche	grondvlak of doorsneevlak
h height	Höhe	hoogte
h_g regression height of d_g	Regressionshöhe von d_g	regressiehoogte van d_g
h_L mean stand height according to Lorey	Bestandesmittelhöhe nach Lorey	gemiddelde opstandshoogte volgens Lorey
j any class out of a series e.g. $d_1, d_2 \ldots\ldots\ldots d_j \ldots\ldots\ldots d_m$	irgend eine Klasse aus einer Reihe	een willekeurige klasse uit een reeks
k form quotient	Formquotient	vormquotiënt
without subscript: $k = \frac{d_{0.5h}}{d_{1.3}}$	ohne Subskript: $k = \frac{d_{0,5h}}{d_{1,3}}$	zonder toevoegsel: $k = \frac{d_{0,5h}}{d_{1,3}}$
k_a absolute form quotient: $k_a = \frac{d_{0.5h+0.65}}{d_{1.3}}$	absoluter Formquotient	absoluut vormquotiënt
k_H natural formquotient according to Hohenadl	echter Formquotient nach Hohenadl	echt vormquotiënt volgens Hohenadl
l length, commercial length	Länge, Derbholzlänge	lengte, werkhoutlengte
m number	Anzahl	aantal
n number, (sub-) total	Anzahl, (Sub-) Total	aantal, (sub-) totaal
N total	Gesamtzahl	totaal
p proportion, probability of success	Verhältnis, Wahrscheinlichkeit von Erfolgen	percentage, kans op succes
p_s coefficient of variation ($p_s = \frac{s_x}{\bar{x}}$)	Variationskoeffizient	variatie-coëfficiënt
q probability of failure ($p + q = 1$)	Wahrscheinlichkeit von Misserfolgen	kans op mislukking
r coefficient of correlation	Korrelationskoeffizient	correlatie-coëfficiënt
R coefficient of multiple correlation	multipler Korrelationskoeffizient	multiple correlatie-coëfficiënt
s standard deviation, standard error	mittlere Abweichung, mittlerer Fehler	standaardafwijking, middelbare fout
s_x standard deviation of $\underline{x}$	mittlere Abweichung von $\underline{x}$	standaardafwijking van $\underline{x}$
$s_{\bar{x}}$ standard error (of the mean $\bar{x}$)	mittlerer Fehler (des Mittels $\bar{x}$)	middelbare fout (van $\bar{x}$)
$s_{\hat{y}}$ standard deviation from regression	mittlere Abweichung von Regression	standaardafwijking van regressie
s(%) relative standard deviation $s(\%) = 100\sqrt{\frac{\left\{\frac{X - \bar{x}}{\bar{x}}\right\}^2}{n - 1}}$	relative Standardabweichung	relatieve standaardafwijking
t Student's t ($t = \frac{x}{\sigma}$)	t nach Student	t volgens Student
v volume	Masse	inhoud
x, x_1, x_2, etc. independent variables	unabhängige Variablen	onafhankelijke variabelen
X individual observed value of $\underline{x}$	individueller Beobachtungswert von $\underline{x}$	afzonderlijke waarneming van $\underline{x}$
$\bar{x}$ mean of x	Mittel von x	gemiddelde van x
$\underline{x}$ The bar underneath x denotes that x is a variable	Der Strich unterhalb x bedeutet dass x ein Variabler ist	de streep onder x betekent dat x een variabele is
y dependent variable	abhängige Variable	afhankelijke variable
$\hat{y}$ best estimate of y, e.g. from a regression equation $y = a + bx$	beste Schätzung von y, z.B. aus einer Regressionsgleichung $y = a + bx$	beste schatting van y, b.v. uit een regressievergelijking $y = a + bx$
$Y - \hat{y}$ deviation from regression	Abweichung von Regression	afwijking van regressie
z (1) in fig. 12: deviation from Visser s structure function	(1) in Abb. 12: Abweichung von der Strukturfunktion nach Visser	(1) in afb. 12: afwijking van Visser's structuurfunctie
(2) in fig. 40: stump height	(2) in Abb. 40: Stockhöhe	(2) in afb. 40: stobhoogte

Table 1. Particulars of the sample tree groups investigated

sample plot	locality	part of the country	absolute quality class	N_o	mixed with	trees felled by	age	$\bar{d}_{1.3}$	$\bar{f}$	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
JL 1	Ter Apel	northern-Norden	12	700	--	thinning-Durchforstung	47	30	0.46	21	21	21	1	22	22			11
						"	50	34	0.46				13	13	13			
JL 2	Odoorn	"	10	12000	white spruce-Weissfichte	"	36	16	0.54	22	22	22		22	22			
JL 3	Frederiksoord	"	8	4000	--	"	14	7	0.54	10	10			10				
						"	29	12	0.52	24	24			24				2
JL 4	"	"	10	10000	--	"	43	17	0.51	33	33	33		33	33			11
						"	47	18	0.50				25	25	25	24	10	10
JL 8	Diepenveen	"	10	2500	Douglas fir-Douglasie	"	43	23	0.47	29	29	29		29	29			10
JL 9	Olst	"	14	4000	several-verschiedene	"	34	16	0.51	23	23	23		23	23			15
JL 11	Breda	southern-Süden	10	unknown	unknown-unbekannt	"	55	30	0.48				2	2	2			
JL 12	Wehl	central-Mitte	12	2000	Norway spruce-Fichte	"	39	18	0.48	40	40	40		40	40			
JL 14	Wageningen	"	6	1200	birch-Birke	"	47	16	0.46				(17)					
JL 16	Elspeet	"	10	1100	--	"	43	20	0.48	33	33	33		33	33			22
						"	45	20	0.49				8	8	8			6
						"	47	22	0.48				24	24	24			
JL 17	"	"	14	1800	Douglas fir-Douglasie	"	40	22	0.48	13	13	13		13	13			13
						clear felling-Kahlschlag	42	25	0.47				30	30	30			
JL 25	Oploo	southern-Süden	4	4000	--	thinning-Durchforstung	38	11	0.56	18	18			18				15
JL 32	De Steeg	central-Mitte	12	unknown	several-verschiedene	"	41	20	0.51				7	7	7			
						"	44	18	0.50				8	8	8			7
JL 34	Rheden	"	14	5000	--	"	14	7	0.56	35	31			35				35
JL 37	Bilthoven	"	12	7000	--	"	17	6	0.56	25	23			25				
JL 38	Willemsoord	northern-Norden	8	10000	--	"	10	4	0.68	25	7			25				13
JL 39	Beekbergen	central - Mitte	8	7000	--	"	20	8	0.55	14	9			14				
JL 41	Ugchelen	"	14	2000	several - verschiedene	"	29	18	0.46				25	25	25			
JL 42	Ede	"	10	5000	--	"	14	6	0.53							25	10	10
D 19	De Steeg	"	10	1600	Douglas fir - Douglasie	selective felling-Aushieb	19	11	0.50	54	54			54				54
- 90	's Heerenberg	"	8	unknown	oak - Eiche	" "	41	20	0.50	27	27	27		27	27			19
						" "	43	21	0.50	10	10	10	21	31	31			
- 91	Frederiksoord	northern - Norden	10	"	unknown - unbekannt	clear felling-Kahlschlag	46	24	0.48				80	80	80			19
- 92	Treek	central - Mitte	10	"	Sitka spruce - Sitkafichte	" "	44	27	0.51				29	29	29			10
R 1, 2	Rips	southern-Süden	10	3300	--	thinning - Durchforstung	20	10	0.52	9	9			9				
E 17	Esbeek	"	16	5000	--	"	16	13	0.54	3	3			3				3
E 20, 21, 22	"	"	10	5000	--	"	18	5	0.62	16	6			16				16
L 9, 10	Loenen	central - Mitte	6	7000	--	"	14	4	0.66	18	5			18				18
Oe 9	Wageningen	"	8	2500	--	"	32	14	0.51	16	16			16				
										518	466	251	273	791	524	49	20	319
Versuchs-fläche	Ort	Teil des Landes	Absolute Standorts-klasse	N_o	Mischhölzer	Hauungsweise	Alter	$d_{1.3}$	$\bar{f}$	n_1	n_2	n_3	(290) n_4	n_5	n_6	n_7	n_8	n_9

Tabelle 1. Einzelheiten der Probestämme

N_o = number of trees per ha at age of establishment (mixed species, if mentioned, are included)
n_1 = sample trees used with preliminary ("first") investigation
n_2 = part of first investigated material of which $d_{1.3} \geqslant 5$ cm
n_3 = part of first material used with investigation on third independent variable
n_4 = second material, used for testing first material
n_5 = sample trees on which the definite volume table with 2 independent variables is based
n_6 = sample trees on which the definite volume table with 3 independent variables is based
n_7 = sample trees used for investigation on length of tree section
n_8 = material used with investigation on intensity of bark measurements
n_9 = sample trees used for bark table.

N_o	Stammzahl pro ha bei der Begründung (einschl. evt. Mischhölzer)
n_1	die bei der ersten (vorläufigen) Untersuchung benutzten Probestämme
n_2	Anteil der zuerst benutzten Probestämme, wovon $d_{1.3} \geqslant 5$ cm
n_3	Anteil der ersten Probestammgruppe, benutzt bei der Untersuchung über der dritten Variabelen
n_4	Zweite Probestammgruppe, benutzt zur Ueberprüfung der ersten Gruppe
n_5	Probestämme, auf welche die endgültige Massentafel mit zwei unabhängigen Variabelen gegründet ist
n_6	Probestämme, auf welche die endgültige Massentafel mit drei unabhängigen Variabelen gegründet ist
n_7	Probestämme, welche für die Untersuchung über die Sektionslänge benutzt wurden
n_8	Probestämme, woran die Intensität der Rindenmessungen untersucht wurde
n_9	Probestämme, welche für die Rindentabelle benutzt wurden.

