SINGLE STEM MODELS
FROM INVENTORY DATA
WITH TEMPORARY PLOTS

by

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1. Introduction

Because of economic reasons several "selective thinning"-schedules are recommended by European silviculturists, and due to growing conservation consciousness clear cutting seems to become something dishonourable or at least something like barbarism, therefore distance dependent tree growth models will be more and more needed for European stands and tree species. Theories on single tree growth as they relate to distance dependent calculated competition indices have been developed by lots of authors as NEWNHAM (1964), MITCHELL (1969), MONSERUD (1976) and many others. Parameters of these models however have been estimated for tree species and sites outside of Europe only. Data bases for evaluation of these parameters as a rule are repeatedly observed plots with stem charts, to get distance- and time related informations on tree growth.

These data bases lack for a wide range of European tree species, growth regions and possible stand treatments. Instead of that we have a well developed stand growth theory, based on thinning experiments, where whole stand data have been observed during nearly 100 years by our forest research stations. These stand growth models have been mathematically described first by ASSMANN and FRANZ (1965) for Norway spruce, and by LEMBCKE et al (1975) for Scotch pine.

I want to show, that it could be possible to get an estimate of the parameters of a distance dependent model for our tree species by using ASSMANN's and FRANZ's stand growth models and data from temporary plots from inventories and other plots that have been observed only once.

2. Stand growth theory:

From ASSMANN's stand growth theory (ASSMANN, 1961) we know that:

1. Site quality can be estimated best from site index systems, which describe dominant height growth depending on age and site class. If we define dominant height as the height of the hundred largest stems per hectar, for most of our species their height growth is more or less independent from stand treatment without regard to early youth development. From FRANZ's (1974) Norway spruce simulator we can get an idea of the influence of early youth stem number on dominant height growth. It seems that there is an optimum stem number of about 2500 stems/ha where early youth dominant height growth can be accelerated by 0.5 to 1.5 m. Such site index systems are one of the basic constituents of our yield tables.

2. Concerning basal area growth, there is a maximum basal area, that is that one, which will be derived by natural mortality.

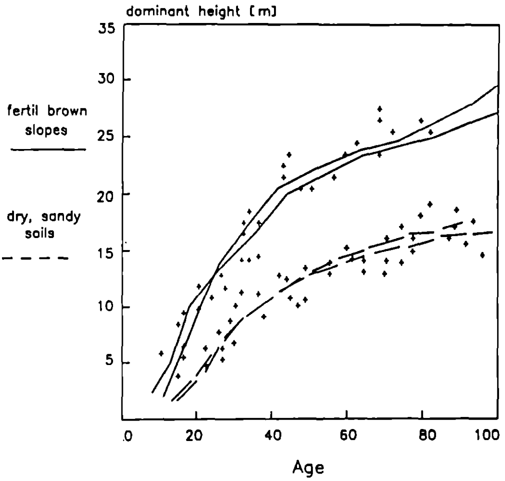
3. Total volume increment will depend on stocking degree, that is real basal area divided by maximum basal area. Relation between stocking degree and volume increment is not linear. There exists an optimum stocking degree, where volume increment is maximum, and ASSMANN defined a "critical stocking degree" where loss of increment is 5 % of maximum increment.

2.1 Estimating parameters of stand growth models

2.11 Dominant height growth, or a site index system can be taken from yield tables, or from growth series (a number of plots of different age and dominant heights on the same site, depending on site classification procedures). If one uses the appropriate yield table, or if the plots of the growth series really come from the same site (especially if there is no interaction between site quality and age) can be tested by stem analyses. (See fig. 1).

Figure 1

Dominant height growth of Scotch pine on two different sites from stem analyses and plots from growth series



Roughly spoken the height growth determined by stem analysis must lie within the range of the plotted values of dominant height versus age from growth series. From a number of such growth series an appropriate site index system for a certain species within a given region can be developed.

