The importance of O'Connor's correlated curve trend (C.C.T.) method for use outside South Africa

[565]

DE BETEKENIS VAN O'CONNOR'S GECORRELEERDE CURVEN VOOR GEBRUIK BUITEN ZUID AFRIKA

Th. F. BURGERS

SAMENVATTING

De „Correlated Curve Trend Plots" (proefvelden ter bestudering van de tendens van gecorreleerde curven), in het kort „C.C.T."-proefvelden, werden ontworpen door A. J. O'Connor in Zuid-Afrika in 1935. Zij bestaan in principe uit twee series proefvelden. De eerste serie proefvelden wordt niet gedund en vertegenwoordigt verschillende plantdichtheden variërende van 1200 bomen per acre tot 50 bomen per acre. De tweede serie wordt gedund op verschillende leeftijd en met verschillende intensiteit. Een vergelijking van de diameteraanwas van beide series leidt tot de vaststelling van een reactie op dunning onder variërende omstandigheden van competitie en dunningsintensiteit.

De kennis van de groei van ongedunde opstanden van verschillende plantdichtheid en van de reactie op dunning onder vrijwel alle omstandigheden maakt het mogelijk resultaten te voorspellen voor een groot aantal dunningsmethoden. Op deze wijze kan ook een financieel optimaal dunningsprogramma worden vastgesteld. Dit betekent een groot voordeel, omdat het tot nu toe alleen mogelijk was een financiële omloop te berekenen, nadat een dunningsprogramma op grond van andere technische overwegingen was vastgesteld.

De verkregen diameter/leeftijd-grafieken zijn altijd vrij regelmatig en ze voldoen aan enige wetmatigheden. Dit maakt het ook mogelijk, om door vergelijking en afleiding diameter/leeftijd-grafieken van redelijke nauwkeurigheid te vinden voor houtsoorten waarvan geen proefvelden bestaan.

In dit artikel is getracht een diameter/leeftijd-grafiek te vinden voor een gemiddelde boniteit Pseudotsuga menziesii. *(Zie grafiek II). Deze grafiek kan gecontroleerd worden door met behulp van het dunningsprogramma, behorende bij groeiklasse 12 van douglas van de opbrengsttabel 1957 van het Bosbouwproefstation-I.B.O. (3), diameters te voorspellen. Als wij dit doen zien wij, dat op 60-jarige leeftijd 27,6 cm voorspeld wordt, terwijl 31,4 cm in werkelijkheid wordt bereikt. De voorspelling met behulp van diameter/leeftijd-curven en de reactie op de dunning is dus vrij sterk aan de veilige kant. We kunnen nu ook een optimaal dunningsprogramma ontwerpen. Als we door stamtalreductie zorgen met de diameteraanwas net op de lijn voor vrijgroeiende bomen te blijven is het zeker, dat we in de kortste tijd de hoogst mogelijke diameters bereiken en aangezien grotere gemiddelde diameters een*

betere prijs op stam geven, is dit in de praktijk vrijwel altijd de optimale dunning.

In de tabel van de voorspelde diametergroei van het optimale dunningsprogramma zien we, dat de diameter van 31,4 cm, die bij het huidige dunningsbeleid bij 60 jaar wordt bereikt, ook reeds bereikbaar is bij 32 jaar. Bij een omloop van 60 jaar kan zelfs een diameter van 50 cm worden bereikt.

Als we nu de geproduceerde houtmassa en de gemiddelde jaarlijkse aanwas berekenen, zien we dat deze bij de optimale dunning minder is; de huidige dunning geeft een maximale gemiddelde aanwas van 12 m³ terwijl de optimale dunning slechts een maximaal gemiddelde van 9,7 m³ te zien geeft. Bij een geheel correcte afleiding van de diameter/leeftijd-grafiek door minder aan de veilige kant te blijven zou dit verschil belangrijk kleiner zijn, maar er blijft altijd een verschil. (Er is een dichtheid, waarbij de grootste houtmassa wordt geproduceerd; deze ligt ongeveer in het midden van de grafiek bij 1000 stamtal per ha (s.p. ha), maar dit is alleen van belang bij papierhout of vezelplaatproduktie als er geen markt is voor ander hout.)