Table 2. Mean form factor based on measurements using sections of different lengths

section lengths from bottom to top Sektionslängen von unten nach oben (m)	sample plot- Versuchsfläche	
	JL 4 $\bar{d}_{1.3}$ = 18.4 cm $\bar{h}$ = 18.4 m n = 24	JL 42 $\bar{d}_{1.3}$ = 6.5 cm $\bar{h}$ = 7.8 m n = 25
0.25 + n x 0.5	0.508	0.535
0.75 + n x 0.5	0.505	0.532
n x 1	0.504	0.526
2 x 1 + n x 2	0.504	0.523
n x 2	0.500	0.514
2 x 1 + n x 4	0.500	0.514
n x 4	0.497	0.503

Tabelle 2. Mittlere Schaftformzahlen als Ergebnis von Messungen bei verschiedenen Sektionslängen

Table. 4. Table of the function $d = \sqrt{\frac{4}{\pi}(g - \frac{1}{2}\Delta g)}$, where d = diameter in mm, g = basal areas in cm^2 and Δg = class interval of g

g	d	g	d	g	d	g	d
1	8.0	105	114.2	410	227.1	810	320.1
2	13.8	110	117,0	420	229.9	820	322.1
3	17.8	115	119.7	430	232.6	830	324.1
4	21.1	120	122.3	440	235.3	840	326.1
5	23.9	125	124.9	450	238.0	850	328.0
6	26.5	130	127.4	460	240.7	860	329.9
7	28.7	135	129.9	470	243.3	870	331.9
8	30.9	140	132.3	480	245.9	880	333.8
9	32.9	145	134.7	490	248.5	890	335.7
10	34.1	150	137.0	500	251.0	900	337.6
12	37.4	155	139.3	510	253.6	910	339.5
14	40.7	160	141.6	520	256.0	920	341.3
16	43.7	165	143.9	530	258.5	930	343.1
18	46.5	170	146.0	540	261.0	940	345.0
20	49.2	175	148.2	550	263.3	950	346.9
22	51.7	180	150.3	560	265.8	960	348.7
24	54.1	185	152.4	570	268.2	970	350.5
26	56.4	190	154.5	580	270.6	980	352.3
28	58.6	195	156.6	590	272.9	990	354.1
30	60.8	200	157.8	600	275.2	1 000	355.3
32	62.8	210	161.6	610	277.5	1 020	358.6
34	64.8	220	165.5	620	279.8	1 040	362.1
36	66.8	230	169.2	630	282.1	1 060	365.6
38	68.6	240	173.0	640	284.3	1 080	369.1
40	70.5	250	176.6	650	286.6	1 100	372.5
42	72.3	260	180.2	660	288.8	1 120	375.9
44	74.0	270	183.7	670	291.0	1 140	379.3
46	75.7	280	187.1	680	293.2	1 160	382.7
		290	190.5	690	295.3	1 180	386.0
50	77.6	300	193.8	700	297.5	1 200	389.3
55	81.8	310	197.1	710	299.6	1 220	392.5
60	85.6	320	200.3	720	301.7	1 240	395.7
65	89.2	330	203.4	730	303.8	1 260	398.9
70	92.7	340	206.5	740	305.9	1 280	402.1
75	96.1	350	209.6	750	308.0	1 300	405.3
80	99.3	360	212.6	760	310.0	1 320	408.4
85	102.5	370	215.6	770	312.1	1 340	411.5
90	105.6	380	218.5	780	314.1	1 360	414.6
95	108.5	390	221.4	790	316.1	1 380	417.7
100	111.4	400	224.3	800	318.2	1 400	420.7

Tabelle 4. Tafel der Funktion $d = \sqrt{\frac{4}{\pi}(g - \frac{1}{2}\Delta g)}$, worin d = Durchmesser in 2 mm, g = Kreisfläche in cm^2 und Δg = Klasseninterval von g

Table 3. Form factors based on two diameter measurements made at right angles and on one single measurement

sample plot	JL 4			JL 42			Versuchsfläche
number of measurements per section	$\bar{f}$	s_f	$s_{\bar{f}}$	f	s_f	$s_{\bar{f}}$	Anzahl der Messungen pro Sektion
2 directions (A and B)	0.504	0.034	0.007	0.526	0.047	0.009	2 Richtungen (A und B)
direction A only	0.504	0.033	0.008	0.528	0.048	0.010	nur Richtung A
direction B only	0.506	0.039	0.007	0.525	0.049	0.010	nur Richtung B
at 1.3 m : A + B; at other positions: alternately A or B	0.504	0.035	0.007	0.530	0.046	0.009	in Brusthöhe: A + B an anderen Messstellen: A oder B abwechselnd

Tabelle 3. Schaftformzahlen, erhalten aus einzelnen Durchmesserbestimmungen und Messungen übers Kreuz

Table 5. Mean time of section measurement and relative cost price per tree with different wage proportions and different team compositions

number of persons Anzahl Personen	measuring time (seconds) per tree Messzeit pro (Baum) Sekunden	proportion of wage of team leader and assistants Lohnverhältnis zwischen Truppführer und Gehilfen.					
		1 : 1		1 : 0.5		1 : 0.3	
		cost price per Kostenpreis pro		cost price per Kostenpreis pro		cost price per Kostenpreis pro	
		second Sekunde	tree Baum	second Sekunde	tree Baum	second Sekunde	tree Baum
1	180	1	180	1	180	1	180
2	60	2	120	1.5	90	1.3	78
3	25	3	75	2	50	1.6	40
4	24	4	96	2.5	60	1.9	46

Tabelle 5. Mittlere Sektionsmessungszeit und Kostenpreisverhältnis bei verschiedenen Lohnverhältnissen und Messtruppzusammensetzungen

Table 6. Mean time of measurement per tree with different measuring methods of a three men team and mean time of calculation by one man

Number of colliper measurements per section	measurement of d or g	time of measuring (seconds)	time of calculation (seconds)	total time (seconds)
2 directions-Richtungen	d	37	110*	147*
1 direction-Richtung	d	24	78*	102*
1 " "	g	27	58	85
Anzahl Durchmesserkluppungen pro Sektion	Messung von d oder g	Messzeit (Sekunden)	Berechnungszeit(Sekunden)	Totalzeit (Sekunden)

Tabelle 6. Mittlere Messungszeit eines 3-Mann-Trupps und mittlere Berechnungszeit bei verschiedenen Messungsmethoden

*) These times include the booking of all individual basal area values on the calculation form. If this was not done and the basal areas were directly added in the calculation machine, the results were achieved in about 7 seconds less.

*) Einschliesslich der Zeit, benötigt für das Eintragen aller individuellen Kreisflächenwerte in den Vordruck. Wenn anstatt dessen die Kreisflächen unmittelbar auf der Rechenmaschine summiert wurden, war etwa 7 Sekunden weniger Zeit benötigt.

Table 7. Survey of the volume table construction methods included in the preliminary investigation

Nr	type	author	modification	function	
				number of independent variables	
				1	2
1	stem form equation Stammkurvengleichung	Wolff von Wülfing	Ferguson		$y = ax + bx^2 + cx^3$ $f_{\frac{1}{4}h} = F(d_{1.3})$
2	" " "	"	writer		$y = ax + bx^2 + cx^3$ $f_{\frac{1}{4}h} = F(h)$
3	" " "	"	Becking		$y = ax + bx^2 + cx^3$ $f_{\frac{1}{4}h}$ = constant
4	regression equation	Berkhout	writer* - Autor*	$\log v = a + b \log d_{1.3}$	
5	Regressionsgleichung	"	writer - Autor	$\log v = a + b \log h$	
6	" "	Bähler and Bosman	-		$\log f = a + b_1 \log d_{1.3} + b_2 \log h$
7	" "	Schumacher and Hall	-		$\log v = a + b_1 \log d_{1.3} + b_2 \log h$
8	" "	Näslund	-		$f = a + b_1 \frac{1}{h} + b_2 \frac{h}{d_{1.3}}$
9	graph-graphische Ausgleichung	Visser	writer - Autor		$\sqrt[3]{v} = F(d_{1.3}, h)$
10	"	Chapman und Meyer	-		$v = F(d_{1.3}, h)$
11	"	" " "	writer (1) Autor		$f = F(d_{1.3}, h)$
12	"	" " "	" (2) "	$f = F(d_{1.3})$	
13	"	" " "	" (3) "	$f = F(h)$	
14	"	" " "	" (4) "	$fh = F(d_{1.3})$	
15	"	" " "	" (5) "	$fg = F(h)$	
Nr	Typus	Autor	Modifikation	1	2
				Anzahl unabhängige Variabele	
				Funktion	

Tabelle 7. Uebersicht der bei der vorläufigen Untersuchung angewandten Ausgleichmethoden für Massentafeln

*) The modification refers to the fact that in this investigation Berkhout's equation was used for the construction of a general volume table whereas Berkhout applied his method on individual stands only.

*) Die Modifikation besteht darin, dass bei dieser Untersuchung die Berkhout'sche Gleichung für einen allgemeinen Massentarif benutzt wurde, während Berkhout seine Methode nur auf Einzelbestände angewendet hat.

Table 8.
Absolute form factors $(f_{\frac{1}{4}h})$ found by the Wolff von Wülfing-Ferguson method

$d_{1.3}$ (cm)	$f_{\frac{1}{4}h}$
1	0.621
2	0.624
3	0.627
4	0.634
5	0.645
6	0.661
7	0.661
8	0.656
9	0.659
10	0.655
11	0.663
12	0.663
13	0.662
14	0.659
15	0.659
≥16	0.655

Tabelle 8.
Absolute Schaftformzahlen $(f_{\frac{1}{4}h})$ mit der Methode nach Wolff von Wülfing Ferguson

Table 9.
Absolute form factors $(f_{\frac{1}{4}h})$ found by the 2nd modification of Wolff von Wülfing's method

h (m)	$f_{\frac{1}{4}h}$
3	0.477
4	0.607
5	0.627
6	0.619
7	0.640
8	0.648
9	0.653
10	0.653
11	0.655
12	0.655
≥13	0.659

Tabelle 9.
Absolute Schaftformzahlen $(f_{\frac{1}{4}h})$ welche bei der Wolff von Wülfing'schen Methode bekommen wurden

Table 10. Some actual class averages from Chapman and Meyer's graphical method
$v = F(d_{1.3}h)$

h (m) / $d_{1.3}$ (cm)	1 - 4 2.5	4 - 7 5.5	7 - 10 8.5	10 - 13 11.5	13 - 16 14.5	16 - 19 17.5
1 - 4 2.5	3.6 2.1	4.8 3.1	7.8 3.8	- -	- -	- -
4 - 7 5.5	- -	6.1 5.0	8.5 5.6	10.4 5.9	- -	- -
7 - 10 8.5	- -	- -	8.8 8.2	11.0 8.7	- -	- -
10 - 13 11.5	- -	- -	9.9 10.8	11.4 11.3	14.1 11.5	16.1 10.8