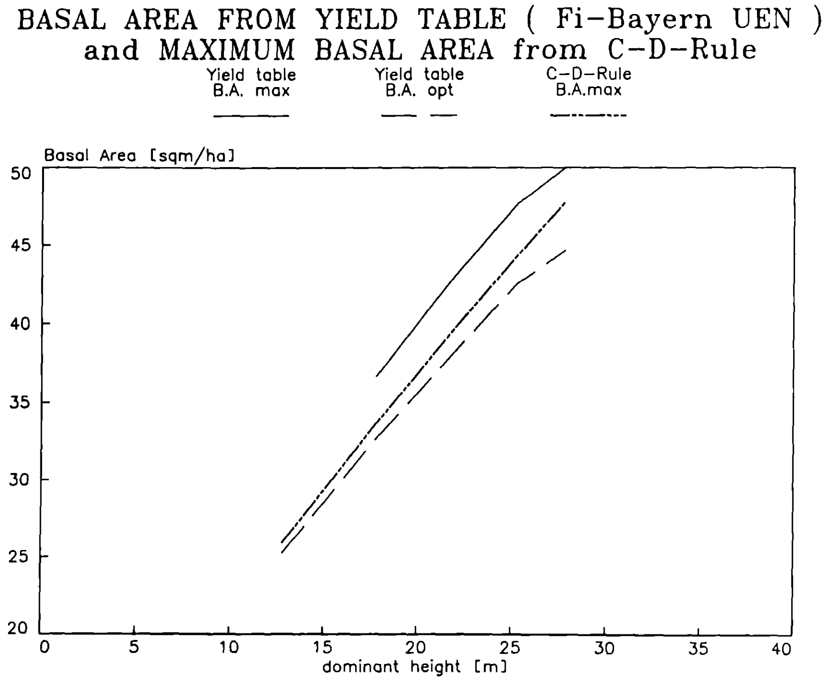
2.12 Estimation of maximum basal area development has first been reported by ASSMANN and FRANZ (1965) in their yield table for Norway spruce in Bavaria. Usually basal area reported in European yield tables is not maximum basal area but that basal area that results from certain thinning schedules. ASSMANN (1961) showed that maximum basal area development depends strongly on the "yield level", a site property which is only weakly correlated with site index. From stands that have been untreated since their establishment, that one, which has the higher basal area (this would be the maximum basal area of the site because it developed naturally) would be assigned to the higher yield level. So to estimate maximum basal area even with ASSMANN's yield table, one has to estimate yield level in advance. From GOULDING's (1972) generalization of KIRA's (1954) competition density rule STERBA (1975) could show, that maximum basal area can be estimated by extrapolation of this relationship (C-D- Rule)

$dg \quad 1 / (a_o \quad h^{a_1} \quad N + b_o \quad h^{b_1})$, where dg is

the diameter for mean basal area, h is the dominant height and N the stem number per hectar. Coefficients a_o through b_1 can be estimated from nonlinear regression with temporary plot data from growth series. With coefficients known for a certain region basal area / ha can be calculated from the above formula. Putting the partial derivate of basal area by stem number to zero, one can get the relationship between maximum basal area and dominant height.

From fig. 2 one can see development of maximum basal area as derived from the above procedure with growth series data from the Bohemian Massif, compared with maximum and optimum basal area development of the Bavarian yield table for Norway spruce. Estimation from growth series seems to be appropriate because from other investigations (MARSCHALL, 1975) we know that the yield level of Spruce at the Bohemian Massif lies beneath the lowest yield level (UEN) of ASSMANN's and FRANZ's yield table.