Als we nu de rentabiliteit berekenen van het huidige dunningsprogramma van 60 jaar en die vergelijken met het optimale dunningsprogramma bij een omloop van 50 jaar, zien we dat er een totale verbetering mogelijk is van 2,9 tot 3,3 %. Doordat de diameters en eveneens de waarde op stam aan de veilige kant werden berekend, is deze verbetering veel minder opvallend, dan hij vermoedelijk in werkelijkheid is. De waarde van staande bomen met een diameter van 45 cm of groter is vrijwel onbekend. Zeer waarschijnlijk zal deze waarde wel belangrijk hoger liggen dan in de diameter/houtwaardegrafiek V, waar zij op 40 gulden per m³ is geschat.

Er kunnen verder nog de volgende conclusies worden getrokken:

1. *Een reductie van het stamtal per hectare bij de aanleg van bos kan een verdere verbetering van de rentabiliteit geven, doordat aanlegkosten en kosten van eerste dunning minder worden bij een gelijktijdig verbeterde groei.*
2. *Indien men zich voorstelt, waar in de diameter/leeftijd-grafiek II de lijnen liggen van 10.000 s.p. ha en hoger, en wat de reactie op de dunning zou zijn volgens grafiek IV bij late eerste dunning, is het verklaarbaar dat veel grovedennenbossen in Nederland een zeer povere groei vertonen.*
3. *Bezwaren, die zouden kunnen bestaan tegen de lage stamtallen van het optimale dunningsprogramma zijn toename van onkruidgroei, windschade, zware vertakking en soms waterloten. Het is echter lang niet zeker, dat deze bezwaren in ernstige mate zullen optreden, de grotere vitaliteit van de bomen kan misschien onkruidgroei en windschade juist tegengaan. Zware vertakking kan nooit een ernstig probleem zijn, want snoeien is toch nodig en de onderste stamblokken in een boom vertegenwoordigen minstens 80 % van de houtmassa en een nog veel hoger percentage van de waarde. Het optreden van waterloten kan bij sommige houtsoorten wel een reden zijn om zware dunningen te vermijden.*
4. *Terugkomende op de eerste conclusie: het is zelfs mogelijk een zeer wijd plantverband te kiezen bijvoorbeeld van 3 × 3 m met 1.111 bomen per*

hectare en gedurende de eerste periode tot ongeveer 15 jaar een periodieke grondbewerking toe te passen. Deze grondbewerking (vergelijkbaar met Dry-farming" in de landbouw) kan een verdere versnelling van de groei en een hogere rentabiliteit geven.

Het lijkt raadzaam enkele C.C.T.-series in Nederland aan te leggen, aangepast aan plaatselijke omstandigheden en in verband met proeven betreffende plantmethoden en verpleging in de beginperiode. Het is zeker dat dit tot een belangrijke verbetering van de rentabiliteit zal leiden, hoger dan de hierboven berekende van 2,9 tot 3,3 %.

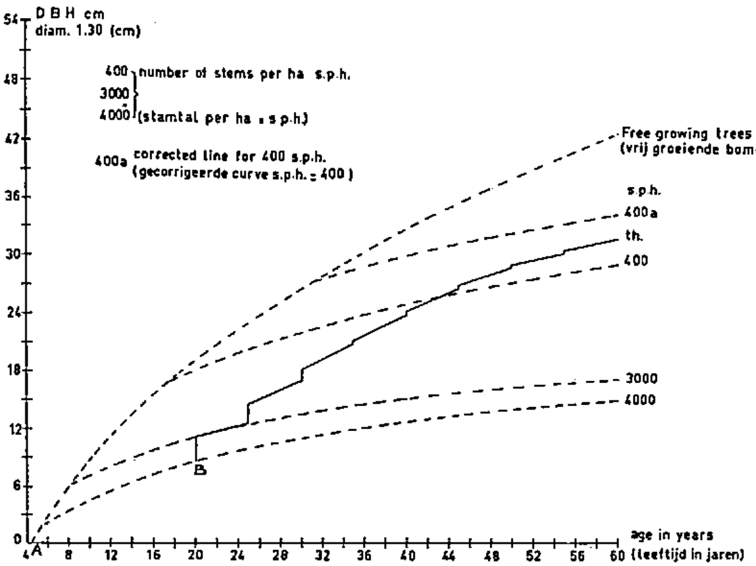
The C.C.T. experiments planned by A. J. O'Connor in South Africa in 1935 consist in principle in two series of plots. The first series of 8 unthinned plots represents densities varying from 1200 stems per acre down to 50 stems per acre. A second series of 10 unthinned plots is thinned at varying ages and with varying thinning degrees. A comparison between the D.B.H. growth of the two series permits the calculation of a response to thinning under varying circumstances of suppression and thinning intensity.

