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Estimation of Increment in the Course of Forest Inventories for Forest Research

by

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Abstract

The periodical radial increment on cores is measured beside the diameter breast high and the height from every tree on a sample plot within a sample which is used for the purpose of forest regulation. More over an estimate of the height growth is needed to calculate the periodical volume increment of the residual stand. A method is used permitting to calculate an estimate for the height growth from the data of the sample. The increment of the thinned trees is estimated by means of change of diameter distributions of the residual stand from age class to age class and by considering the radial increment curves. The increment of the residual stand and of the thinned trees are essential by calculating the increment of the total stand of single age classes and the total production of a time serie which is combined by the plots of a sample.

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1. Introduction

In Austria 2o years ago the necessity to reduce the expenditure of work and the requirement to increase the informations and the accuracy of surveys led to the introduction of sample plot inventories in the survey of forest conditions. In surveying the forest conditions for forest management as well as in the national forest inventory of Austria, along with an inventory of the growing stock, an inventory of the increment is carried out. Together with statistics of the volume felled or, in the Austrian Forest Inventory, together with the inventory of the felled quantity these three sources of informations are the basis of the assessment of the effects of the way in which (mainly in the last decade) the stands were treated and the connected exploitation.

2. Indirect estimation of the current increment of the total stand.

If in surveys, besides characteristics of yield also characteristics of site are comprised, the possibility exists - if there is a sufficient number of sample plots - of the estimation of the actual and potential total growth production (GWL) for certain site units and stand types by analyses of the growth production as a basis for a general middle- and long-term regulation of production and yield. If there is a sufficient number of sample plots for each unit of survey and site - besides the execution of simple growth production analyses - it is also possible to construct local growth production tables, resp. site-yield-tables or the execution of growth simulations, resp. predictions of growth production (FRANZ 1972) for different variants of treatment.

Magin (1965) showed a possibility to estimate the total growth production in an inventory by using the k-values deduced from permanent experiments

$$k = \sqrt{1/a \quad e^{b \cdot \ln(N/\Delta N)}}$$

and subsequently also the current increment for certain survey units as a basis for simple growth production analyses. His formula for the GWL-integration is

$$GWL = V_a \quad \sum_a^t \Delta V_V + \sum_a^t V_A$$

The disadvantage of this method is that the effect of different developments of the number of trees or different degrees of thinning on the current increment of stand units combined to a growth series, may be estimated for the single periods only with a rough approximation by assuming different values for k by using an assumed initial number of stems and also estimation of the removed and remaining number of trees.

With the value for k a value is introduced in the calculations which corresponds to a certain conception of the model in respect to thinning which corresponds with the way actually used and the thinning grade only approximately. As well as for each specific thinning program a separate yield table should be constructed, also the corresponding specific values for k should be available if the GWL-calculations should result in values for the increment applicable for all age classes.

3. Direct estimation of the current increment of the total stand.

It was obvious to look for a method to determine the current (resp. periodic) increment of the different stands and their individual trees that is of the leading and, by treatment, influencable bearers of the increment directly, in order to get a better and more objective estimation of the effects of different stand treatments (thinning, fertilization, etc.) Therefore it was proposed by Pollanschütz (1968) to include in investigations of growth production and the connected GWL-estimations besides the results of an inventory of the growing stock also the results of an increment inventory in the calculations. This way of GWL-estimation and the estimation of the total increment of certain age classes can be written in formulas as follows:

$$GWL \quad V_a \quad \sum_a^t pZ_{Ges}$$

$$pZ_{Ges\,(a)} \quad pZ_I + pZ_A$$

$$pZ_V \quad pZ_I \;/\; PI$$

$$pZ_{Ges\,(k)} \quad pZ_V + pZ_A$$

$$pZ_{V/m} = \frac{pZ_V}{N_V}$$

$$pZ_A \quad \frac{N_A \quad pZ_{V/m} \cdot c}{2}$$

V_a initial volume

V_V volumen of the remaining stand

N_a = removed stand

GWL = 'Gesamtwuchsleistung' = total growth production

pZ_V periodic increment of the remaining stand, calculated for average climatic conditions (corrected pZ)

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pZ_A half of the periodic increment of the removed stand

relation between pZ of the volume-mean-tree of the removed stand and pZ of the volume - mean-tree of the remaining stand

N_V number of stems of the remaining stand

PI climatic index of the periodic increment

$pZ_{Ges(a)}$ = total periodic increment (actual)

$pZ_{Ges(k)}$ = total periodic increment (corrected)

pZ_I = periodic increment of the remaining stand calculated from the data of the inventory (actual pZ)

$pZ_{V/m}$ = periodic increment of the volume-mean-tree of the remaining stand

Form the inventory the values for V_a, V_V, N_V, pZ_I, are needed; if not only the "actual" but also the for average climatic conditions - expected increment is to be calculated also the value for PI (resp. an estimated value for the periodic year ring index, see chapter 6). Compared with the method of Magin, besides the values for N and V from the volume inventory, instead of the k - values, the values for the current increment directly from the increment inventory of the preceding period pZ_I and, in respect to the increment of the removed stems, the not so effective and therefore not so critical corrected value c is used. This corrected value c can be approximately deduced from the change - caused by age - of the diameter distribution and by using the calculated diameter increment curve for the respective period and finally by using a suited cubing-function with the required values for d(iameter) and h(eight). In this process all needed values are deduced directly from the volume and increment inventory. The inclusion of values, e. g. the values for k, from other investigations is not necessary. The only 'outside elements' are the general functions of the form and bark factor used in the determinations of volume and increment.