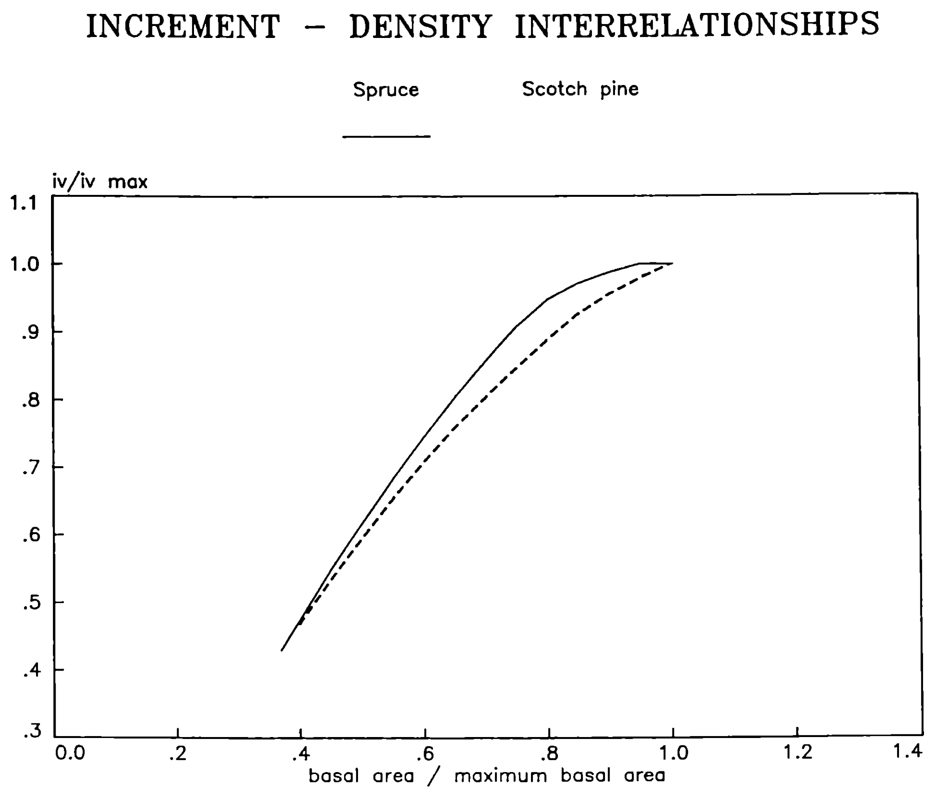
Figure 2



ASSMANN,FRANZ,1963 and STERBA,1974

2.13 Estimation of current volume increment can use the density increment relationship as stated by ASSMANN (1961). Fig. 3 shows the interrelationship between relative volume increment (i_v/i_{vmax}) and natural stocking degree (basal area / maximum basal area) as it is given for Norway spruce by ASSMANN and FRANZ (1963) and for Scotch pine by LEMBCKE et al (1975). Knowing maximum volume increment from an appropriate yield table, and maximum basal area from 2.12 one can calculate volume increment estimates for every given natural stocking degree from this figure.

Figure 3



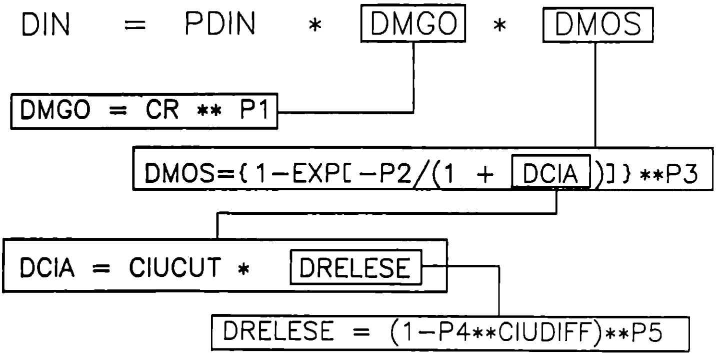
acc. to ASSMANN & FRANZ, 1963 and LEMBCKE et al (1975)

3. The competition model of MONSERUD´s and EK´s distance dependent single stem simulator FOREST

Figure 4 shows a simplified version of this model for estimating diameter increment of a certain stem in a stand. In this model real diameter increment (DIN) is calculated from potential diameter increment (PDIN) which is reduced by two multipliers. The potential diameter increment should be that diameter increment which an open grown tree with the same height as the tree in question would have.

Figure 4

MONSERUD's COMPETITION MODEL
(simplified)



DIN	diameter increment
PDIN	potential diameter increment
DMGO	factor to adjust for crown ratio (CR)
DMOS	factor to adjust for competition
DCIA	competition index, adjusted by DRELESE
CIUCUT....	competition before removal of competitors
DRELESE...	factor to adjust competition for ability to react to changing competition
CIUDIFF....	change of competition by removing competitors

The multiplier DMGO would reduce this increment depending upon the crown ratio. This takes into account, that a tree that has been released strongly for example 30 years ago, will seem to be an "open grown tree" today, but has a lower crown ratio and lower increment, than a really open grown tree would have. The second multiplier DMOS reduces diameter increment depending upon competition, where competition is evaluated as an index of overlap (CIUCUT) of the zones of influence. This zone of influence is defined as a circle around the tree with a radius equal to that of an open grown tree of the same height. This competition index is modified, when it changes (CIUDIFF) within the growing period. This takes into account, that a tree can't utilize all the free space which it gets, immediately after thinning.