It becomes possible to predict results for a great variety of thinning regimes, by adding increment of unthinned plots, response and arithmetic increase. It is also possible to determinate the financial optimum thinning regime. With other methods of financial calculation only a financial rotation can be calculated, while the thinning regime is planned on technical, not financial considerations.

By comparison of D.B.H. growth of actual C.C.T. series with D.B.H. growth of other species for which no C.C.T. series exist, acceptable D.B.H./Age graphs can be obtained, which can be used with reasonable accuracy to predict D.B.H. growth of the other species also.

These D.B.H./Age graphs are always fairly regular in form (see graph II dotted lines). Mathematical equations of the type $y = a + b \log x$ can be calculated for the various density lines. A relationship can be established between the b factors of these equations (representing the inclination and the increment) and the growing space per tree. It was also found, that the basal area of stands at the connecting points was mostly constant. These rules make a number of deductions possible, when only a few points or lines of the graph are known. In this article an attempt is made to find a D.B.H./Age graph for average site quality Douglas fir *(Pseudotsuga menziesii)* in Holland and predict its growth under an optimum thinning regime. As a basis a low site-quality D.B.H./Age graph deducted from C.C.T. data of *Pinus roxburghii* is compared with D.B.H. growth of average site quality Douglas fir in Holland. (Growth class 12 of the Production Table prepared by the Forest Research Station in Holland).

In Graph I the relation between D.B.H. and Age is represented for: unthinned plots of freegrowing trees, plots of 4000 stems per hectare (s.p. ha), plots of 3000 stems per hectare and plots of 400 stems per hectare (dotted lines) and compared with D.B.H. -growth of average site-quality Douglas fir under the following thinning regime:



Graph I. Theoretical 4th site quality *Pinus roxburghii* compared with average site quality *Pseudotsuga menziesii.*

Grafiek I. (Theoretische 4e boniteit Pinus roxburghii *vergeleken met de gemiddelde boniteit van* Pseudotsuga menziesii)
D.B.H./age relation *(verband diameter op 1,30 en leeftijd)*
------ : 4th site quality longleaf-pine *(4e boniteit longleaf-pine)*
——th : thinning regime Douglas for 2nd site quality *(dunningsmethode douglas 2e boniteit).*

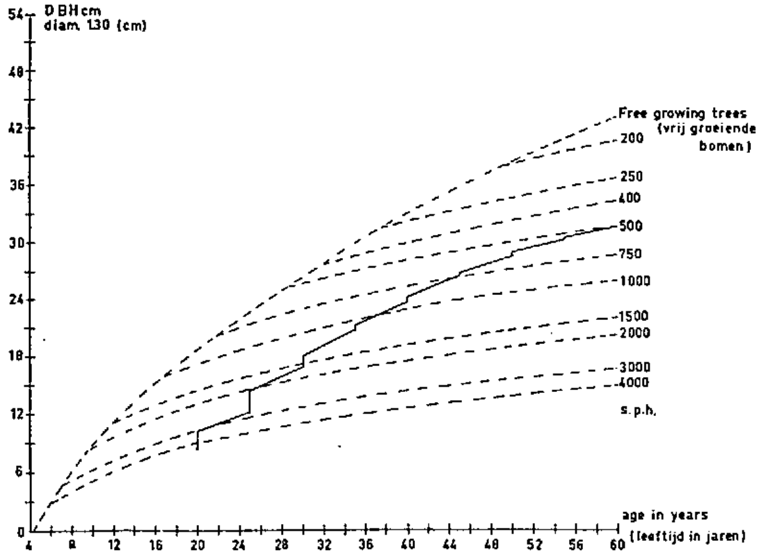
Age years	s.p.ha after thinning	D.B.H. before thinning cm	D.B.H. of thinnings cm	D.B.H. after thinning cm	H after thinning m	form-factor
15	4000	—	—	—	7.0	—
20	2305	8.5	6.0	11.0	10.3	0.522
25	1445	12.2	10.0	14.4	13.4	0.504
30	1020	16.9	14.0	18.0	16.3	0.487
35	795	20.7	18.0	21.1	18.7	0.475
40	650	23.7	21.0	24.1	20.8	0.463
45	555	26.4	23.0	26.7	22.5	0.453
50	490	28.5	25.0	28.8	24.1	0.446
55	450	30.1	28.0	30.3	25.4	0.440
60	415	31.4	29.0	31.6	26.5	0.436

It is found that the beginning point (A) and the point B 8.5 cm at 20 years practically coincide.

