RADIAL INCREMENT ALONG THE BOLE OF TREES PROBLEMS OF MEASUREMENT AND INTERPRETATION

by

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1. RADIAL-, CROSS SECTIONAL AREA-, AND VOLUME INCREMENT.

The most interesting thing a forest mensurationist wants to know is the volume of trees and stands. Therefore a forest-yield researcher, one who is occupied with the interrelationships between site, treatment of stands and forest yield, is interested in volume increment of stems and stands, because monetary value of stems and stands depends on volume.

Volume increment can be defined as the sum of cross-sectional area increment of one meter sections or as the integral of cross-sectional area increment over the total length of the bole. In addition, cross-sectional area increment is a better measure of yield relevant growth response than radial increment.

Figure 1:

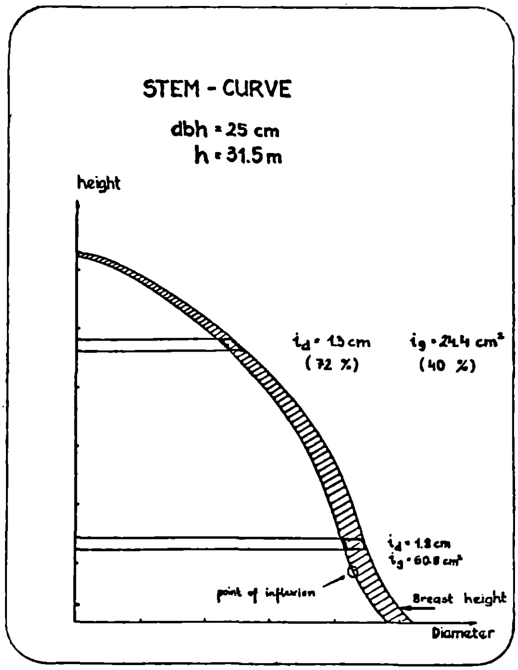


Figure 1 shows a model of the change of the shape of a tree as it may result from growth. The hatched area means volume increment over a certain period. The first thing one can see is that breast height seems not to be a " representative " location for measuring stem form, because it often lies beneath the point of inflexion of the stem-curve and the greatest part of the stem lies above this point. Table 1 shows a typical distribution of diameter increment and cross-sectional area increment along the bole in different ages of a tree, when increment at breast height is set at 100 percent. Both, diameter increment and area increment have a minimum between 1 and 12 m height, depending on age and thus on total height. A comparison of both distributions shows that the percentage of area increment is a better measure of total growth because it corresponds to the relative contribution to total volume growth. This can be seen from figure 1 too. This comes from the effect of diameter itself on cross-sectional area increment. So the same diameter increment would mean very different volume increments whether cross-sectional diameter is large or not. This holds also for different dbh.

Table 1: DISTRIBUTION OF INCREMENT ALONG THE BOLE
(from ASSMANN, 1961)

height of cross section (m)	Diameter increment (id) in age							Cross-sectional area increment (ig)						
	30-	40-	50-	60-	70-	80-	90-100	30-	40-	50-	60-	70-	80-	90-100
0.4	103	125	127	148	126	129	115	112	135	143	173	149	153	137
1.3	100	100	100	100	100	100	100	100	100	100	100	100	100	100
4.3	127	109	98	100	90	86	87	108	101	93	95	86	82	82
8.3	174	142	108	103	86	86	81	94	110	93	92	77	77	72
12.3		187	134	113	91	80	77		101	98	91	75	67	64
16.3			142	141	112	95	81			72	89	79	69	61
20.3			147	173	155	127	96			27	67	82	78	63
23.3				200	186	151	113				30	65	73	62
25.3					195	171	132					40	60	60
27.3						170	130						40	44
29.3							143							27

2. INTERACTIONS BETWEEN SITE AND TREATMENT CONDITIONS AND DISTRIBUTION OF INCREMENT.

If the relative distribution of cross-sectional area increment (ig) from table 1 would hold over a wide range of site-factors, weather conditions and forest treatments, or would vary only randomly around these values for short periodes (up to five years), it would be enough to measure radial increment at breast height together with the dbh and total height of the tree - even though breast height is not quite representative. Unfortunately - but typical for the nature of growth - there exist many interactions between weather conditions, treatments and the distribution of cross-sectional area increment over the bole. I would like to demonstrate some of these interactions which were found by stem analysis.