3.1 Estimating parameters of MONSERUD's competition model

MONSERUD (1975) estimates the parameters of his model by means of a program (FORFIT) for nonlinear regression with data from repeatedly observed plots with stem charts. Since such data are not available for us we would have to use another way. FILLA (1981) described that way in detail. The following will be an extract from this work.

3.11 Parameters for potential growth:

Parameters for potential height growth we can get from a site index system, as MONSERUD did. Parameters for potential diameter growth we can get from extrapolation of the modified C-D-Rule or from trees from the stem charts that seem to be "growing in the open". Fig. 5 shows how both ways lead towards equations of the same form. Because of the different data (open grown trees for the one, and extrapolated relations from plot data for the other) we get different parameters. Comparison of the resulting "open grown diameter" seems to give better results from the extrapolated C-D-Rule, because the h/d ratio seems to be rather constant in that case, whereas the rather high h/d ratio for small (young) trees from the single open grown trees could be a hint, that these young trees were not really open grown, though they were used in regression only when their crown ratio was 1.

Figure 5

D.B.H of "OPEN GROWN TREES" and from EXTRAPOLATING C-D-RULE (Scotch pine)

1. DATA = open grown trees, Regression: d=a*h**b

2. DATA = plots, where dominant height, diameter of mean basal
area stem and number of stems/ha is determined
Regression: dg=1/(a'*hdom**b'*N/ha+c'*hdom**d')

for extrapolated "open grown tree" N/ha=0
and dg=1/(c'*hdom**d')

Comparing 1. with 2. d is dg,h is hdom and a=1/c' and b=-d'

Example for Scotch pine with data from a forest inventory

	open grown diameter estimated from			
dominant height	open grown trees		extrapolated C-D-Rule	
h	d	h/d	d	h/d
5	6.4	78	7.7	65
10	14.1	71	15.2	66
15	22.1	68	22.5	67
20	30.5	66	29.8	67
25	39.1	64	37.0	68

3.12 Parameters for DMGO

If competition is nearly zero, one can show that DMOS is nearly 1 (See fig. 4). So if we find stem charts of stands with a very low stocking degree, we could estimate DMGO and the parameter P1 from these plots. Giving P1 a starting value, we can calculate potential diameter increment, and from crown ratio and the starting value of P1 diameter increment of every tree of the stand. Adding up these increments we get the stand's increment and its basal area after the growing period. Comparing with the increment stocking degree relationship from fig. 3 and redefining P1 we can find the appropriate value for P1.

3.13 Estimating parameters P2 and P3 for calculating DMOS

If there are stands with no thinning and no mortality within the growing period, CIUDIFF will be zero (see fig. 4). With CIUDIFF 0, DRELESE is 1 and so DCIA, the adjusted competition index equals CIUCUT, the computed competition index without removal of any tree. Taking stem charts of stands which have stocking degrees so, that there is some competition but probably no mortality within the next ten years, we can again find P2 and P3 by approximating their values so, that simulated increment of the stand fits to the increment from yield tables, using increment reduction from fig. 3.

3.14 Estimating parameters P4 and P5 for adjusting competition index to allow for response to sudden crown release.

Using stem charts where thinning is simulated by removing different numbers of trees, one can simulate increment depending on approximate values for P4 and P5. From ABETZ (1977) we know, that, when young Norway spruce stands are thinned geometrically down to half of their stem numbers, basal area increment is reduced to 80 within 5 years, and height increment is reduced to 50 within the same time. So P4 and P5 have to be estimated by the following iteration procedure. With meanwhile known parameters P1 to P3, and good guesses for P4 and P5, geometrical thinning is done on stem charts, and growth is simulated. Guesses for P4 and P5 are then improved until the above mentioned relative reduction of increment is got by simulation.