The 400 s.p. ha line is too low for 2nd s.q. Douglas fir (2nd s.q. is average site quality if 3 different site qualities are adopted). Experience has shown, that D.B.H. growth of the thinned stand begins to run parallel to D.B.H. growth of the unthinned stand of the same density from about 10 years after the last thinning and then about 1 to 3 inch below it. The correct position of the 400 s.p. ha line can be assumed to be 1 inch or 2.5 cm above the line of the thinned plot. This is a conservative assumption.

This corrected line of 400 s.p. ha connects with the line for free-growing trees at 32 years. The connecting point of the uncorrected line of 400 s.p. ha is at 18 years. In other words: competition in the unthinned plot of 400 s.p. ha of Douglas fir begins at a much later age, than in a similar plot of Pinus roxburghii.

This is not surprising, the colder climate in Holland causes a slower growth of tree species, and the point where the roots reach each other and start to compete must be at a later age. We can assume now, that the 4000 s.p. ha line is more or less in its correct position with a connecting point at six years and that the correct 400 s.p. ha line has a connecting point at 32 years. The ages for the other connecting point can be deducted now.

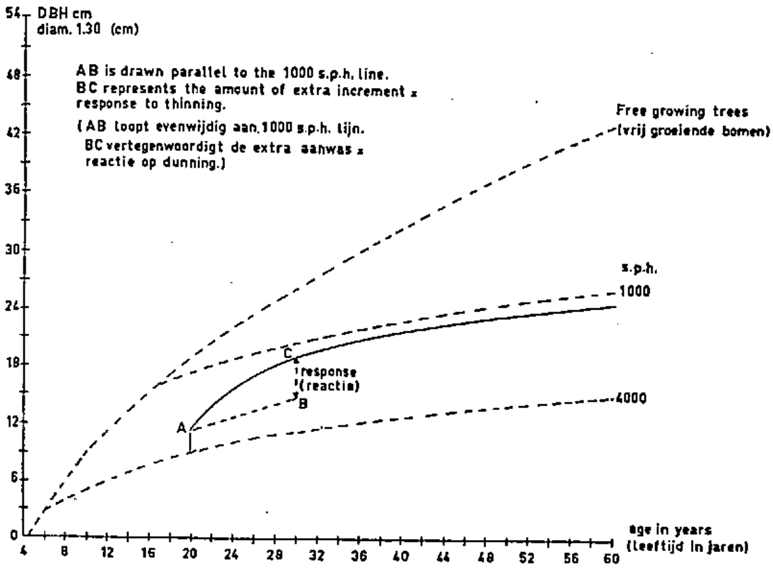


Graph II. D.B.H./age relation for different densities of 2nd site quality *Pseudotsuga menziesii* compared with growth class 12. Production table Forest Research Station — Institute of Forestry Research, Wageningen, Holland.

Grafiek II. (Het verband tussen diameter op 1,30 en leeftijd voor verschillende plantdichtheden van de 2e boniteit Pseudotsuga menziesii *vergeleken met groeiklasse 12 van de opbrengsttabel 1957 van Bosbouwproefstation — Instituut voor Bosbouwkundig Onderzoek).*

A D.B.H./Age graph can now be constructed using the corrected connecting points and the B factors of low site quality *Pinus roxburghii*. (Graph II dotted lines). The D.B.H. growth of 2nd s.q. Douglas fir is also represented in this graph. The D.B.H. growth of the thinned plots follows steeper lines than the D.B.H. growth of the corresponding unthinned plots of the same density, as shown in Graph II.

What exactly happens to D.B.H. development after thinning is best shown in Graph III. This graph represents a theoretical case of a thinning from



Graph III. D.B.H./age relation for a plot thinned from 4000 to 1000 s.p.ha at 20 years compared with the unthinned plots of 4000 and 1000 s.p.ha.