Tabelle 10. Einige bei der graphischen Methode nach Chapman und Meyer tatsächlich gefundenen Klassenmittelwerte

Table 12. Results of the first-investigated construction methods

author	method	number of		equation	aggregate perc. deviation		distribution of uncorrected aggregate percentual deviation over height classes				
		entries	independent variables		uncorrected	corrected	h ≤ 5 m n = 37	6-10m n=128	11-15 m n=112	16-20 m n=141	> 21 m n=100
1 Wolff von Wülfing/Ferguson	stem form	2	(4+)2	$y = ax + bx^2 + cx^3 \quad 0.621 < f_{\frac{1}{4}h} < 0.661$	41 843	39 993	7 360	10 805	8 290	10 831	4 557
2 Wolff von Wülfing/writer-Autor	equation-Stamm-	2	(4+)2	$0.543 \leqslant f_{\frac{1}{4}h} \leqslant 0.659$	41 562	37 054	5 461	11 257	9 065	11 135	4 644
3 Wolff von Wülfing/Becking	Kurvengleichung	2	(4+)2	$f_{\frac{1}{4}h} = 0.658$	38 957	37 913	5 995	10 056	7 739	10 657	4 510
4 Berkhout	calculation-Berechnung	1	1	$\log v = 2.11262 + 2.56725 \log d_{1.3}$	142 426	138 009					
5 Berkhout, modif.	calculation-Berechnung	1	1	$\log v = -5.57818 + 3.34552 \log h$	930 261	851 765	60 506	202 700	258 027	242 964	166 064
6 Bähler & Bosman	calculation-Berechnung	2	2	$\log f = -0.160759 - 0.157363 \log d_{1.3} + 0{,}015148 \log h$	34 942	34 842	8 971	7 200	6 881	8 388	3 502
7 Schumacher & Hall	calculation-Berechnung	2	2	$\log v = -0.43739 + 1.75811 \log d_{1.3} + 1.09953 \log h$	36 589	36 258	5 568	9 371	6 928	11 551	3 171
8 Näslund	calculation-Berechnung	2	2	$f = 0.3856 + 0.9211\frac{1}{h} + 0.0534\frac{h}{d_{1.3}}$	32 609	32 609	5 850	9 703	6 214	7 694	3 148
9 Visser	graph-graphische Ausgleichung	2	(2)	$\sqrt[3]{v} = F(d_{1.3}, h)$	41 100	40 760	6 461	11 867	7 785	9 770	5 217
10 Chapman & Meyer	graph-graphische Ausgleichung	2	2	$v = F(d_{1.3}, h)$	49 064	47 154	7 713	23 612	7 290	7 062	3 387
11 Chapman & Meyer, modif. 1	graph-graphische Ausgleichung	2	2	$f = F(d_{1.3}, h)$	27 090	27 090	4 048	6 350	5 790	7 595	3 307
12 Chapman & Meyer, modif. 2	graph-graphische Ausgleichung	2	1	$f = F(d_{1.3})$	27 566	27 559	4 229	7 226	5 700	7 134	3 277
13 Chapman & Meyer, modif. 3	graph-graphische Ausgleichung	2	1	$f = F(h)$	28 889	28 887	4 682	7 528	5 833	7 296	3 550
14 Chapman & Meyer, modif. 4	graph-graphische Ausgleichung	1	1	$fh = F(d_{1.3})$	106 876	106 876					
15 Chapman & Meyer, modif. 5	graph-graphische Ausgleichung	1	1	$fg = F(h)$	687 503	686 782	57 797	174 954	160 726	170 503	123 523
Autor	Methode	Eingänge	unabhängige Variabele	Gleichung	Nicht korrigierte	Korrigierte	Verteilung der gesamten prozentuellen Streuung über Höhenklassen				
		Anzahl			gesamte prozentuelle Streuung						

Tabelle 12. Ergebnisse der bei der vorläufigen Untersuchung angewandten Methoden

Table 11. Distribution of the first-investigated material over diameter and height classes

$d_{1.3}$ \ h	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	n
1	2																								2
2	1	10																							11
3		11	3	2																					16
4			7	4	6	6																			23
5			3	6	4	7	3	1																	24
6				5		7	7	6																	25
7				1		9	3	7	1																21
8						6	7	5	3	1															22
9							5	4	7	4															20
10							3	8	4	1	3	3													22
11								4	6	3	2	5		1											21
12								1	6	7	2	2	2												20
13								1	5	3	2	4	4	1	1			1							22
14									2	3	2	3	6	7	3	4	2	2	1						35
15									1	1	1	1	3	2	3	2	1			2					17
16												1	4	3	1	6	2	3	2	2					24
17													2	2	2	3	4	3	3						19
18													1	2	3	5	3	5	7	1					27
19														2	5	2		4	4	4					21
20													1	1	2	6	3	4	5	3	4	1			30
21																	4	5	2		1				12
22															1	3	2	3		4	1	1	1		16
23																3		1		3	2				9
24														1			1	2	5	3	2	2			16
25																	3	1		2	4	1			11
26																	1	2	1	3	1	1	1		10
27																			1	1	1				3
28																		1		1		1	1		4
29																		1		1			1		3
30																									
31																									
32																				1		2	1		4
33																			1		1	2			4
34																				1		1			2
35																									
36																						1			1
37																								1	1
n	3	21	13	18	10	35	28	37	35	23	12	19	23	22	21	34	26	38	32	32	17	13	5	1	518

Tabelle 11. Verteilung der bei der vorläufigen Untersuchung benutzten Probestämme nach Durchmesser und Höhe

Table 13. Example of a systematic reduction of means due to logarithmic transformation

tree number Baumnummer	v (cm^3)	log v	f	log f
342	1180	3.0719	0.819	0.9133 - 1
343	1020	3.0086	0.750	0.8751 - 1
344	1210	3.0828	0.840	0.9243 - 1
345	1390	3.1430	0.869	0.9390 - 1
346	1400	3.1461	0.778	0.8910 - 1
347	1360	3.1335	0.618	0.7910 - 1
362	1240	3.0934	0.861	0.9350 - 1
431	1100	3.0414	0.803	0.9047 - 1
447	1430	3.1553	0.694	0.8414 - 1
449	1090	3.0374	0.727	0.8615 - 1
	$\Sigma v = 12420$ $\bar{v} = 1242$ $\log \bar{v} = 3.0941$ $\frac{v' - \bar{v}}{\bar{v}} = -0.0064$	$\Sigma \log v = 30.9134$ $\overline{\log v} = 3.0913$ $v' = 1234$	$\Sigma f = 7.759$ $f = 0.7759$	$\Sigma \log f = 8.8763 - 10$ $\overline{\log f} = 0.8876 - 1$ $f' = 0.7720$ $\frac{f' - \bar{f}}{\bar{f}} = -0.0050$

Tabelle 13. Beispiel einer systematischen Reduktion von Mittelwerten infolge der logarithmischen Transformation

Table 19. Standard volume table for Japanese larch (m^3)

$d_{1.3}$ (m)	h (m) / f	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	n	$d_{1.3}$ (m)
1	1.28	0.0002	0.0003	0.0004																													2	1
2	0.82	0005	0008	0010	0.0013	0.0015																											11	2
3	0.676	0010	0014	0019	0024	0029	0.0033	0.0038																									16	3
4	0.598		0023	0030	0038	0045	0053	0060	0.0068	0.0075																							23	4
5	0.569		0034	0045	0056	0067	0078	0089	010	011	0.012	0.013																					24	5
6	0.554		0047	0063	0078	0094	011	013	014	016	017	019	0.020	0.022																			25	6
7	0.546			0084	010	013	015	017	019	021	023	025	027	029	0.031	0.034																	21	7
8	0.539				014	016	019	022	024	027	030	032	035	038	041	043	0.046																22	8
9	0.533				017	020	024	027	031	034	037	041	044	047	051	054	058	0.061															20	9
10	0.527					025	029	033	037	041	046	050	054	058	062	066	070	075	0.079														22	10
11	0.522					030	035	040	045	050	055	060	065	069	074	079	084	089	094	0.099													21	11
12	0.518						041	047	053	059	064	070	076	082	088	094	100	105	111	117	0.123												20	12
13	0.514							055	061	068	075	082	089	095	102	109	116	123	130	136	143	0.150											24	13
14	0.510								071	078	086	094	102	110	118	126	133	141	149	157	165	173	0.181										40	14
15	0.506								081	089	098	107	116	125	134	143	152	161	170	179	188	197	206	0.215									21	15
16	0.503									101	111	121	131	142	152	162	172	182	192	202	212	222	233	243	0.253								36	16
17	0.500									113	125	136	148	159	170	182	193	204	216	227	238	250	261	272	284								26	17
18	0.497									126	139	152	164	177	190	202	215	228	240	253	266	278	291	303	316	0.329							44	18
19	0.494										154	168	182	196	210	224	238	252	266	280	294	308	322	336	350	364							44	19
20	0.491										170	185	201	216	232	247	263	278	293	309	324	340	355	371	386	401	0.417						46	20
21	0.489										186	203	220	237	254	271	288	305	322	339	356	373	390	407	423	440	457						33	21
22	0.487											222	240	259	277	296	314	333	351	370	388	407	425	444	462	481	499						46	22
23	0.484											241	262	282	302	322	342	362	382	402	423	443	463	483	503	523	543	0.563					34	23
24	0.482												284	305	327	349	371	393	414	436	458	480	502	523	545	567	589	611					43	24
25	0.480												306	330	353	377	400	424	448	471	495	518	542	565	589	612	636	660					33	25
26	0.478												330	355	381	406	431	457	482	507	533	558	584	609	634	660	685	710					27	26
27	0.476													382	409	436	463	491	518	545	572	600	627	654	681	709	736	763	0.790				9	27
28	0.474													409	438	467	496	525	555	584	613	642	671	701	730	759	788	817	847				10	28
29	0.472													437	468	499	530	562	593	624	655	686	718	749	780	811	842	874	905				7	29
30	0.471														499	532	565	599	632	665	698	732	765	798	831	865	898	931	964	0.998			7	30
31	0.469														531	566	602	637	672	708	743	778	814	849	885	920	955	991	1,026	1.062			7	31
32	0.467														564	601	639	676	714	751	789	827	864	902	939	977	1,015	1,052	1,090	1.127			11	32
33	0.466														597	637	677	717	757	796	836	876	916	956	996	1,035	1,075	1,115	1,155	1,195			8	33
34	0.464															674	716	758	801	843	885	927	969	1,011	1,053	1,096	1,138	1,180	1,222	1,264			2	34
35	0.463															712	757	801	846	890	935	979	1.024	1,068	1,113	1,157	1.202	1.246	1,291	1.335	1.380		1	35
36	0.461															751	798	845	892	939	986	1,033	1.079	1.126	1.173	1,220	1.267	1.314	1,361	1.408	1.455		2	36
37	0.460																840	890	939	989	1.038	1.087	1.137	1.186	1,236	1,285	1.335	1,384	1.433	1.483	1.532		1	37
38	0.458																884	936	988	1,040	1,091	1.143	1.195	1.247	1.299	1,351	1.403	1.455	1.507	1,559	1,611		-	38
39	0.457																928	983	1.037	1.092	1.146	1.201	1.256	1.310	1,365	1,419	1.474	1.529	1.583	1,638	1.692		1	39
40	0.456																	1.031	1.088	1.145	1,203	1.260	1,317	1.374	1,432	1,489	1.546	1.603	1.661	1.718	1.775	1.832	-	40
41	0.454																	1.080	1.140	1.200	1,260	1,320	1.380	1.440	1.500	1.560	1.620	1.680	1.740	1.800,	1.860	1.920	-	41
42	0.453																		1.193	1,255	1,318	1.381	1.444	1.507	1.569	1.632	1,695	1.758	1.820	1.883	1.946	2.009	1	42
43	0.452																		1.247	1,312	1,378	1.444	1.509	1.575	1.641	1.706	1.772	1.838	1.903	1,969	2.034	2,100	-	43
44	0.451																			1.371	1.439	1.508	1.576	1.645	1.713	1.782	1.850	1.919	1.987	2,056	2,124	2,193	-	44
45	0.450																			1.430	1.502	1.573	1.645	1.716	1.788	1.859	1.931	2.002	2.074	2.145	2.217	2,288	-	45
46	0.448																				1.565	1.639	1.714	1.788	1.863	1.937	2.012	2.087	2,161	2.236	2,310	2,385	-	46
47	0.447																				1.630	1.707	1.785	1.863	1.940	2.018	2.095	2.173	2.251	2.328	2.406	2.483	-	47
48	0.446																					1.776	1.857	1.938	2.019	2.099	2.180	2.261	2.342	2.422	2.503	2.584	-	48
49	0.445																					1.847	1.931	2.015	2.099	2.183	2.267	2.351	2.434	2.518	2.602	2.686	-	49
50	0.444																					1.918	2.006	2.093	2.180	2.267	2.354	2.442	2.529	2.616	2.703	2.790	-	50
n			3	21	13	18	10	35	28	37	35	23	13	19	23	32	35	60	57	98	71	64	32	37	20	7	-	-	-	-	-	-	791	
h		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32		