4. Planned validation of the model

In 1977 this project was started with funding from the "Fonds zur Förderung der Wissenschaftlichen Forschung in Österreich" (Project numbers 3304 and 4357). In that year we established 23 plots in stands of Norway spruce and Scotch pine. For these plots stem charts, dbh, top height and clear bole lenghth of all trees were recorded. These plots we did not thin at all, to get information on mortality, which we can't get from inventory. Parameters of MONSERUD's competition model were estimated from inventory data (potential growth, crown radius for competition index, development of crown ratio as depending upon dbh, top height, site class, age and stand density) using stem charts of the 23 plots only for simulation. Validation of this model is impossible with these data. We can only say, that compared with stand growth theory and yield tables the simulated results seem to be plausible. But this is, because the idea of estimating parameters of the single stem model was to ask: how must single stems grow, that the whole stand where they grow behaves like stand growth theory and yield tables say. To get this result it was nessesary to state some mortality model, which we defined as a tolerance value for diameter increment where a tree was to die. This tolerance value was found in that way, that on these until now untreated plots, simulation with estimated parameters gave maximum basal area development.

First revision of the 23 plots is done just now and treatments with reference to JOHANN's (1982) proposal will be applied this winter, so that real validation and improvement of the model will not be possible before 1987. But if we will be able by then to show, that the model gives not only plausible results, but is also accurate within an acceptable range, it is not only this model which is validated but also the method to estimate parameters for single stem simulators from theory and from only one observation of plots.

5. Summary

On the one hand distance dependend tree growth models have their own theory. The simulator FOREST by EK and MONSERUD for example includes a competition model where

"potential growth" of a certain tree is said to be the growth of an open grown tree with the same height. This potential growth is reduced by some multipliers which are functions of crown ratio, competition index, change of competition index (by cuttings or mortality) and tolerance of the species. The parameters of this model have been estimated from a great number of plots from which data (including stem charts) have been observed through at least two growth periods.

On the other hand for the most important tree species in Central Europe we have a well developed theory on growth-density interrelationships for whole stands. For Norway spruce in Bavaria and for Scotch pine in Eastern Germany these interrelationships had been parameterized for calculating yield tables including tables for growth at different stocking degrees.

In this paper an attempt is reported to determine parameters of FOREST for Norway spruce and Scotch pine with data from plots, that have been observed only once (temporary plots from a forest inventory), so that different simulated stand treatments fulfill growth theory of the appropriate yield tables.

It is shown that parameterization in that way is feasible and simulation runs of this version of FOREST give plausible results.

Zusammenfassung

Einzelstammwachstumsmodelle aus Inventurdaten mit temporären Probeflächen:

Distanzabhängige Einzelbaummodelle haben eine eigene Theorie. So enthält der Simulator FOREST von EK und MONSERUD ein Konkurrenzmodell, in dem das "potentielle Wachstum" eines Baumes dem Wachstum eines Solitärs gleicher Höhe gleichgesetzt

wird. Dieses potentielle Wachstum wird durch Multiplikatoren, die ihrerseits vom aktuellen Kronenprozent und vom Konkurrenzindex und von dessen Änderung abhängen, auf das tatsächliche Wachstum reduziert. Die Parameter dieses Modells wurden von MONSERUD aus einer großen Anzahl mehrmals beobachteter Probeflächen mit Baumverteilungskarten geschätzt.

Dagegen gibt es in Mitteleuropa für die wichtigsten Baumarten eine weitentwickelte Bestandeswachstumstheorie, die den Zuwachs des Gesamtbestandes und der Mittelstämme in Abhängigkeit von der Bestandesdichte (Bestockungsgrad) zu erklären vermag. Für Fichte in Bayern und für Kiefer in der DDR sind diese Beziehungen als mathematische Wachstumsmodelle formuliert und parameterisiert.

Dieser Beitrag berichtet von dem Versuch, die Parameter des Simulators FOREST für die Baumarten Fichte und Kiefer mit Daten nur einmal beobachteter Probeflächen so zu schätzen, daß die Simulationsergebnisse der Bestandeswachstumstheorie und den absoluten Angaben der jeweils gültigen Ertragstafel entsprechen.

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