Grafiek III. (Het verband tussen diameter op 1,30 en leeftijd bij dunning van 4000 op 1000 stammen per ha (s.p.ha) op 20-jarige leeftijd, in vergelijking met de ongedunde veldjes van 4000 en 1000 s.p.ha).

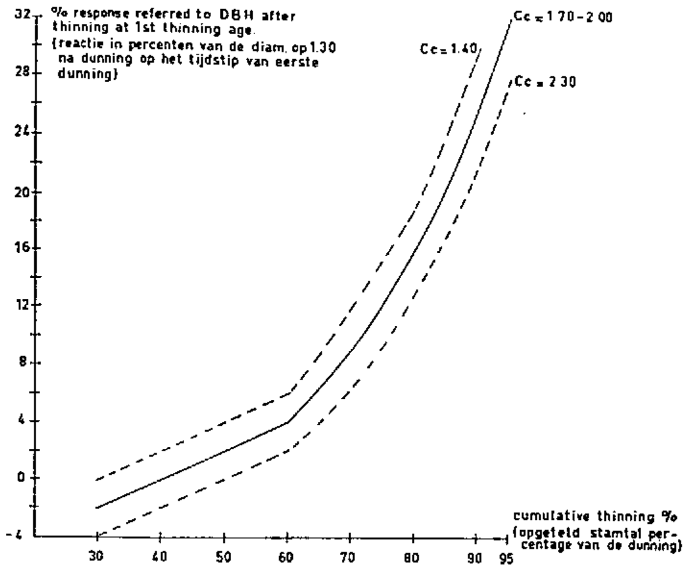
4000 s.p. ha to 1000 s.p. ha at 20 years. The D.B.H. growth is very fast during a period of 8 to 14 years after thinning and afterwards remains parallel to the line of the density after thinning, when no further thinnings are done.

In the first period of fast growth there is an „extra increment"; growth is much faster than on the 1000 s.p. ha line. The extra increment can be called „reaction to thinning" or „response to thinning". It can be shown in graph III by drawing a line through point A (D.B.H. after thinning at 20 years) parallel to the 1000 s.p. ha line (density). The response to thinning at 30 years is represented by the line B.C. This extra increment can be expressed as a percentage of the D.B.H. after thinning.

The response not only depends on the thinning percentage but also on the degree of competition the trees have suffered before they were thinned. Thinning at early ages produces only light competition, thinning at later ages produces a heavier competition.

In Graph IV the amount of this reaction to thinning is represented for different coefficients of competition and for different degrees of thinning. (Coefficient of competition = C.c. = D.B.H. of free-growing tree/D.B.H. of actual tree after thinning). For low coefficients of competition (light suppression) the response is higher, for high coefficients of competition (heavy suppression) the response is lower. Response is also different for different species. Here a conservative average was used. In the present case, Douglas fir at 20 years the coefficient of competition is 18.5/10.0 = 1.85.

With D.B.H. growth read from graph II and response percentages read



Graph IV. Relation between thinning percentage and response to thinning. Average South African pine species under normal coefficients of competition.

Grafiek IV. (Verband tussen stamtalpercentage van de dunning en reactie op dunning; een gemiddelde van Zuidafrikaanse pinus-soorten bij normale competitie-coefficiënten: 1,40—2,30).

from graph IV it is now possible to test graph II, comparing calculated D.B.H. growth with actual D.B.H. growth as follows:

Age	s.p.ha before thin-ning	cumula-tive thin-ning %	D.B.H. 5 y ago cm	arith-metic increa-se cm	response cm	increment cm	D.B.H. predicted cm	D.B.H. actual cm
20	4000	40%	—	—	—	—	9.0	8.5
25	2305	64%	9.0	2.5	0.0	(14.6—13.2)	12.9	12.2
30	1445	74%	12.9	2.2	0.5	(17.2—16.0)	16.8	16.9
35	1020	80%	16.8	1.1	0.9	(21.7—20.5)	20.0	20.7
40	795	84%	20.0	0.4	0.4	(25.1—24.0)	21.9	23.7
45	650	86%	21.9	0.4	0.5	(26.1—25.2)	23.7	26.4
50	555	88%	23.7	0.3	0.3	(30.0—29.1)	25.2	28.5
55	490	89%	25.2	0.3	0.3	(30.9—30.0)	26.7	30.1
60	450	—	26.7	0.2	0.1	(31.5—30.9)	27.6	31.4

The predicted D.B.H. is lower than the actual D.B.H. If we had chosen a somewhat higher site-quality from the *Pinus roxburgii* data the difference could have been smaller or non existant. This is an indication, that the lines of graph II for unthinned plots are on a safe conservative side.