4. Estimation of the increment of the remaining individual trees

The most effective and most important component of the GWL-calculation and of the calculation of the total current increment (pZ_{Ges}) for the single age classes is the periodic increment of the remaining stand, deduced from the inventory, <u>that is the actual increment of the past period of the remaining trees (pZ_I)</u> or the periodic increment corrected with the climatic index (pZ_V).

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In sample plot inventories for forest management purposes in Austria, it is usual to measure the diameter (d) in breast height, tree height (h) and the periodic radial increment (z_r) of each tree of a sample plot.

In the course of calculation the volume at the end of the period (v_E) and the volume increment of the past period (z_V) of each tree is determined as the difference between volume at the end and volume at the beginning of the period,

$$z_V = v_E - v_A$$

In volume calculations functions of the form factor (with the values diameter in breast height and tree height) are used, $\hat{f} = F(d,h)$. For all important tree species the coefficients of the following form factor functions are now at our disposal for the estimation of the stem wood over bark:

$$\hat{f}_{SmR} = a_o + a_1 \cdot \ln^2 d + a_2 \cdot \frac{1}{h} + a_3 \cdot \frac{1}{d} + a_4 \cdot \frac{1}{d^2} + a_5 \cdot \frac{1}{d \cdot h} + a_6 \cdot \frac{1}{d^2 \cdot h}$$

The volume of the stem wood is calculated with the general formula

$$v_{SmR} = \frac{\pi}{4} \quad d^2 \quad h \quad \hat{f}_{SmR}$$

In order to determine the volume of the single tree at the beginning of the period (v_A) we need - under consideration of the available equations of the form factors - only the values for d_A and h_A. The diameter in breast height at the beginning of the period

$$d_A \quad (d_E - 2 \quad z_r \quad \hat{Rf})$$

is to be determined from the measured data of the inventory. Since the radial increment is measured under bark, general for all main species avai- laible - functions of the bark factor $\hat{Rf} = F(d_E)$ are used as is shown in the formula. (General form of the multiple regression equation $\hat{Rf} = c_o + c_1 \cdot d + c_2 \quad \frac{1}{d}$).

The height at the beginning of the period (h_A) is determined by subtracting the estimated value of the height increment (z_H) - determined in a special calculation process from the height measured at the end of the period $h_A = h_E - z_h$.

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5. Calculation process for etsimating the height increment

For the special calculation process for the determination of the estimate of the height increment (z_H) it is presumed that of each sample plot not only the age (t) but also the dominant-height-quality-class of the main species (B) is known. Age is determined in the course of the survey by boring. The dominant-height-quality-class could be determined with the aid of yield tables. Since the basis of each yield table are certain growing processes and models of treatment, they can not be applied to each growth series of certain site units. It seems therefore to be appropriate to calculate the equation $\hat{H}_o = F(t,B)$ for each main species of certain site units and stand types from the data surveyed in the course of a volume inventory.

The dominant height determined during the survey and "inventory specific" for each sample plot is - for example when chosing the Bitterlich angle count basal area factor 4 - defined as the mean height of the three trees with the biggest diameter. As site class (B) the dominant height at the age of 1oo ($H_{o(1oo)}$) is used. If not only the estimation of the pZ_I but also an intensive and estended processing of a sample inventory is planned, e.g. growth production analysis, then for securing the - from time series deduced - relation $\hat{H}_o=F(t,B)$ also some stem analyses are required. For the approximate description of the development of the dominant height (see fig. 1) up to now mostly the following basic modell has proved its usefullness:

$$\ln \hat{H}_o = a_o + a_1 \cdot \ln t + a_2 \cdot \ln^2 t + a_3 \cdot \ln B + a_4 \cdot \ln t \cdot \ln B + a_5 \cdot \ln^2 t \cdot \ln B$$

or a basic modell in which the values for $\ln^2 t$ were substituted by $\ln^3 t$ (this second basic modell is mostly then of advantage when - especially for poor site classes in the first life periods - a relatively strough delayed height growth is to be found (for example high up in the mountains). Which has as a consequence a clearly significant turning point in the curves of the development of the dominant heights). From transformation of the function $\hat{H}_o$ F(t,B) the multiple regression equation B F($\hat{H}_o$,t) results for the specific main species. This equation permits now the determination of the site class of each sample plot by computer.