Sample tree data:
Trees mainly from thinnings, partly from selective and clear fellings of plantations of Japanese larch in the Netherlands, 10 - 55 years old; measured in sections of 1 and 2 metres.

Volume:
Total stem volume over bark (no allowances for stump or top) in cubic metres.

Construction method:
Regression of form factor on d.b.h.; for trees below 5 cm d.b.h. (n = 52) graphically estimated; for bigger trees (n = 739) calculated according to f = 0.6463 - 0.1190 log d. Standard errors of estimate of regression constant and regression coefficient, and standard deviation from regression are 0.0078; 0.0064 and 0.035 respectively; coefficient of variation = 7.0

Probestammdaten:
Hauptsächlich Durchforstungsstämme, teilweise auch Stämme aus Lichtungen und Kahlschlägen niederländischer Bestände von Japanlärche, 10 - 55 Jahre alt und in 1- und 2-m Sektionen gemessen.

Masse:
Schaftholzmasse mit Rinde (ohne Reduktion für Zopfholz oder Stockhöhe) in fm.

Aufstellungsmethode:
Regression von Schaftformzahl auf Brusthöhendurchmesser; für Stämme unter 5 cm Brusthöhendurchmesser (n = 52) mittels graphischer Ausgleichung; für stärkere Stämme (n = 739) berechnet nach f = 0.6463 - 0.1190 log d.
Die mittleren Fehler der Regressionskonstante und des Regressionskoeffizients, sowie die mittlere Abweichung von Regression sind bezw. 0.0078; 0.0064 und 0.035; der Variationskoeffizient beträgt 7.0.

Tabelle 19. Massentafel der Japanischen Lärche (m^3)

Table 29 a. Partial form factor f_1 based on $d_{1.3}$ and d_6

$d_{1.3}$ (cm) d_6 (cm)	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	n	(cm) $d_{1.3}$ d_6 (cm)
6	0.812	0.741																																								0	6
7	0.926	0.854	0.788	0.726																																						3	7
8	1.024	0.952	0.886	0.824	0.769	0.716																																				3	8
9	1.110	1.038	0.972	0.911	0.855	0.802	0.753	0.708																																		4	9
10	1.188	1.116	1.050	0.989	0.933	0 880	0.831	0.786	0.742	0.700																																12	10
11		1.186	1.119	1.058	1.002	0.950	0.901	0.855	0.811	0.769	0.731	0.694																														19	11
12			1.183	1.122	1.066	1.014	0.965	0.919	0.876	0.834	0.795	0.758	0.724	0.689																												27	12
13				1.182	1.126	1.073	1.024	0.979	0.935	0.893	0.854	0.818	0.783	0.748	0.716	0.685																										28	13
14					1.180	1.127	1.078	1.033	0.989	0.947	0.909	0 872	0.837	0.802	0.770	0.739	0.709	0.681																								49	14
15						1.178	1.129	1.084	1.040	0.998	0.959	0.923	0.888	0 853	0.821	0 790	0.760	0.732	0.704	0.678																						42	15
16							1.176	1.131	1.087	1.045	1.007	0.970	0.935	0.900	0.869	0.837	0.807	0.779	0.751	0.725	0.699	0.674																				49	16
17								1.175	1.131	1.089	1.051	1.014	0.979	0.944	0.913	0.881	0.851	0.823	0.795	0.769	0.743	0.718	0.694	0.669																		44	17
18									1.173	1.131	1.093	1.056	1.021	0.986	0.955	0.923	0.894	0.866	0 838	0.811	0.785	0.761	0.736	0.712	0.691	0.668																47	18
19										1.172	1.134	1.097	1.062	1.027	0.995	0.964	0 934	0.906	0.878	0.852	0.826	0.801	0.777	0.752	0.731	0.709	0.688	0.667														41	19
20											1.171	1.134	1.099	1.064	1.033	1.001	0.971	0.943	0.915	0.889	0.863	0.839	0.814	0.790	0.769	0.746	0.725	0.704	0.683	0.664												50	20
21												1.170	1.135	1.100	1.068	1.037	1.007	0.979	0.951	0.925	0.899	0.874	0.850	0.825	0.804	0.781	0.760	0.739	0.718	0.699	0.680	0.661										29	21
22													1.169	1.134	1.102	1.071	1.041	1.013	0.985	0.959	0.932	0.908	0.883	0.859	0.838	0.815	0.794	0.773	0.752	0.733	0.714	0.695	0.677	0.660								16	22
23														1.167	1.136	1.104	1.075	1.047	1.019	0.992	0.966	0.942	0.917	0.893	0.872	0.849	0.828	0.807	0.786	0.767	0.748	0.728	0.711	0.693	0.676	0.658						10	23
24															1.166	1.135	1.105	1.077	1.049	1.023	0.997	0.972	0.949	0.923	0.902	0.880	0.859	0.838	0.817	0.797	0.778	0.759	0.741	0.724	0.706	0.689	0.671	0.656				7	24
25																1.165	1.136	1.108	1.080	1.053	1.027	1.003	0.978	0.954	0.933	0.910	0.889	0.868	0.847	0.828	0.809	0.789	0.772	0.754	0.737	0.719	0.702	0.686	0.670	0.655		13	25
26																	1.164	1.136	1.108	1.082	1.056	1.031	1.007	0.982	0.961	0.939	0.918	0.897	0.876	0.857	0.837	0.818	0.801	0.783	0.766	0.748	0.731	0.715	0.699	0.683	0.668	14	26
27																		1.163	1.135	1.109	1.083	1.058	1.034	1.010	0.989	0.966	0.945	0.924	0.903	0.884	0.864	0.845	0.828	0.810	0.793	0.775	0.758	0.742	0.726	0.710	0.695	6	27
28																			1.163	1.136	1.110	1.086	1.061	1.037	1.016	0.993	0.972	0.951	0.930	0.911	0.891	0.872	0.855	0.837	0.820	0.802	0.785	0.769	0.753	0.738	0.722	5	28
29																				1.162	1.135	1.111	1.086	1.062	1.041	1.018	0.997	0.976	0.955	0.936	0.917	0.898	0.880	0.863	0.845	0.828	0.810	0.794	0.779	0.763	0.747	2	29
30																					1.161	1.136	1.112	1.087	1.066	1.044	1.023	1.002	0.981	0.961	0.942	0.923	0.905	0.888	0.870	0.853	0.835	0.820	0.804	0.788	0.773	0	30
31																						1.160	1.136	1.111	1.090	1.067	1.046	1.025	1.004	0.985	0.966	0.947	0.929	0.912	0.894	0.877	0.859	0.843	0.828	0.812	0.796	1	31
32																							1.159	1.135	1.114	1.091	1.070	1.049	1.028	1.009	0.990	0.970	0.953	0.935	0.918	0.900	0.883	0.861	0.851	0.836	0.820	1	32
33																								1.158	1.137	1.115	1.094	1.073	1.052	1.032	1.013	0.994	0.977	0.959	0.942	0.924	0.907	0.891	0.875	0.859	0.844	2	33
34																									1.158	1.135	1.114	1.093	1.072	1.053	1.034	1.014	0.997	0.979	0.962	0.944	0.927	0.911	0.895	0.880	0.864	0	34
35																										1.157	1.136	1.115	1.094	1.075	1.056	1.036	1.019	1.001	0.984	0.966	0.949	0.933	0.917	0.902	0.886	0	35
36																											1.156	1.135	1.114	1.095	1.076	1.057	1.039	1.022	1.004	0.987	0.969	0.952	0.938	0.922	0.906	0	36
37																												1.156	1,135	1.115	1.096	1.077	1.059	1.042	1.024	1.007	0.989	0.974	0.958	0.942	0.927	0	37
38																													1.155	1.136	1.116	1.097	1.080	1.062	1.045	1.027	1.010	0.994	0.978	0.963	0.947	0	38
39																														1.154	1.135	1.116	1.098	1.081	1.063	1.046	1.028	1.013	0.997	0.981	0.965	0	39
40																															1.154	1.134	1.117	1.099	1.082	1.064	1.047	1.031	1.016	1.000	0.984	0	40
41																																1.153	1.136	1.118	1.101	1.083	1.066	1.050	1.034	1.018	1.003	0	41
42																																	1.152	1.135	1.118	1.100	1.083	1.067	1.051	1.035	1.020	0	42
43																																		1.152	1.134	1.117	1.099	1.084	1.068	1.052	1.036	0	43
44																																			1.151	1.134	1.116	1.101	1.085	1.069	1.053	0	44
45																																				1.151	1.133	1.118	1.102	1.086	1.070	0	45
n	5	1	1	16	21	19	27	40	35	52	37	34	41	44	38	35	16	6	11	5	9	10	8	4	2	2	2	0	0	1	0	0	2	0	0	0	0	0	0	0	0	524	n