Figure 2:

Distribution of cross-sectional area increment influenced by crown release

(from ASSMANN, 1961)

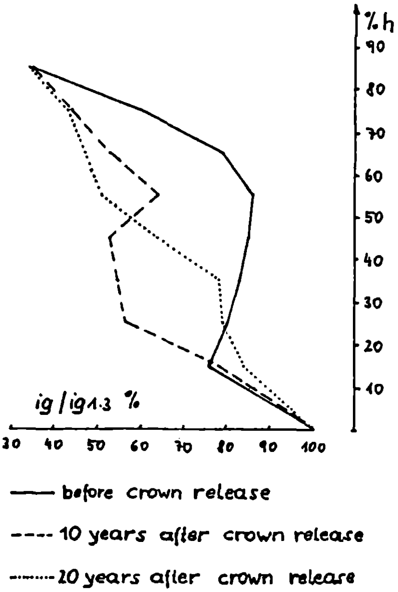


Figure 2 is intended to demonstrate the effect of crown release. The solid line shows the cross-sectional area increment at 15, 25 etc. percent of total height of the tree when area increment at breast height is set at 100 percent. This figure corresponds well to table 1. One can notice the minimum at about 15 percent of the total height and the second maximum of increment at about half of the tree's height. Ten years after crown release (dotted line) distribution has changed. The point of minimum increment has moved upwards and this minimum itself has decreased to 55 percent. That means that as a reaction to crown release, the additional increment has not been placed evenly over the whole bole, but has been moved downwards over-proportionally. Again 10 years later even the point of minimum increment has vanished. In both cases from measuring radial increment at breast height only, volume increment would have been greatly over-estimated.

Figure 3 shows the influence of precipitation and social status (expressed as height/dbh ratio of the trees) on cross-sectional area increment. Data come from 15 stem analysis of 40-year - old Picea abies stems from the control plot of a fertilizer trial at " OTTENSCHLAG ". The solid line is the relative ig of those two years within the observation period whose precipitation was maximum. The dotted line comes from increments of the two years with minimum precipitation. First comparing social status it seems that the relative height of the second maximum of increment moves upwards with increasing suppression, the relative amount of the maximum increases from about 90 to 125 percent of increment at breast height. Comparing the two lines for the predominant and dominant trees, relative increments in the upper parts of the bole in dry years are greater than in wet years. Assuming that there is more total increment in wet years, this means that the additional relative increment increases with the distance from the top of the tree. Similar observations have been made by TOPCUOGLU (cited from ASSMANN, 1961).

Figure 3: Distribution of cross-sectional area increment influenced by precipitation and social status.

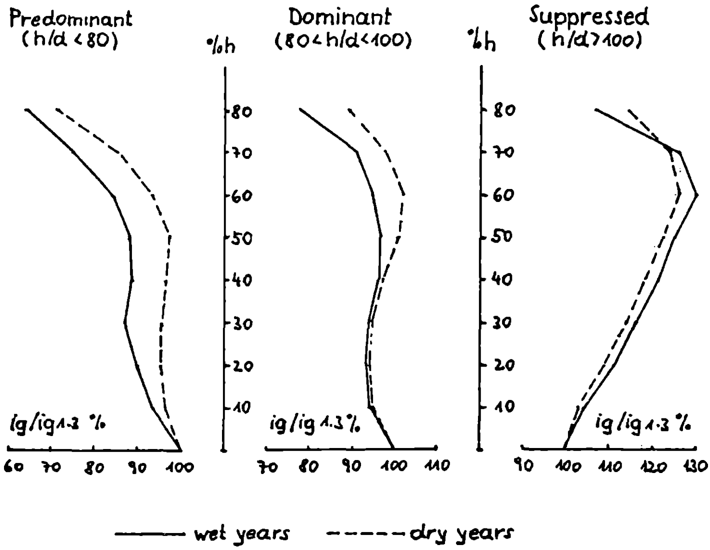


Figure 4: Distribution of cross-sectional area increment influenced by fertilization