As the following step for each calculation unit (that are groups of site units or stand types) and for each tree species the estimated multiple regression equations $\hat{h}$ F(d,t,B) are determined. In looking for a suited mathematical modell we can start from the following basic conception

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DEVELOPMENT OF THE DOMINANT HEIGHT
Norway spruce, District Ottenstein

$$\ln H_0 = a_0 + a_1 \cdot \ln t + a_2 \cdot \ln^3 t + a_3 \cdot \ln B + a_4 \cdot \ln t \cdot \ln B + a_5 \cdot \ln^3 t \cdot \ln B$$

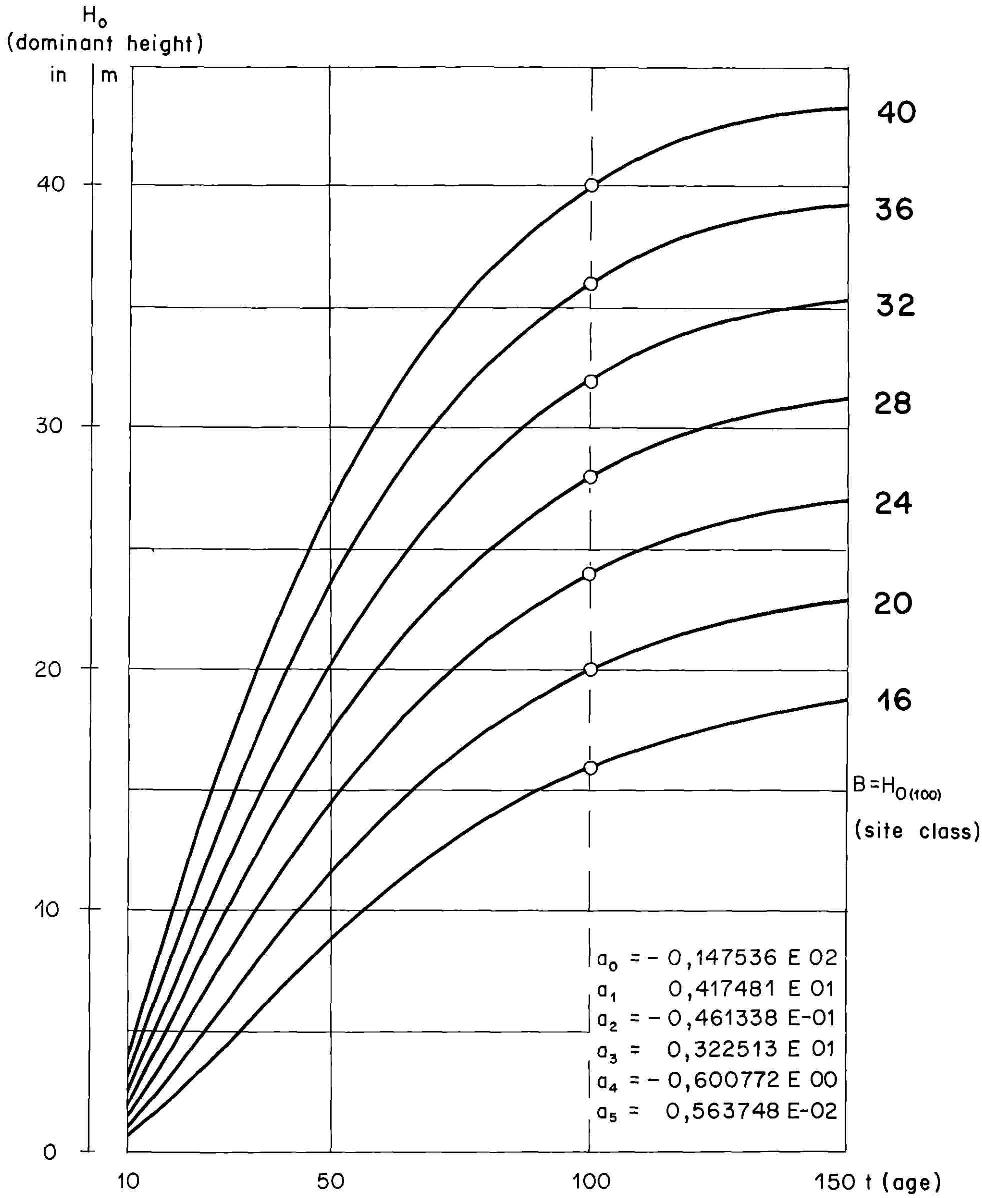

fig 1

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HEIGHT IN DEPENDENCE OF BREAST HEIGHT DIAMETER, AGE, AND SITE CLASS

Norway spruce, pure stands, District Ottenstein

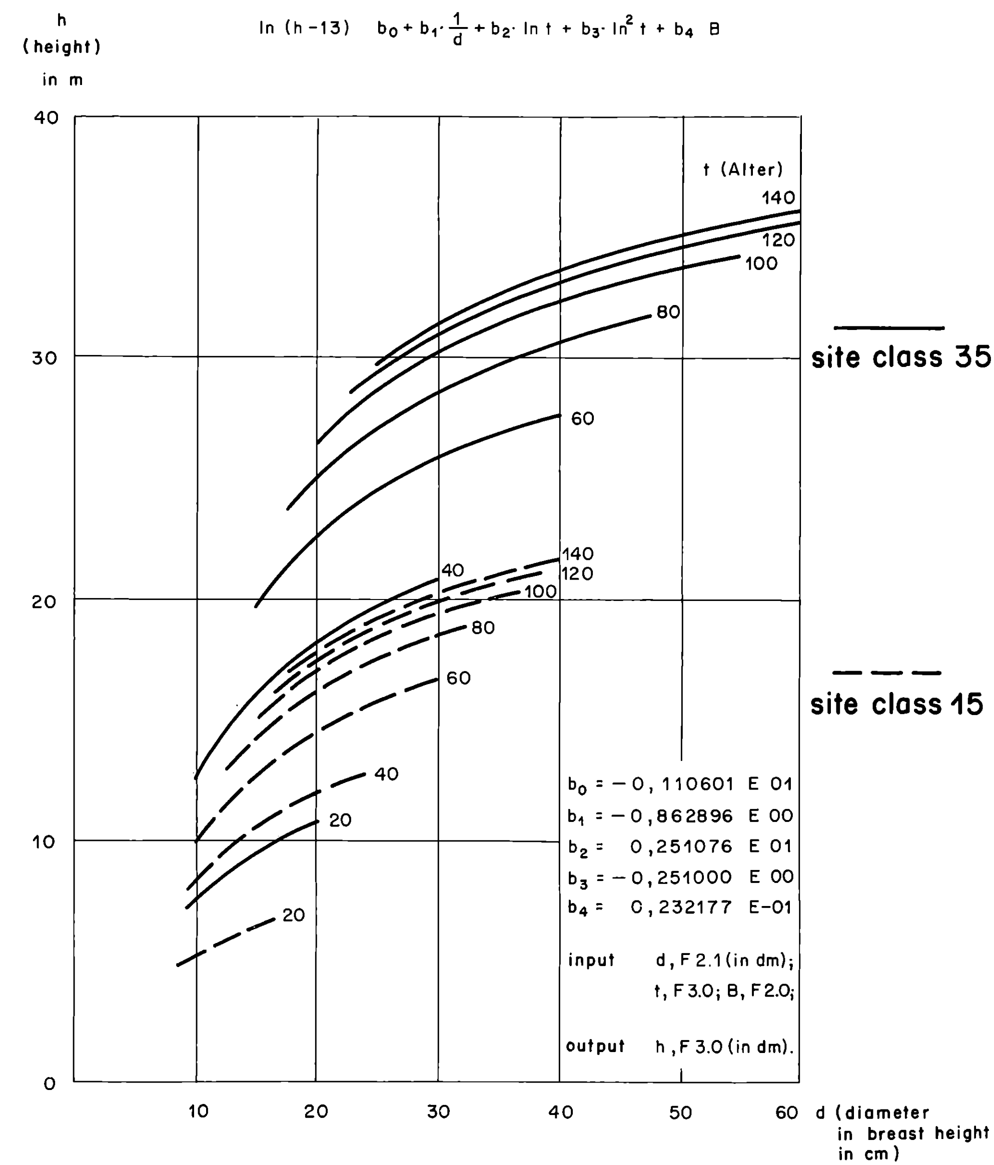

fig 2

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$\hat{h}$ oder $\ln\hat{h} = (a_o + a_1 \cdot \frac{1}{d}) \cdot (b_o + b_1 \cdot \ln t + b_2 \cdot \ln^2 t) \cdot (c_o + c_1 \cdot B)$ resp.

$\hat{h}$ oder $\ln\hat{h} = (a_o + a_1 \cdot \ln d + a_2 \cdot \ln^2 d) \cdot (b_o + b_1 \cdot \frac{1}{t}) \cdot (c_o + c_1 \cdot B)$

and by assuming different combinations of variables we can find the most suited regression equation for each tree species and calculation unit. Also another conception than the above mentioned, may be the foundation for a plausible and suited regression equation. As example of often used specific (for a certain case) multiple regression equations are mentioned:

a) $\ln h \quad b_o + b_1 \cdot \frac{1}{d} + b_2 \cdot \ln t + b_3 \cdot \ln^2 t + b_4 \cdot B$

b) $\ln h \quad b_o + b_1 \cdot \ln d + b_2 \cdot \ln^2 d + b_3 \cdot \frac{1}{t} + b_4 \cdot B$

c) $\ln h \quad b_o + b_1 \cdot \frac{1}{d} + b_2 \cdot \frac{1}{t} + b_3 \cdot B$

(Under consideration of the determination of the diameter in 1.3 m it is of advantage to use the tree height not measured from the ground but from breast height).

In fig. 2 the result of the estimation is presented for the - in case a) mentioned - multiple regression equation for dominant-height-site-class 35 and 15.