Sample tree data:
Trees from plantations of Japanese larch in the Netherlands, measured in sections of 1 and 2 metres.

Form factor:
Refers to total stem wood volume over bark.

Construction method:
Breast height form factor calculated as:
$f = f_1 + f_2$, where $f_1 = 1.245 - 1.749 \log d_{1.3} + 1.692 \log d_6$
and $f_2 = -0.415 \log h$.
Standard deviation from regression: 0.016; coefficient of variation: 3.3

Probestammdaten:
Stämme aus niederländischen Bestände von Japanlärche, gemessen in 1- und 2- m Sektionen.

Formzahl:
Schaftholzformzahl mit Rinde.
Aufstellungsmethode:
Brusthöhenformzahl berechnet nach:
$f = f_1 + f_2$, worin $f_1 = 1.245 - 1.749 \log d_{1.3} + 1.692 \log d_6$ und $f_2 = -0.415 \log h$
Mittlere Abweichung von Regression: 0.016; Variationskoeffizient: 3.3

Tabelle 29 a. Teilformzahl f_1 gegründet auf $d_{1.3}$ und d_6

Table 29. Form factor table for Japanese larch based on $d_{1,3}$, d_6 and h

Tabelle 29. Schaftformzahltafel für japanische Lärche,
gegründet auf $d_{1,3}$

The total form factor is obtained by adding two partial form factors: $f = f_1 + f_2$. The partial form factor f_1 is read from table 29a, please turn overleaf! The partial form factor f_2 is read from table 29b, see below.

Die Totalformzahl errechnet sich als die Summe der beiden Teilformzahlen: $f = f_1 + f_2$. Die Teilformzahl f_1 ist aus der Tabelle 29a abzulesen, bitte wenden! Die Teilformzahl f_2 ergibt sich aus Tabelle 29b, siehe unten.

Table 29 b. Partial form factor f_2 based on h

h (m)	f_2	n	h (m)	f_2	n
10	-0.415	0	20	-0.540	95
11	-0.432	0	21	-0.549	69
12	-0.448	0	22	-0.557	55
13	-0.462	3	23	-0.565	33
14	-0.476	5	24	-0.573	36
15	-0.488	11	25	-0.580	18
16	-0.500	30	26	-0.587	2
17	-0 510	38	27	-0 594	0
18	-0.521	63	28	-0.601	0
19	-0.531	66	29	-0.607	0
			30	-0.613	0

Tabelle 29 b. Teilformzahl f_2 gegründet auf h

Table 30. Example of volume calculation by means of table 29. Basic data (breast height diameter of all trees) and final result.

$d_{1.3}$ (cm)	n	v_d (m^3)	nv_d (m^3)
1	2	3	4
11	2	0.053	0.106
12	-	0.071	-
13	-	0.090	-
14	5	0.111	0.555
15	3	0.133	0.399
16	5	0.157	0.785
17	14	0.182	2.548
18	14	0.209	2.926
19	20	0.238	4.760
20	32	0.268	8.576
21	42	0.300	12.600
22	44	0.333	14.652
23	36	0.367	13.212
24	32	0.404	12.928
25	22	0.441	9.702
26	8	0.481	3.848
27	6	0.522	3.132
28	3	0.564	1.692
29	1	0.608	0.608
30	1	0.653	0.653
	290		93.682

Tabelle 30. Beispiel einer Massenberechnung mit Hilfe von Tabelle 29. Ausgangsdaten (Brusthöhendurchmesser von allen Bäumen) und Endergebnis.

Table 31. Example of volume calculation by means of table 29. Sample tree data.

nr.	$d_{1.3}$ (cm)	d_6 (cm)	h (m)	f_1	f_2	f	gh (m^3)	v (m^3)
1	2	3	4	5	6	7	8	9
1	16	12	17	0.965	-0.510	0.455	0.342	0.156
2	22	19	20	1.062	-0.540	0.522	0.760	0.397
3	21	17	19	1.014	-0.531	0.483	0.657	0.317
4	13	10	17	0.989	-0.510	0.479	0.226	0.108
5	19	15	18	0.998	-0.521	0.477	0.511	0.244
6	20	15	18	0.959	-0.521	0.438	0.565	0.247
7	16	10	16	0.831	-0.500	0.331	0.322	0.107
8	16	12	18	0.965	-0.521	0.444	0.362	0.161
9	16	12	18	0.965	-0.521	0.444	0.362	0.161
10	17	12	16	0.919	-0.500	0.419	0.363	0.152
11	19	14	18	0 947	-0.521	0.426	0.511	0.218
12	19	14	18	0.947	-0 521	0.426	0.511	0.218
13	16	11	16	0.901	-0.500	0.401	0.322	0.129
14	13	10	16	0.989	-0.500	0.489	0.213	0.104
15	22	17	18	0.979	-0.521	0.458	0.684	0.313
16	18	14	17	0.989	-0.510	0.479	0.432	0.207
17	20	16	19	1.007	-0.531	0.476	0.597	0.284
18	20	15	18	0.959	-0.521	0.438	0.565	0.247
19	15	12	18	1.014	-0.521	0.493	0.319	0.157
20	20	16	18	1.007	-0.521	0.486	0.565	0.275
21	23	18	19	0.986	-0.531	0.455	0.788	0.359
22	16	12	17	0.965	-0 510	0.455	0.342	0.156
23	17	15	18	1.084	-0.521	0.563	0.409	0.230
24	23	19	18	1.027	-0.521	0.506	0.747	0.378
25	20	15	19	0.959	-0.531	0.428	0.597	0.256

Tabelle 31. Beispiel einer Massenberechnung mit Hilte von Tabelle 29. Probestammdaten.

Table 32. Relationship of top diameter (d_{top}) and diameter at breast height ($d_{1.3}$)

$d_{1.3}$ (cm)	d_{top} (cm)
0 - 1.9	0
2 - 3.9	1
4 - 5.9	2
6 - 8.9	3
9 - 11.9	4
12 - 16.9	5
17 - 22.9	6
≥23	7

Tabelle 32. Beziehung zwischen Zopfdurchmesser (d_{top}) und Brusthöhendurchmesser ($d_{1.3}$)

Table 35. Comparison of actual volumes and regression volumes of sample trees, measured in one section. The regression volumes are derived from the standard volume table nr 19 and corrected by the figures of table nr 34

locality	breast height diameter class	volume according to table 19	table 19 + 34	measurement in 1 section	difference between (5) and (4), expressed as a percentage of (4)
1	2	3	4	5	6
Gortel, 4 c n = 50	5 10	0.443 0.669	0.396 0.634	0.412 0.634	+ 3.9 + 0.2
	all	1.112	1.030	1.046	+ 1.6
Gortel, 56 a n = 50	5 10 15	0.165 1.825 0.308	0.148 1.728 0.298	0.154 1.707 0.317	+ 4.1 - 1.2 + 6.4
	all	2.298	2.174	2.178	+ 0.2
Soeren Zuid, 2 a n = 35	5 10	0.280 0.193	0.250 0.183	0.278 0.181	+10.8 - 0.8
	all	0.473	0.433	0.459	- 5.9
Soeren Zuid, 3 a n = 146	5 10	0.972 2.098	0.870 1.987	0.929 1.890	+ 6.7 - 4.9
	all	3.070	2.857	2.819	- 1.3
Soeren Zuid, 11 a n = 73	5 10	0.539 0.456	0.482 0.432	0.498 0.455	+ 3.3 + 5.3
	all	0.995	0.914	0.953	+ 4.2
Total	all	7.948	7.408	7.455	+ 0.6
Ort	Durchmesserklasse	Massenermittlung nach Tabelle 19	Tabelle 19 + 34	Mittenfläche	Differenzen zwischen (5) und (4), ausgedrückt als Prozentsatz von (4)

Tabelle 35. Gleichung von beobachten Massen und Regressionsmassen von Stämmen, welche nach der Mittenfläche kubiert wurden. Die Regressionsmassen wurden mit Hilfe der Massentafel (Tabelle 19) bestimmt und korrigiert mit Hilfe von Tabelle 34

Table 36. Relationship between bark percentage and breast height diameter according to Schober, 1953

$d_{1.3}$ (cm)	bark percentage Rindenprozent
7 - 10	25
11 - 15	21
16 - 20	19
21 - 25	18
26 - 30	17
31 - 35	16
36 - 40	15
41 - 45	14

Tabelle 36. Beziehung zwischen Rindenprozent und Brusthöhendurchmesser nach Schober, 1953