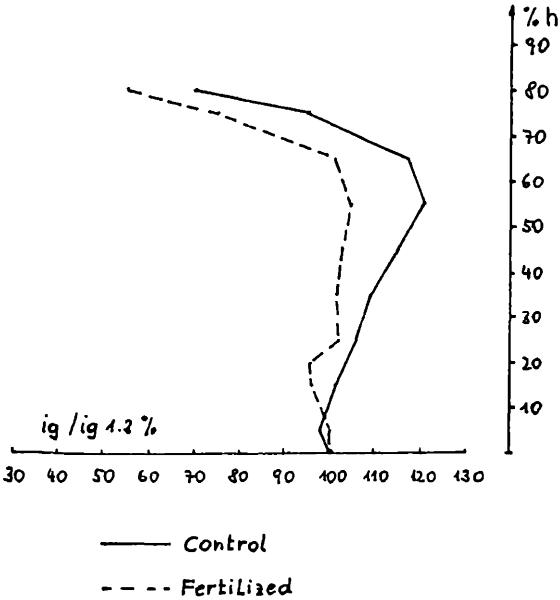


Figure 4 shows the relative distribution of cross-sectional area increment for control and fertilized trees. The second maximum lies in both treatments at about 65 percent of the height. However, its magnitude has decreased from 120 to 100 percent due to fertilization. Additional increment also has been accumulated near the bottom of the tree. In general, it seems that " additional increment ", regardless from where it comes, is found in the lower parts of the stem. This means that increasing volume increment would be overestimated from observation of dbh only, and decreasing volume increment would be underestimated from the same method.

3. EVALUATING VOLUME INCREMENT FROM FORM - FUNCTIONS.

Even though we know these facts, it is rarely feasible to estimate volume increment in most forest yield experiments with either stem - analysis or with dendrometers placed every two meters along the bole. The usual way of volume increment evaluation is shown in table 2. In this case, volume is calculated by reducing the volume of a cylinder of diameter = dbh and height total height, with a certain " form - factor " f. Usually this form - factor is estimated from standard volume equations as a function of dbh and height. Function (1) shows such an equation as it has been developed for Austria by POLLANSCHÜTZ (1974). With diameter-, and height - increment, the volume after a certain period can be reestimated in the same way, and difference will be an estimation of volume increment. Standard deviation of functions like (1) will lie between 7 and 10 percent (POLLANSCHÜTZ, 1974). This method would be biased in the same way as has been discussed with stem analysis.

Table 2: USUAL INCREMENT EVALUATION FROM FORM—FUNCTIONS

v=d^2*PI/4*h*f, v1=d1^2*PI/4*h1*f1: iv=v1−v, d1=d+id, h1=h+ih

f=b0+b1*log(d)^2+b2/h+b3/d+b4/d^2+b5/d/h ....[1]

or:

f=a0+a1*(d03/d)+a2*(h/d)+a3/d ....[2]

where d03 is the cross—section diameter in 3/10th of the height

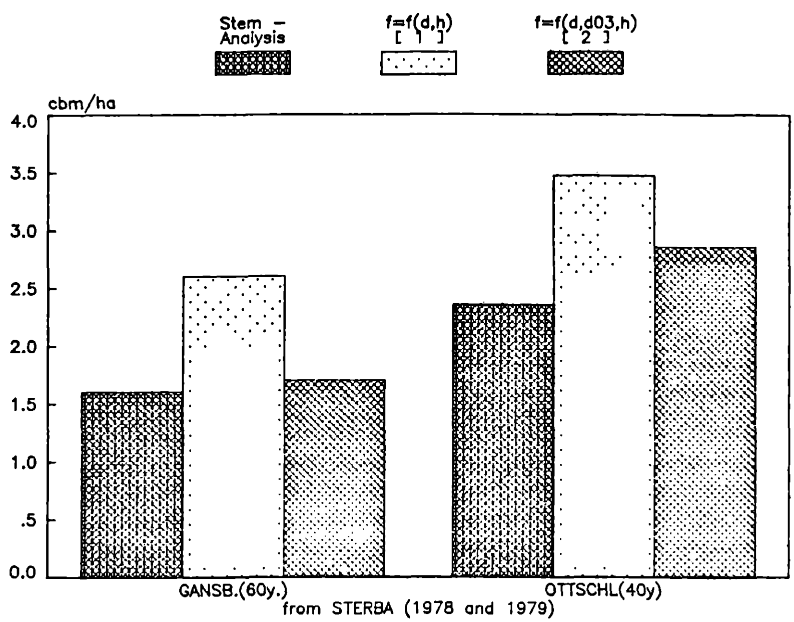
When using [1] only id and ih must be observed,

when using [2] additional observation of diameter increment at 3/10th of total height is necessary

POLLANSCHÜTZ (1965) showed that form - function (2) would have less standard error (3   5 percent only) by taking diameter at 3/10th of total height. Similar approaches have been made by SCHIFFEL (1899) with diameter at 50 percent of total height and by ROIKO - JOKELA (1976) with diameter at 7 m above the ground. The Scandinavians have used diameter at 6 m height above the ground for building form factor tables since 1900 (See ILVESALLO, 1947).