When the coefficients of the regression equation $\hat{h} = F(d,t,B)$ for each calculation unit (site units and stand types) and for each tree species are available, with the values B, d_E, t_E, d_A, t_A the estimates for the height at the end ($\hat{h}_E$) and at the beginning ($\hat{h}_A$) of the period are determined. The estimate for the height increment is the difference of these values,

$$z_h = \hat{h}_E - \hat{h}_A.$$

In the calculation of z_h not the measured value from the survey (h_E) but the deduced estimate ($\hat{h}_E$) from the function $\hat{h} = F(d,t,B)$ is used. In the following calculation of v_A, $h_A = h_E - z_h$ is used, that means that it was started out from the measured value (h_E).

6. Determination of the actual and for average climatic conditions expected growth production of the remaining stand

Since all the needed measured values and estimates are available the volume v_E and the periodic increment $z_V = v_E - v_A$ can be determined. The determination of the growing stock of the remaining stand (V_V) and of the periodic increment (pZ_I) of each sample plot (resp. calculation unit, whereby a

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conversion to data per hectare takes place) can be carried out, because $V_V = \Sigma v_E$ and $pZ_I \doteq \Sigma z_V$. In the determination of the GWL for a management class (or district) and in the estimation of the total current increment for the single age classes, the pZ_I values are used, if the "actual" growth production is wanted.

If the - for average climatic conditions valid - increment production is to be estimated, then also the expected, resp. corrected values $d_{E(k)}$ and $h_{E(k)}$ have to be determined. The calculation

$$d_{E(k)} \quad d_A + (2 \cdot z_r \cdot \hat{R}F/I),$$

is to be carried out in which the year-ring index (I) of the different species is deduced from an additional investigation (see Pollanschütz, 1967 P.284-286). By using the regression equation $\hat{h} = F(d,t,B)$ at first the estimate $h_{E(k)}$ will be determined under consideration of $d_{E(k)}$. The corrected value of the height increment is calculated with the formula $z_{h(k)} = \hat{h}_{E(k)} - h_A$ and the "corrected" value for the height at the end of the period, used for the volume calculation, is

$$h_{E(k)} = h_A + z_{h(k)}$$

The - for average climatic conditions - expected value at the end of the period and the expected periodic volume increment for the single age classes result from the sums of the "corrected" values of the individual trees, $V_{V(k)} = \Sigma v_{E(k)}$ and $pZ_V = \Sigma z_{v(k)}$. The climatic index (PI) of the periodic increment of the single age classes, mentioned in part 3, is the relation between pZ_I and pZ_V and is considered indirectly in the above mentioned calculations.

7. Comparisons of growth production and growth production tables

If the sample plots of a certain stand type of a site unit are arranged according to density, resp. according to certain series of stem number development (or series of basal area development) then - by GWL-calculations - the effects of different treatment programs can be estimated with good results. Also comparisons between fertilized and not fertilized management classes are possible, if sample plots from fertilized and not fertilized forest areas can be united to two growth series of comparable stem numbers and analog stand types of a site unit.

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FITTED VALUES OF THE GROWTH SERIES

Norway spruce, pure stands, District Ottenstein, site unite A

Age	Fitted values in dependence of age (from the inventory)						Calculated values		
	H_O	H_g	N_V	D_G	HF	$Q = pZ_{I/1m^2 G}$	G_V	V_V	pZ_I
	m	m		cm	m	Vfm_{SmR}	m^2	Vfm_{SmR}	Vfm_{SmR}
10	3,3	(1,5)	4185	1,70	(1,20)	(0,630)	(1,0)	(1,1)	(0,60)
15	6,2	(4,3)	3240	4,31	(2,70)	(0,619)	(4,7)	(12,7)	(2,92)
20	9,1	7,1	2699	6,94	4,20	0,605	10,2	42,8	6,17
25	12,0	10,0	2301	9,47	5,64	0,587	16,2	91,3	9,51
30	14,9	12,7	2003	12,04	6,87	0,565	22,8	156,5	12,88
35	17,6	15,3	1760	14,48	7,99	0,536	29,0	231,8	15,54
40	20,1	17,8	1559	16,57	9,09	0,509	33,6	305,4	17,10
45	22,4	20,1	1390	18,38	10,10	0,480	36,9	372,8	17,71
50	24,4	22,0	1248	20,10	10,97	0,452	39,6	434,3	17,90
55	26,3	23,8	1127	21,73	11,71	0,426	41,8	489,6	17,81
60	28,1	25,4	1024	23,26	12,39	0,403	43,5	538,9	17,53
65	29,8	26,9	935	24,67	13,02	0,384	44,7	581,9	17,16
70	31,3	28,3	857	26,11	13,48	0,364	45,9	618,9	16,71
75	32,6	29,6	788	27,47	13,91	0,348	46,7	649,6	16,25
80	33,8	30,7	727	28,81	14,26	0,333	47,4	675,7	15,78
85	34,7	31,7	672	30,13	14,57	0,319	47,9	698,1	15,28
90	35,6	32,7	622	31,38	14,91	0,307	48,1	717,3	14,77
95	36,4	33,6	576	32,64	15,22	0,296	48,2	733,4	14,27
100	37,1	34,4	534	33,90	15,49	0,285	48,2	746,5	13,74
105	37,7	35,2	496	35,10	15,76	0,276	48,0	756,3	13,25
110	38,2	35,9	461	36,33	15,96	0,266	47,8	763,0	12,71