Table 39. Relationship of total bark percentage of a tree and bark percentage at different heights

sample plot Versuchsfläche	JL 42	JL 4	JL 1
age - Alter	14	47	47
$\bar{d}_{1.3}$ (cm)	7	18	28
total bark % totales Rindenprozent	32	21	18
bark % at Rindenprozent in			
1.3 or/oder 1.5 m	26	17	17
0.1 h	30	20	17
0.3 h	<u>31</u>	<u>21</u>	<u>18</u>
0.5 h	29	<u>21</u>	<u>18</u>
0.7 h	35	26	21
0.9 h	-	28	27

Tabelle 39. Beziehung zwischen Total-Rindenprozent von Einzelstämmen und Rindenprozent in verschiedenen Höhen

Table 33. Deviations from normally estimated mean form factors ($\bar{f}$), due to measurement of the tree in one section only and such with different minimum top diameters (d_{top})

d_{top} (cm)	0		practice (Table 32)		7.6		normal f	n
$d_{1.3}$ (cm)	Δf	%	Δf	%	Δf	%		
1.5 (1 - 2)	-0.174	-21.5	-0.174	-21.5	-0.810	-100	0.810	13
5 (3 - 7)	-0.061	-10.5	-0.064	-11.0	-0.583	-100	0.583	109
10 (8 -12)	-0.028	- 5.3	-0.044	- 8.3	-0.195	- 37.0	0.527	105
15 (13 -17)	-0.016	- 3.2	-0.024	- 4.7	-0.053	- 10.5	0.507	117
20 (18 -22)	-0.017	- 3.4	-0.017	- 4.2	-0.029	- 5.9	0.495	106
25 (23 -27)	-0.013	- 2.7	-0.010	- 3.5	-0.018	- 3.7	0.480	49
32.5 (28 -37)	-0.022	- 4.8	-0.023	- 5.0	-0.024	- 5.2	0.458	19
general average algemeines Mittel	-0.032	- 6.0	-0.039	- 7.4	-0.103	- 19.5	0.528	518
d_{top} (cm)	0		Praxis (Tabelle 32)		7.6		normale Sektionsmessung	n

Tabelle 33. Abweichungen von den in der normalen Weise ermittelten Schaftformzahlen (f) infolge Massenermittlung nach Mittenfläche mit verschiedenen Zopfstärken

Table 34. Percentages by which the volumes, read from the normal volume table should be reduced to obtain an estimate of commercial volume over bark.

assortment	mid-diameter (cm)	correction (expressed as a percentage)
0 a	- 4.9	- 15
0 b	5 - 9.9	- 8
1 a	10 - 14.9	- 5
1 b	15 - 19.9	- 4
≥2	≥20	- 4
Sortenklasse	Mittendurchmesser	Korrektionsprozent

Tabelle 34. Prozentsätze, womit die aus der normalen Massentafel abgelesenen Massen reduziert werden müssen, um eine Schätzung der Verkaufsmasse mit Rinde zu bekommen

Table 37. Relationship between bark percentage, breast height diameter and height according to Hummel, Irvine and Jeffers, 1951

$d_{1.3}$ (cm)	height (m) 9	12	15	18	21	24	average
	bark percentage						
7 - 10	17	17	17				17
11 - 15	17	17	17				17
16 - 20	17	16	16	16	16		16
21 - 25			15	14	14	14	14
	Rindenprozent						
$d_{1.3}$ (cm)	9	12	15	18	21	24	im Durchschnitt
	Höhe						

Tabelle 37. Beziehung zwischen Rindenprozent, Brusthöhendurchmesser und Höhe nach Hummel, Irvine und Jeffers, 1951

Table 38. Bark percentage based on 5 different measurements of 10 trees from plot JL 4(series numbers 1 - 5) and on 3 different measurements of 10 trees from plot JL 42 (series nrs a - c)

series nr	section length (m)	bark measurements	mean bark %
1	1	double, at 1 metre's interval doppelt, jede 1 m	20.8 ± 1.6
2	1	double, at 2 metre's interval doppelt, jede 2 m	20.7 ± 1.6
3	2	double, at 2 metre's interval doppelt, jede 2 m	20.9 ± 2.0
4	2	double, at 4 metre's interval doppelt, jede 4 m	21.3 ± 1.9
5	2	single, at 4 metre's interval einzeln, jede 4 m	21.0 ± 2.5
a	1	double, at 1 metre's interval doppelt, jede 1 m	32.1 ± 5.1
b	1	double, at 2 metre's interval doppelt, jede 2 m	32.2 ± 5.2
c	1	single, at 2 metre's interval einzeln, jede 2 m	31.6 ± 5.9
Seriennr.	Sektionslänge	Rindenmessung	Rindenprozent im Durchsnitt

Tabelle 38. Rindenprozent gegründet auf 5 verschiedenen Messungsmethoden von 10 Probestämmen aus Versuchsfläche JL 4 (Seriennr. 1-5) und auf 3 verschiedenen Methoden von 10 Probestämmen aus Versuchsfläche JL 42 (Seriennr. a - c)

Table 41. Actually found bark percentages of different diameter classes

assortment Sortenklasse	$d_{\frac{1}{2}l}$ (cm)	n	bark percentage Rindenprozent
0 a	- 4.9	54	18.5
0 b	5 - 9.9	93	17.4
1 a	10 - 14.9	63	16.5
1 b	15 - 19.9	65	18.9
≥2	≥20	15	18.1
mean - im Durchschnitt		290	17.8

Tabelle 41. Nach Durchmesserklassen angeordnete, tatsächlich beobachtete Rindenprozente

Table 14. Trend of form factors from different construction methods, with increasing diameter and height

$d_{1.3}$(cm) h (m)	2 4	4 6	6 8	8 9	10 11	12 13	14 15	16 17	18 19	20 20	22 21	24 21	26 22	26 23	30 23	32 23	34 24	36 24
Δh				W.v.W.	S.&H.	Ndsl.	W.v.W.	S.&H.	Ndsl.	W.v.W.	S.&H.	Ndsl.	W.v.W.	S.&H.	Ndsl.			
- 5							.535	.481	.493	.497	.459	.479	486	.438	.469			
- 4						.528	.526	.485	.492	.489	.461	.478	.482	.440	.468			
- 3				.613	.519	.522	.518	.489	.491	.483	.465	.477	.478	.442	.467			
- 2				.574	.525	.518	.510	.492	.490	.484	.467	.477	.477	.445	.467			
- 1				.555	.530	.515	.503	.494	.491	.479	.470	.476	.474	.446	.466			
W.v.W.	0.723	.614	.565	.533	.523	.521	.493	.488	.480	.473	.471	.474	.469	.460	.470	.470	.467	.467
S.& H.	0.712	.629	.588	.553	.535	.520	.506	.497	.491	.481	.474	.462	.455	.449	.442	.435	.430	.424
Ndsl.	0.723	.619	.572	.548	.528	.514	.504	.497	.491	.485	.483	.476	.472	.469	.465	.464	.462	.460
graph	0.800	.614	.554	.534	.523	.516	.510	.504	.498	.493	.488	.482	.477	.471	.466	.460	.454	.450
+ 1				.520	.540	.513	.484	.500	.491	.473	.476	.476	.469	.451	.467			
+ 2				.491	.544	.514	.485	.504	.492	.473	.478	.476	.465	.453	.467			
+ 3				.483	.548	.515	.473	.507	.492	.468	.480	.478	.465	.454	.467			
+ 4					.551	.516	.476	.509	.493	.467	.482	.478	.460	.456	.468			
+ 5							.468	.511	.495	.463	.486	.478	.460	.458	.469			

Tabelle 14. Abhängigkeit der mit Hilfe von verschiedenen Methoden bestimmten Regressions-Schaftformzahlen von Durchmesser und Höhe

Table 15. Results of form factor harmonizations according to $f = a + b \log x$, where $x = \frac{h - 1.3}{d_{1.3} h}$ and $x = d_{1.3}$, respectively

$x = \frac{h - 1.3}{d_{1.3}\, h}$	$x = d_{1.3}$
$n = 466$ $a = 0.4020$ $b = 0.1333$ $\Sigma(F - \hat{f})^2 = 0.5994$ $s_{\hat{f}} = 0.036$ $r = 0.585$ $s\ (\%) = 7.0$	$n = 466$ $a = 0.6495$ $b = -0.1218$ $\Sigma(F - \hat{f})^2 = 0.6010$ $s_{\hat{f}} = 0.036$ $r = -0.583$

Tabelle 15. Ergebnis von Ausgleichungen der Schaftformzahl mit Hilfe der Funktion $f = a + b \log x$, worin $x = \frac{h - 1.3}{d_{1.3} h}$, bezw. $x = d_{1.3}$

Table 16. Preliminary form factor table

$d_{1.3}$ (cm)		$d_{1.3}$	f	$d_{1.3}$	f
		15	.506	30	.470
1	1,28	16	.503	31	.468
2	.82	17	.500	32	.466
3	.676	18	.497	33	.464
4	.598	19	.494	34	.463
5	.569	20	.491	35	.461
6	.555	21	.488	36	.460
7	.547	22	.486	37	.458
8	.540	23	.484	38	.457
9	.533	24	.481	39	.456
10	.528	25	.479	40	.454
11	.523	26	.477	41	.453
12	.518	27	.475	42	.452
13	.514	28	.473	43	.450
14	.510	29	.471	44	.449

Tabelle 16. Vorläufige Schaftformzahltafel

Table 17. Comparison of the parameters of $f = a + b \log d_{1.3}$ calculated from the first and second group of sample trees and the two combined

n	466	273	739
a	0.6495	0.6080	0.6463
s_a	0.0091	0.031	0.0078
b	-0.1218	-0.0907	-0.1190
s_b	0.0079	0.023	0.0064
$s_{\hat{f}}$	0.036	0.034	0.035

Tabelle 17. Vergleich der Parameter der Funktion $f = a + b \log d_{1.3}$, berechnet mit Hilfe der ersten und der zweiten Probestammgruppen, und mit allen Probestämmen

Table 18. Analysis of covariance of the first and the second group of sample trees

Source of variation	sum of squares	degrees of freedom	mean sum of squares	F	P
1 2	0.925581 0.923627	736 735	0.001257		
differences between regression coefficients Differenz zwischen Regressionskoeffizienten	0.001954	1	0.001954	1.55	0.22
3 1	0.925583 0.925581	737 736	0.001258		
level differences Niveaudifferenzen	0.000002	1	0.000002	6.29	0.97
Variationsquelle	Kwadratensumme	Freiheitsgrade	Mittlere Kwadratensumme	F	P