From Graph II we can now deduct the optimum thinning regime, which follows the line for freegrowing trees. This is so because in this way the highest D.B.H. is produced in the shortest time.

Prediction of D.B.H. growth of the optimum regime:

Age	s.p.ha before thinning	Thinning %	Cumul. Thinning %	D.B.H. n y ago	arithmetic increase	increment	D.B.H. predicted
y	cm			cm	cm	cm	cm
0	4000	—	—	0	0	0	0.0
6	4000	50%	50%	0	0	(2.7— 0.0)	2.7
10	2000	40%	70%	2.7	0.2	(9.0— 2.7)	9.2
15	1200	33%	80%	9.2	0.6	(14.1— 9.0)	14.9
20	800	44%	89%	14.9	0.7	(18.6—14.1)	20.1
25	450	—	—	20.1	1.4	(23.0—18.6)	25.9
30	450	47%	94%	25.9	—	(26.2—23.0)	29.1
35	240	—	—	29.1	1.9	(29.4—26.2)	34.2
40	240	17%	95%	34.2	—	(32.4—29.4)	37.2
45	200	—	—	37.2	1.1	(35.3—32.4)	41.2
50	200	20%	96%	41.2	—	(38.2—35.3)	44.1
55	160	—	—	44.1	1.3	(40.4—38.2)	47.6
60	160	—	—	47.6	—	(42.6—40.4)	49.8

Response to thinning does not exist in this case because the increment is already the highest increment possible, following the line for free-growing trees.

Conclusion:

The 31 cm D.B.H., which under the actual regime is reached at 60 years can be reached at 32 years under this thinning regime. In 60 years nearly 50 cm D.B.H. can be reached, while under the actual regime only 31 cm is reached.

Volume production:

1. Actual regime.

Age	Volume per hectare before thinning	Volume per hectare of thinnings	Volume per hectare after thinning	Total volume	Total mean annual increment per year per ha
y	U.B. cbm	U.B. cbm	U.B. cbm	U.B. cbm	U.B. cbm
20	139	21	118	139	7.0
25	195	36	159	216	8.6
30	248	43	205	305	10.2
35	292	45	247	392	11.2
40	327	42	285	472	11.8
45	353	36	317	540	12.0
50	374	31	343	597	11.9
55	389	26	363	643	11.7
60	401	25	376	681	11.4

2. Optimum regime.

Age y	Volume per hectare before thinning U.B. cbm	Volume per hectare of thinnings U.B. cbm	Volume per hectare after thinning U.B. cbm	Total volume U.B. cbm	Total mean annual increment per year per ha U.B. cbm
6	0	0	0	0	0.0
10	20	4	16	20	2.0
15	72	8	64	76	5.1
20	144	36	108	156	7.8
30	243	85	158	291	9.7
40	247	19	228	380	9.5
50	332	44	288	484	9.7
60	365	—	—	561	9.3

y = year; ha = hectare; U.B. cbm = cubic meters under bark.

For the calculation of these volumes it was assumed, that height and form factor are the same at the same age, independent of the thinning regime. The volumes and increments are lower under the optimum regime. This is always so, but often the difference is smaller. Comparison of the rates of return: The Faustmann formula is used for this purpose in the following form:

$$Se = \frac{Yr + \Sigma Ta \times 1.op^{r-a} - \Sigma PRa' \times 1.op^{r-a'} - CL\ 1.op^{r-a''} - c\, 1.op^{r}}{1.op^{r} - 1} - \frac{e}{o.op}$$

In this formula Se is the land expectation value. The value at which land can be bought for use as forest can be estimated at fl 2000 per hectare, supposing it has no extra recreational value. r = rotation. Yr = final yield at r years. Ta = value of thinnings at a years, b years and so on.