table 1

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If only sample plots with a great number of stems per hectare (sample plots from the densest parts of a stand) are used and also the - by the climatic index - corrected value pZ_V, then the approximative estimation of the "potential" productivity of a certain stand type of a certain site unit and also the construction of a specific growth production table (site quality table) is possible. By using a sample plot of fairly dense and loose parts of stands also an increment reduction table can be deduced, similar to those enclosed to the yield tables for spruce by ASSMANN-FRANZ (1963).

If we make, in respect to species mixture and its changes with time, certain assumptions, according to the above mentioned course of calculations also for mixed stands growth production tables may be constructed and comparisons of productivity of different stand types may be carried out.

As an example, for the estimation of the current total increment of single age classes presented in part 3, data of the sample plot inventory of 1971 of the forest district of Ottenstein in Lower Austria are used. The "actual" increment of the single age classes is to be estimated. Calculations are made for pure stands of spruce on fresh or very fresh sites with good nutrition conditions. The dominant-height-site-class of the growth series is between B=36 and B=39. Available are 315 sample plots (angle count, basal area factor 4) between age 2o and 1o5.

The single steps of the calculation are roughly presented below (see table 1):

a) Determination of the development of the stem numbers by fitting the N_V-values per hectare, found in the course of the inventory in dependence of age (ln N in depence of t). The fitting is carried out only for sample plots with an age of more than 35 yrs, since in this growth series only from this age upward no ingrowth is to be expected; only diameters greater than 1o cm were used. The extrapolation of the fitted curve showed an initial number of stems (age 3 yrs) of 6.ooo, corresponding very well with the number of plants chosen by the management of the district.

b) Fitting the diameters of the basal area mean tree (D_G) in dependence of age, where the earliest ingrowth over the step in diameter measuring (in 1.3 m breast height was assumed for age 7.

c) Fitting the stand form heights (HF) in dependance of age.

d) Fitting the quotient $Q = pZ_I / 1\ m^2 G$ (periodic increment of the remaining stand per 1 sqm basal area) found from the results of the inventory.

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CALCULATION OF THE PERIODIC INCREMENT OF THE TOTAL STAND AND OF THE TOTAL GROWTH PRODUCTION

Norway spruce, pure stands, District Ottenstein, site unite A

Age	Fitted values of the remaining stand (from the inventory)					i_v	Correction factor	Increment of the removed stand		stand		Removed stand
	N_V	V_V	pZ_I	ΔN_V	ΔV_V	$pZ_{I/m}$	C	$pZ_{A/m}$	pZ_A half period only	pZ_{Gesamt}	GWL	V_A
	R1	R2	R3	R4	R5	R6=(R3:R1) · 5	R7	R8 R6 · R7	R9=(R4·R8)·0,5	R10=(R3+R9)·5	R11=V_{20}+Σ R10	R12=R10−R5
20	(2699)	(42,8)	9,51	398	48,5	0,0206	0,326	0,0067	1,33	48,9	(42,8)	0,4
25	2301	91,3	12,88	298	65,8	0,0322	0,348	0,0112	1,67	66,1	91,7	0,9
30	2003	156,5	15,54	243	75,3	0,0441	0,366	0,0161	1,96	79,7	157,8	4,4
35	1760	231,8	17,10	201	73,6	0,0548	0,382	0,0209	2,10	87,6	237,5	14,0
40	1559	305,4	17,71	169	67,4	0,0637	0,396	0,0252	2,13	90,7	325,1	23,3
45	1390	372,8	17,90	142	61,5	0,0717	0,408	0,0293	2,08	91,6	415,8	30,1
50	1248	434,3	17,81	121	55,3	0,0790	0,419	0,0331	2,00	91,1	507,4	35,8
55	1127	489,6	17,53	103	49,3	0,0855	0,428	0,0366	1,88	89,5	598,5	40,2
60	1024	538,9	17,16	89	43,0	0,0917	0,437	0,0401	1,78	87,6	688,0	44,6
65	935	581,9	16,71	78	37,0	0,0974	0,445	0,0433	1,69	85,2	775,6	48,2
70	857	618,9	16,25	69	30,7	0,1031	0,452	0,0466	1,61	82,9	860,8	52,2
75	788	649,6	15,78	61	26,1	0,1085	0,457	0,0496	1,51	80,4	943,7	54,3
80	727	675,7	15,28	55	22,4	0,1136	0,463	0,0526	1,45	77,9	1024,1	55,5
85	672	698,1	14,77	50	19,2	0,1187	0,468	0,0556	1,39	75,2	1102,0	56,0
90	622	717,3	14,27	46	16,1	0,1238	0,472	0,0584	1,34	72,7	1177,2	56,6
95	576	733,4	13,74	42	13,1	0,1286	0,477	0,0613	1,29	70,0	1249,9	56,9
100	534	746,5	13,25	38	9,8	0,1335	0,481	0,0642	1,22	67,5	1319,9	57,7
105	496	756,3	12,71	35	6,7	0,1378	0,484	0,0667	1,17	64,7	1387,4	58,0
110	461	763,0									1452,1	