When reexamining figures 2 through 4, it seems that the utilization of a second diameter within the region of 3/10th of total height (d03) would describe the change of form sufficiently. An example based on two fertilizer - trials with Picea abies (GANSBACH with 65-year-old trees and OTTENSCHLAG with 40-year-old trees) is used to demonstrate this hypothesis. In both experiments, extra increment due to fertilization has been evaluated by stem-analysis,by the standard form function method of POLLANSCHÜTZ (1974) and from a form-function method using d03 (parameters of function from BRAUN, 1969). These three estimates are presented in figure 5. As expected,standard form function method has overestimated the effect of fertilization between 50 and 60 percent. On the other hand, form - function method (2) seems to provide a good estimator for real fertilizer response as far as volume increment is concerned.

Figure 5: Additional increment of two fertilizer trials from different increment evaluation methods.



Finally it should be pointed out that for the evaluation of any volume increment response to certain changes in site parameters or stand characteristics, radial increment should be observed at a position at about 30 percent of the total height of trees additionally to the observation of dbh increment.

4. SUMMARY

Because foresters are interested in volume increment rather than radial increment in breast height, area increment along the bole seems to be a more interesting measure for the respose of trees to certain treatments. Literatur and own data show, that the distribution of area increment along the bole interacts with weather conditions during the observed year, with the social status of the tree and so with thinning -, and with fertilization. The usual methods of evaluating volume increment from radial increment in breast height and height increment only, using standard volume equations ignore these interactions. Examples show, that response of volume increment to fertilization and thinning may be overestimated considerably when using standard methods. Observing radial increment at a second height of the tree (e.g. at approximately 3/10th of the total height) together with an appropriate volume equation gives much better results.

ZUSAMMENFASSUNG: Der Radialzuwachs entlang des Baumschaftes - ein Meß- und Interpretationsproblem.

Weil Forstleute eher am Volumszuwachs als am Radialzuwachs in Brusthöhe interessiert sind, muß der Verteilung des Kreisflächenzuwachses über die ganze Schaftlänge erhöhte Aufmerksamkeit geschenkt werden. Aus der Literatur und anhand eigener Daten wird gezeigt, daß der Verlauf des Kreisflächenzuwachses über der Schaftlänge von der Witterung in der beobachteten Zuwachsperiode, von der soziologischen Stellung des Baumes im Bestand - und damit von der Durchforstung -, und von Düngungsmaßnahmen abhängt. Bei Zuwächsen, die mittels der üblichen Verfahren aus Brusthöhendurchmesserzuwachs und Höhenzuwachs mit Hilfe regionaler Formzahlfunktionen ermittelt werden, muß dies beachtet werden, weil die so ermittelten Effekte von Bestandesbehandlungen bedeutend überschätzt werden können, wie einige Beispiele zeigen. Beobachtet man dagegen auch noch den Durchmesser und dessen Zuwachs in einer weiteren Höhe am Schaft (z.B. in ca 3/10 der Höhe), und verwendet man eine entsprechende Formzahlfunktion, die diese Durchmesser mitberücksichtigt, dann erhält man wesentlich richtigere Resultate.

5. LITERATURE CITED:

ASSMANN,E. 1961: Waldertragskunde. BLV München

BRAUN,R. 1969: Österreichische Forstinventur 1961-70. Methodik der Auswertung und Standardfehlerberechnung. Mitt.d.FBVA Mariabrunn, Wien. 84

ILVESALLO,A. 1947: Volume tables for standing trees. Metsätieteellisen tutkimuslaitoksen julkaisuja. 34. 4

POLLANSCHÜTZ,J. 1965: Eine neue Methode der Formzahl- und Massenbestimmung stehender Bäume. Mitt.d.FBVA Mariabrunn, Wien. 68

POLLANSCHÜTZ,J. 1964: Formzahlfunktionen der Hauptbaumarten Österreichs. Allg.Forstzeitung 85, 12:341-343

STERBA,H. 1978: Methodische Erfahrungen bei Einzelstammdüngungsversuchen. Allg.Forst-u.Jagdzeitung 149, 2/3:35-40

STERBA,H. 1979: FPP-Projekt "Formveränderung durch Düngung". Unpublished res.report.