1 = deviations from regression with joint gradient — Abweichungen von Regression mit gemeinschaftlichem Neigungswinkel

2 = deviations from original regressions — Abweichungen von originellen Regressionen

3 = deviations from regression of the total — Abweichungen von Regression vom Total

Tabelle 18. Kovarianz-Analyse der ersten und zweiten Probestammgruppe

Table 20. Comparison of form factors (x 100) from the State forest district Breda, as observed by Tutein Nolthenius, with the table values

source / Quelle \ $d_{1.3}$ (cm)	6	7	8	9	10	11	12	13
Breda	55	61	49	54	52	51	56	51
table - Tafel	55	55	54	53	52	52	52	51
difference / Differenz +	0	6		1	0		4	0
difference / Differenz -			5			1		

Tabelle 20. Vergleich von durch Tutein Nolthenius im Staatsforstamt Breda gefundenen Schaftformzahlen (x 100), mit den Tafelwerten

Table 21. Comparison of form factors from a number of foreign volume tables and those found for the Netherlands

$d_{1.3}$(cm)	Netherlands Niederlande	foreign Ausland	h (m) 6	10	14	18	22	26	30	34
6	0.554	Takahashi	.524	.519						
		Andersen	.575	.575						
		Hummel	-	-						
		Schober	.512	.555						
12	0.518	Takahashi	.507	.504	.501					
		Andersen	.539	.539	.557					
		Hummel	.574	.486	-					
		Schober	.471	.477	.550					
18	0.497	Takahashi	.498	.496	.494	.493	.492			
		Andersen		-	.527	.547	.560	(.560)		
		Hummel		.495	.486	.498	-			
		Schober		.444	.457	.480	.514	.556		
24	0.482	Takahashi		.490	.488	.487	.486	.485	.485	
		Andersen		-	.496	.522	.537	(.537)	-	
		Hummel		-	.482	.484	.491	-	-	
		Schober		-	-	.459	.481	.508	.534	
30	0.471	Takahashi		.485	.483	.482	.481	.481	.480	
		Andersen		-	-	-	.515	(.515)	-	
		Hummel		-	.481	.476	.476	-	-	
		Schober		-	-	.448	.458	.470	.485	
36	0.461	Takahashi		.520	.493	.474	.460	.448	.438	-
		Andersen		-	-	-	.492	(.492)	-	-
		Hummel		-	-	.470	.468	-	-	-
		Schober		-	-	-	.442	.445	.452	.465
42	0.453	Takahashi			.472	.454	.440	.428	.419	-
		Andersen			-	-	.469	(.469)	-	-
		Hummel			-	-	-	-	-	-
		Schober			-	-	.429	.430	.432	.439
48	0.446	Takahashi			.474	.453	.436	.423	.412	-
		Andersen			-	-	-	-	-	-
		Hummel			-	-	-	-	-	-
		Schober			-	-	-	.422	.423	.426

Tabelle 21. Vergleich von Schaftformzahlen verschiedener ausländischer Autoren mit den für die Niederlande gefundenen

Table 22. Volume table based on standard height curves

d_g (cm)	6					7			
h_g (m)	5	6	7	8	9	6	7	8	9
$d_{1.3}$ (cm)	v (m^3)								
2	0.001	.001	.001	.001	.002	.001	.001	etc.*	
3	.002	.002	.003	.003	.004	.002	.002		
4	.003	.004	.004	.005	.006	.003	.004		
5	.005	.006	.007	.008	.010	.006	.007		
6	.008	.009	.011	.013	.014	.009	.010		
7	.012	.014	.016	.018	0.020	.013	.015		
8	.015	.018	.020	.023	.026	.018	.020		
9	.020	.024	.027	.031	.034	.022	.025		
10	.025	.029	.033	.037	.041	.029	.033		
11	.032	.037	.042	.047	.052	.035	.040		
12	.038	.044	.050	.056	.063	.044	.050		
13	.048	.055	.061	.068	.075	.051	.058		
14						.063	.071		

Tabelle 22. Massentafel basiert auf Einheitshöhenkurven

*) The complete table will be published separately.
Die vollständige Tafel wird gesondert veröffentlicht

Table 23. Proportional error due to multiplication of the basal areas of all diameter classes with one uniform height h_g

sample plot- Versuchsfläche	d_g (cm)	h_g (m)	ΔV
JL 1	33.87	24.99	- 0.27%
JL 17	25.47	24.29	- 0.43%
JL 41	20.56	17.96	- 0.49%
JL 39	7.84	9.72	- 1.28%
JL 42	7.00	7.70	- 1.67%

Tabelle 23. Prozentueller Fehler infolge Multiplizierung der Grundflächen aller Durchmesserklassen mit derselber Höhe h_g

Table 24. Parameters and standard deviation from regression of the equation $d_t = a + bd_x$ for different values of x

d_x	a	b	$s_{\hat{d}t}$
$d_{1.3}$	+0.57	0.659	0.41
$d_{0.05h}$	-0.07	0.671	0.50
$d_{0.1h}$	-0.10	0.719	0.38
$d_{0.3h}$	+0.05	0.828	0.25
$d_{0.5h}$	+0.22	0.987	0.36
$d_{0.7h}$	+0.57	1.328	0.73
$d_{0.9h}$	+1.58	2.925	1.80

Tabelle 24. Parameter und mittlere Abweichung von Regression der Gleichung $d_t = a + bd_x$, für verschiedene Werte von x

Table 25. Mean values of deviations from regression with equations (2) and (3)*

sample plot	mean $(F - \hat{f})$ - values x 10^4 equation (3)*	equation (2)	n
1	+43	-18	21
2	+52	+319	22
4	- 5	+92	33
8	-77	-34	29
9	+ 8	-22	23
12	-38	-219	40
16	-17	-38	33
17	+59	-178	13
90	+43	+118	37
Versuchsfläche	Gleichung (3)* Mittelwerte für $(F - \hat{f})$ x 10^4	Gleichung (2)	n

Tabelle 25. Mittelwerte von Abweichungen von Regression bei den Gleichungen (2) und (3)*

*) Equation - Gleichung (2): $f = a + b_1 \log d_{1.3} + b_2 \log d_6$

Equation - Gleichung (3): $f = a + b_1 \log d_{1.3} + b_2 \log d_6 + b_3 \log h$

Table 26. Frequency distribution of the deviations from regression with equation (3); using the same material as of that given in table 25

sample plot	number of trees where $F > \hat{f}$	$F = \hat{f}$	$F < \hat{f}$	results sign test
1	12	1	8	$p > 0.20$
2	15	0	7	$p = 0.13$
4	18	1	14	$p > 0.20$
8	7	0	22	$p = 0.01$
9	11	0	12	$p > 0.20$
12	17	2	21	$p > 0.20$
16	17	0	16	$p > 0.20$
17	9	0	4	$p > 0.20$
90	22	0	15	$p > 0.20$
Versuchsfläche	Anzahl Stämme wobei			Ergebnisse der Zeichenprüfung

Tabelle 26. Häufigkeitsverteilung der Abweichungen von Regression bei Gleichung (3); die Probedaten sind dieselben wie bei Tabelle 25

Table 27. Testing results of equation (3) with new material

sample plot Versuchsfläche	mean Mittelwerte für $(F - \hat{f}) \times 10^4$	n
1	+ 66	14
4	- 52	25
11	- 25	2
14	+169	17
16	- 36	32
17	+103	30
32	+100	15
41	- 12	25
90	- 16	21
91	- 41	80
92	+143	29
total - Total	+ 21	290

Tabelle 27. Prüfungsergebnisse der Gleichung (3) mit neuen Probedaten

Table 28. Frequency distribution of the deviations from regression of the material of table 27

sample plot	number of trees where $F > \hat{f}$	$F = \hat{f}$	$F < \hat{f}$	results sign test
1	9	1	4	$p>0.20$
4	9	0	16	$p>0.20$
11	1	0	1	$p>0.20$
14	11	0	6	$p>0.20$
16	13	0	19	$p>0.20$
17	26	1	3	$p<0.0001$
32	11	0	4	$p= 0.12$
41	13	1	11	$p>0.20$
90	12	0	9	$p>0.20$
91	32	1	47	$p= 0.11$
92	25	0	4	$p= 0.0001$
Versuchsfläche	Anzahl Stämme wobei			Ergebnisse der Zeichenprüfung

Tabelle 28. Häufigkeitsverteilung der Abweichungen von Regression der Probedaten von Tabelle 27

Table 42. Table of stand form factors for Japanese larch

d_g (cm)	f_G	d_g (cm)	f_G
4	0.602		
5	0.572	25	0.482
6	0.557	26	0.480
7	0.549	27	0.478
8	0.542	28	0.476
9	0.536	29	0.474
10	0.530	30	0.472
11	0.525	31	0.471
12	0.520	32	0.469
13	0.516	33	0.468
14	0.512	34	0.466
15	0.508	35	0.464
16	0.505	36	0.463
17	0.502	37	0.462
18	0.499	38	0.460
19	0.496	39	0.459
20	0.493	40	0.457
21	0.491	41	0.456
22	0.489	42	0.455
23	0.486	43	0.453
24	0.484	44	0.452

Tabelle 42. Bestandesformzahltafel für japanische Lärche

Table 43. Volume tariff for Japanese larch based on mean basal area diameter and normal stand height

d_g (cm)	h_g (m)	v (m^3)	Δv (Δh=1m)	d_g (cm)	h_g (m)	v (m^3)	Δv (Δh=1m)
4	5	0.004	0.001				
5	6	0.007	0.001	25	22	0.521	0.024
6	7	0.011	0.002	26	22	0.561	0.025
7	8	0.017	0.002	27	23	0.629	0.027
8	9	0.024	0.003	28	23	0.674	0.029
9	10	0.034	0.004	29	24	0.751	0.031
10	11	0.046	0.004	30	24	0.801	0.033
11	12	0.060	0.005	31	25	0.889	0.036
12	12	0.071	0.006	32	25	0.943	0.038
13	13	0.089	0.007	33	26	1.041	0.040
14	14	0.110	0.008	34	26	1.100	0.042
15	15	0.135	0.009	35	26	1.161	0.045
16	16	0.162	0.010	36	27	1.272	0.047
17	17	0.194	0.011	37	27	1.341	0.050
18	17	0.216	0.013	38	27	1.409	0.052
19	18	0.253	0.014	39	28	1.535	0.055
20	19	0.294	0.015	40	28	1.608	0.057
21	19	0.323	0.017	41	29	1.746	0.060
22	20	0.372	0.019	42	29	1.828	0.063
23	21	0.424	0.020	43	29	1.908	0.066
24	21	0.460	0.022	44	30	2.062	0.069