Comment

Volume increment of the mean stem of the remaining stand

table 2

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e) With these fitted values (N_V, D_G, HF and Q) it is now possible to calculate the other needed an "fitted" stand data $G_V = (N_V \times D_G)$, $V_V = (G_V \times HF)$ and pZ_I $(G_V \times Q)$ for alle age classes.

f) If a complete growth production table is to be made also the dominant heights (H_o) and the mean heights weighted by basal area (H_G) have to be fitted.

g) The following calculation of the total periodic increment (pZ_{Ges}) of the single age classes is presented in table 2. The columns for the GWL (total growth production), the average total increment (dGZ), and the removed stand (V_A) are completed only for the example. Since the "actual" increment of the remaining stand (pZ_I) was used for the calculations, the values have a systematic positive or negative error because of the climatic influence of the preceding period. (In this case these values are overestimated since the climatic index was more than 1). Usable values for general growth production comparisons, valid for a local growth production table of the removed stand (V_A) are obtainded only if not the directly - from the data of the inventory - calculated values of the periodic increment (pZ_I), but the - for average climatic conditions - expected values of the periodic increment of the remaining stand (pZ_V) are used for the calculations presented in d) -g).

From the development series of the single significant values of the stands it is obvious that in the stands of spruce of very good site class up to now in the young growth between age 15 and 25 only slight measures (cleaning, resp. reductions of stem numbers,precommercial thinnings) were carried out by management. Presently commercial thinnings are to be expected only from age 3o upwards. Slight to moderate thinnings have been carried out in short intervals until the final cut of the stands at age 9o - 11o. As a consequence of the slow, but in the final result relatively strong, opening up of the stands - besides natural regeneration ocally heavy overgrowing with grass can be found.

8. Estimation of the increment in the Austrian Forest Inventory

Finally the difference of the increment estimations between sample plot inventories of forest management and of the national forest inventory should be indicated. In the 'Austrian Forest Inventory 1961-197o' as well

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as in the 'Austrian Forest Inventory 1971-198o' - under consideration of the high requirements of accuracy - besides d, h, and z_r also the $d_{o,3h}$ (diameter in o,3 of the total height of each tree) and z_h are measured. Therefore in the course of processing of volume inventories form factor functions of the general form $\hat{f} = F(d, h_{o,3h}, h)$ are in use. In this respect the papers 'Methodik der Auswertung und Standardfehler-Berechnung der Österreichischen Forstinventur' (Technique of Evaluation and Calculation of the Standard-Error in the Austrian Forest Inventory) by R. BRAUN (1969) and 'Eine neue Methode der Formzahl- und Massensbestimmung stehender Bäume' (A New Method of Determining Form-Factor and Volume of Standing Trees) by J. POLLANSCHÜTZ (1965) should be mentioned.

Since in the Austrian Forest Inventory contrary to forest management, besides the radial increment under bark (z_r) also the height increment (z_h) is determined in field work, only an additional estimate for the change of the 'upper diameter' ($d_{o,3h}$) over bark is necessary in the course of increment inventory processing. In a special investigation multiple regression equations for the main species have been determined which permit the estimation of the 'upper diameter' ($d_{o,3h}$) of 5 years ago, i.e. for the beginning of the increment period (see BRAUN). The general regression equation is

$$\hat{d}_{o,3h\ mR} \quad a_o + a_1 \cdot \left(\frac{d_{1,3\ oR}}{D_{1,3\ oR}}\right) \quad D_{o,3H\ mR}$$

D is used for the diameter at the end and d for the diameter at the begin of the period. The 'upper diameter over bark at the end of the period' is determinded with the Spiegelrelaskop by BITTERLICH the 'breast height diameter under bark at the end of the period' by calipers and measurement of the bark thickness, and the 'breast height diameter under bark at the begin of the period' by increment boring. Analog to the determination of the periodic volume increment in the course of the above mentioned processing and evaluation of sample plot inventories of forest management, the annual current increment in the Austrian Forest Inventory is determined for each sample tree by the formula

$$LZ = \frac{V_{actual} \qquad V_{5\ years\ before}}{5}$$

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9. Final remarks

The intensive processing and analysis of a sample plot inventory for forest management as well as for a national inventory in which for each element of survey the connection to a certain site unit and certain stand type ist determined, gives the possibility of growth simulations and investigations of production. The results of such investigations are basic features for example in the course of general 'Development plans for forestry and timber economy' for middle and long term studies of timber supply. In national inventories the result of an intensive processing and analysis, resp. finally the result of interpretation is the basis for forest policy and for general decisions in forestry.