Tabelle 43. Massentarif für Japanlärche, gegründet auf Durchmesser und normaler Bestandeshöhe

Table 45. Relationship between limits of diameter classes at half of merchantable length ($d_{\frac{1}{2}l}$) and at breast height diameter ($d_{1.3}$)

$d_{\frac{1}{2}l}$ (cm)	$d_{1.3}$ (cm)
5	6
10	13
15	20
20	27
25	34
30	42

Tabelle 45. Beziehung zwischen Mittendurchmesser des abgezopften Langholzes ($d_{\frac{1}{2}l}$) und Brusthöhendurchmesser ($d_{1.3}$)

Table 40. Bark percentage expressed as a percentage of over bark volume and given as a function of $d_{1,3}$ (over bark) and double bark thickness at breast height

$d_{1.3}$ over bark (cm) / double bark thickness (cm) at breast height	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	Doppelte Rindenstärke (cm) in Brusthöhe / $d_{1.3}$ mit Rinde (cm)
5	5.2	8.8	12.3	15.7	19.0	22.3	25.5	28.7	31.7	34.7	37.6	40.5	43.2	45.9	48.6	51.1																																			5
6	4.6	7.6	10.5	13.4	16.3	19.0	21.8	24.5	27.1	29.7	32.2	34.7	37.2	39.5	41.9	44.2	46.4																																		6
7	4.1	6.7	9.3	11.8	14.2	16.7	19.0	21.4	23.7	26.0	28.2	30.4	32.6	34.7	36.8	38.9	40.9	42.9	44.8																																7
8	3.8	6.1	8.3	10.5	12.7	14.8	17.0	19.0	21.1	23.1	25.1	27.1	29.1	31.0	32.9	34.7	36.6	38.4	40.1	41.9	43.6																														8
9	3.6	5.6	7.6	9.5	11.5	13.4	15.3	17.2	19.0	20.9	22.7	24.5	26.2	28.0	29.7	31.4	33.1	34.7	36.4	38.0	39.5	41.1	42.6																												9
10	3.4	5.2	7.0	8.8	10.5	12.3	14.0	15.7	17.4	19.0	20.7	22.3	23.9	25.5	27.1	28.7	30.2	31.7	33.2	34.7	36.2	37.6	39.1	40.5																											10
11	3.2	4.9	6.5	8.1	9.7	11.3	12.9	14.4	16.0	17.5	19.0	20.6	22.0	23.5	25.0	26.4	27.8	29.2	30.6	32.0	33.4	34.7	36.1	37.4	38.7	40.0																									11
12	3.1	4.6	6.1	7.6	9.1	10.5	12.0	13.4	14.8	16.3	17.7	19.0	20.4	21.8	23.1	24.5	25.8	27.1	28.4	29.7	31.0	32.2	33.5	34.7	35.9	37.2	38.4	39.5																							12
13	2.9	4.4	5.7	7.1	8.5	9.8	11.2	12.5	13.9	15.2	16.5	17.8	19.0	20.3	21.6	22.8	24.1	25.3	26.5	27.7	28.9	30.1	31.3	32.4	33.6	34.7	35.9	37.0	38.1																						13
14	2.8	4.1	5.4	6.7	8.0	9.3	10.5	11.8	13.0	14.2	15.5	16.7	17.9	19.0	20.2	21.4	22.6	23.7	24.9	26.0	27.1	28.2	29.3	30.4	31.5	32.6	33.7	34.7	35.8	36.8	37.8																				14
15	2.8	4.0	5.2	6.4	7.6	8.8	9.9	11.1	12.3	13 4	14 6	15.7	16.8	17.9	19.0	20.2	21.2	22.3	23.4	24.5	25.5	26.6	27.6	28.7	29.7	30.7	31.7	32.7	33.7	34.7	35.7	36.7	37.6																		15
16			5.0	6.1	7.2	8.3	9.4	10.5	11.6	12.7	13.8	14.8	15.9	17.0	18.0	19.0	20.1	21.1	22.1	23.1	24.1	25.1	26.1	27.1	28.1	29.1	30.0	31.0	31.9	32.9	33.8	34.7	35.6	36.6																	16
17				5.8	6.9	7.9	9.0	10.0	11.0	12.1	13.1	14.1	15.1	16.1	17.1	18.1	19.0	20.0	21.0	22.0	22.9	23.9	24.8	25.7	26.7	27.6	28.5	29.4	30.3	31.2	32.1	33.0	33.9	34.7	35.6	36.4															17
18						7.6	8.6	9.5	10.5	11.5	12.5	13.4	14.4	15.3	16.3	17.2	18.1	19.0	20.0	20.9	21.8	22.7	23.6	24.5	25.4	26.2	27.1	28.0	28.8	29.7	30.6	31.4	32.2	33.1	33.9	34.7	35.5	36.4													18
19							8.2	9.1	10.1	11.0	11.9	12.8	13.7	14.6	15.5	16.4	17.3	18.2	19.0	19.9	20.8	21.6	22.5	23.4	24.2	25.0	25.9	26.7	27.5	28.4	29.2	30.0	30.8	31.6	32.4	33.2	33.9	34.7	35.5												19
20									9.6	10.5	11.4	12.3	13.1	14.0	14.8	15.7	16.5	17.4	18.2	19.0	19.9	20.7	21.5	22.3	23.1	23.9	24.7	25.5	26.3	27.1	27.9	28.7	29.4	30.2	31.0	31.7	32.5	33.2	34.0	34.7	35.5										20
21											10.9	11.8	12.6	13.4	14.2	15.0	15.9	16.7	17.5	18.3	19.0	19.8	20.6	21.4	22.2	22.9	23.7	24.5	25.2	26.0	26.7	27.5	28.2	29.0	29.7	30.4	31.2	31.9	32.6	33.3	34.0	34.7	35.4								21
22												11.3	12.1	12.9	13.7	14.5	15.2	16.0	16.8	17.5	18.3	19.0	19.8	20.6	21.3	22.0	22.8	23.5	24.2	25.0	25.7	26.4	27.1	27.8	28.5	29.2	29.9	30.6	31.3	32.0	32.7	33.4	34.1	34.7							22
23														12.4	13.2	13.9	14.7	15.4	16.1	16.9	17.6	18.3	19.0	19.8	20.5	21.2	21.9	22.6	23.3	24.0	24.7	25.4	26.1	26.8	27.5	28.1	28.8	29.5	30.1	30.8	31.5	32.1	32.8	33.4	34.1	34.7					23
24																13.4	14.1	14.8	15.6	16.3	17.0	17.7	18.4	19.0	19.7	20.4	21.1	21.8	22.5	23.1	23.8	24.5	25.1	25.8	26.5	27.1	27.8	28.4	29.1	29.7	30.3	31.0	31.6	32.2	32.9	33.5	34.1	34.7			24
25																		14.3	15.0	15.7	16.4	17.0	17.7	18.4	19.0	19.7	20.4	21.0	21.7	22.3	23.0	23.6	24.3	24.9	25.5	26.2	26.8	27.4	28.1	28.7	29.3	29.9	30.5	31.1	31.7	32.3	32.9	33.5	34.1		25
26																			14.5	15.2	15.8	16.5	17 1	17.8	18.4	19.0	19.7	20.3	21.0	21.6	22.2	22.8	23.5	24.1	24.7	25.3	25.9	26.5	27.1	27.7	28.3	28.9	29.5	30.1	30.7	31.3	31.9	32.4	33.0	33.6	26
27																					15.3	15.9	16.6	17 2	17.8	18.4	19.0	19.7	20.3	20.9	21.5	22.1	22.7	23.3	23.9	24.5	25.1	25.7	26.2	26.8	27.4	28.0	28.6	29.1	29.7	30.3	30.8	31.4	32.0	32.5	27
28																						15.5	16.1	16.7	17.3	17.9	18.5	19.0	19.6	20.2	20.8	21.4	22.0	22.6	23.1	23.7	24.3	24.9	25.4	26.0	26.6	27.1	27.7	28.2	28.8	29.3	29.9	30.4	31.0	31.5	28
29																								16.2	16.7	17.3	17.9	18.5	19.0	19.6	20.2	20.8	21.3	21.9	22.4	23.0	23.6	24.1	24.7	25.2	25.8	26.3	26.8	27.4	27.9	28.5	29.0	29.5	30.1	30.6	29
30																									16.3	16.8	17.4	17.9	18.5	19.0	19.6	20.2	20.7	21.2	21.8	22.3	22.9	23.4	23.9	24.5	25.0	25.5	26.1	26.6	27.1	27.6	28.2	28.7	29.2	29.7	30
31																											16.9	17.4	18.0	18.5	19.0	19.6	20.1	20.6	21.2	21.7	22.2	22.8	23.3	23.8	24.3	24.8	25.3	25.8	26.4	26.9	27.4	27.9	28.4	28.9	31
32																													17.5	18.0	18.5	19.0	19.6	20.1	20.6	21.1	21.6	22.1	22.6	23.1	23.6	24.1	24.6	25.1	25.6	26.1	26.6	27.1	27.6	28.1	32
33																															18.0	18.6	19.0	19.6	20.1	20.6	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.4	25.9	26.4	26.9	27.4	33
34																																18.1	18.6	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.4	22.9	23.4	23.9	24.3	24.8	25.3	25.7	26.2	26.7	34
35																																		18.6	19.0	19.5	20.0	20.5	20.9	21.4	21.9	22.3	22.8	23.3	23.7	24.2	24.6	25.1	25.5	26.0	35
36																																				19.0	19.5	20.0	20.4	20.9	21.3	21.8	22.2	22.7	23.1	23.6	24.0	24.5	24.9	25.4	36

Tabelle 40. Rindenprozent, dargestellt als Prozentsatz der Masse mit Rinde, und abgeleitet aus Brusthöhendurchmesser und doppelter Rindenstärke in Brusthöhe