The modern means of electronic data processing (EDP) gives us the possibility to work out from an enormous quantity of data an easily perceptible number of stand characteristics. Further on to win in the course of analyses of growth production, growth simulations, and production studies from a minimum of data a maximum of information. If suited sample plot inventories are existing this occasion a very much improved production estimation should not be missed in the interest of an appropriate and promising regulation of production and yield and with this an improvement of the planning of exploitation and management of the forest stands.

1o. Summary

Depending on environment factors the estimation of the actual and potential yield of stands in certain sites assumes the determination of the total periodical volume increment of single age-classes.

Within a sample for purpose of forest regulation diameter breast high (d), height (h) and the periodical radial increment (z_r) are measured on every tree of the sample-plot. More over an estimate for the height is needed for the calculation of the volume increment. The estimation of this value assumes the determination of the site-class of every sample-plot by means of the regression equation $\hat{B} = F(H_o, t)$. H_o stands for the height of dominant trees and t for the age. B means the site-class defined as height of dominant trees in the age of 1oo, $- H_{o(1oo)}$. The height increment results in the difference between the height at the end (h_E) and the height at the beginning (h_a) of the period. The height is estimated by means of the regression equation deduced from the data of the survey, $\hat{h} = F(d, t, B)$. The periodical volume increment results according

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$z_v = v_E - v_A$ for the calculating the volume the form-factor-functions $\hat{f} = F$ (d, h) with independent variables d and h are used.

Additional to the determination of the periodical volume increment of the residual stand the increment of the thinned stand is estimated by means of the factor c to reach the total periodical volume increment. The factor c stands for the relation of the volume increment of the mean tree of the remaining stand to that of the removed stand.

The analysis of growth production and the construction of specific yield-tables assumes the intensiv analysis of the data of a sample for purpose of forest regulation as discussed in the paper. They are the basis of the significant and successful yield regulation, the treatment of stands and the preparation of working plans.

11. Zusammenfassung

Eine den tatsächlichen örtlichen Verhältnissen entsprechende Schätzung der aktuellen und der potentiellen Leistungsfähigkeit bestimmter Bestandestypen auf bestimmten Standortseinheiten setzten eine objektive Ermittlung des gesamten periodischen Zuwachses in den einzelnen Altersstufen voraus.

Im Rahmen von Stichprobe-Inventuren der Forsteinrichtung werden von jedem Baum einer Probefläche die Meßwerte Brusthöhendurchmesser (d) und die Baumhöhe (h) und der periodische Radialzuwachs (z_r) gemessen. Außerdem wird um den Volumenzuwachs berechnen zu können ein Schätzwert für den Höhenzuwachs benötigt. Die Berechnung dieses Schätzwertes setzt eine Bonitierung mit Hilfe einer Beziehungsgleichung $\hat{B} = F(H_o, t)$ jeder Probefläche voraus. Hiebei bedeuten H_o die Oberhöhe der Hauptbaumart, t das Alter und B die Oberhöhenbonität im Alter 100, $- H_{o(100)}$. Der Höhenzuwachs wird als Differenz der Höhe am Ende (h_E) und der Höhe am Anfang (h_A) der Periode berechnet, wobei eine aus den Meßwerten der Vorratsinventur abgeleitete Beziehungsgleichung zur Schätzung der Höhe Verwendung findet $\hat{h} = F(d, t, B)$. Der periodische Zuwachs des Einzelbaumes ergibt sich gemäß $z_v = v_E - v_A$, wobei zur Volumenschätzung Formzahlfunktionen mit den Eingangsgrößen d und h Verwendung finden, $\hat{f} = F(d, h)$.

Abgesehen von der Ermittlung des periodischen Zuwachses des verbleibenden Bestandes wird, um zum gesamten periodischen Zuwachs zu gelangen, unter Einführung eines Korrekturwertes c der Zuwachs des ausscheidenden Bestandes im Zuge der Berechnung der Gesamtwuchsleistung (GWL) ermittelt.

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Der Korrekturwert c bedeutet das Verhältnis des Volumenzuwachses des Zuwachsmittelstammes des verbleibenden Bestandes zu dem des ausscheidenden Bestandes.

Die in der Abhandlung skizzierte intensive Aufbereitung und Analyse der Daten einer Stichprobe-Inventur der Forsteinrichtung stellt die Basis für die Wuchsleistungsanalysen und die spezifischen Wuchsleistungstabellen dar. Diese bilden wiederum die Grundlage für eine verbesserte Leistungseinschätzung im Interesse einer sinnvollen und erfolgversprechenden Ertragsregelung und somit einer Verbesserung der Nutzungsplanung und der Bewirtschaftung der Waldbestände.

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