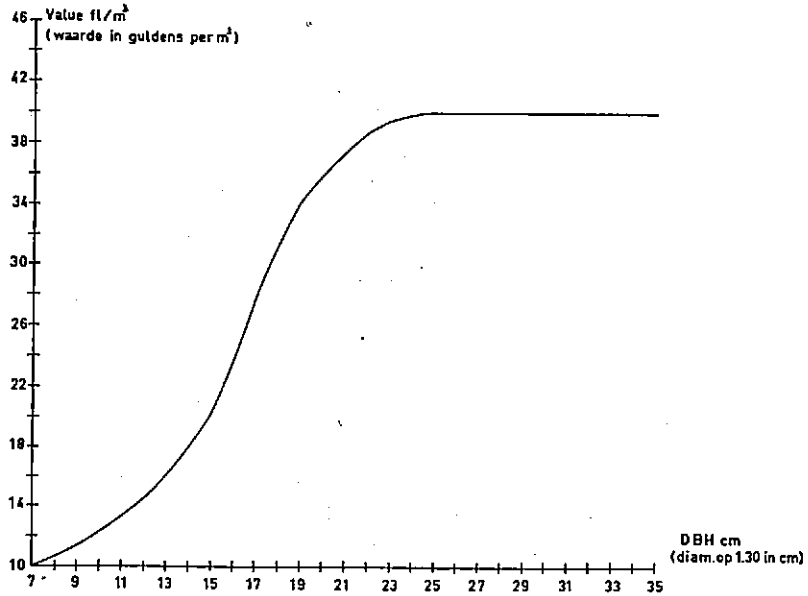
The value of these thinnings and of the final yield per cbm can be read from graph V, indicating the relation between D.B.H. and value in guilders per cbm. This graph was obtained from the following values for standing trees:

Mean D.B.H.	7—10 cm	fl 10	per cbm
„ „	10—20 cm	fl 20	„ „
„ „	20—30 cm	fl 40	„ „

c = cost of plantation. This can be estimated at fl 1800 per hectare.
e = overhead expenses. These can be estimated at fl 50 per year per hectare.
PR = pruning costs. These can be estimated at:

age 15	years	fl 0.40	per tree
age 20	„	fl 0.50	„ „
age 25	„	fl 0.80	„ „

It is assumed, that only the trees destinated to reach the final yield are pruned.
CL = cost of clearing or of the first thinning. If stands are planted at 4000 s.p.ha or if strong competition of oaks or other trees or shrubs occurs, there will be expenses at the age of first thinnings. These can be estimated at fl 150 per hectare.



Graph V. Douglas fir D.B.H./value graph for standing mean trees.
Grafiek V. (Verband tussen de houtwaarde per m³ en de diameter op 1,30 van normale douglasbomen).

Using these data and the already known volume production of the two regimes, the following rates of return are calculated:

Rotation years	Rate of return Actual regime	Rate of return Optimum regime
40	2.9%	3.2%
50	3.1%	3.3%
60	2.9%	3.1%

Conclusion:

By adopting a financial rotation of 50 years the rate of return can be improved with 0.2 % *. By adopting the optimum regime another improvement of 0.2 % is possible.

It is clear, that this improvement should be quite welcome for the private owner of forests or other owners, when expressed in total extra income per year. However it is not impressive, when compared with other cases of optimum regimes and it helps little to make investment in forestry equivalent to other investments. This is due to very high soil value and costs. The improvement in D.B.H. growth was impressive, but not so the increase in rate of

*) An improvement of the rate of return by 0.2% is important. It means that all capitals involved show this increase (soil fl 2000, plantation cost fl 1800, pruning fl 340, cleaning fl 150 per hectare). It is completely accidental that the result is 0.2%. Repeatedly data were taken on the safe side. Exact data would probably show an increase somewhere around 1%.

return. This may be partly due to the fact that the deduction of the D.B.H./ Age graph was kept on the safe side, but it is mainly due to the fact, that in Holland high prices are obtained for small size trees, and that for D.B.H.'s over 25 cm the values do not increase any more.

There are indications, that this situation could very well change in the future because:

a) The cost of extraction for trees of 7-10 cm is increasing.
b) The market for trees from 10-20 cm is difficult.
c) The market for trees from 20-30 cm is easier.
d) Probably higher prices can be obtained for trees over 45 cm D.B.H. Sales of trees of this size are still sporadic, but there are indications that the price of these trees could well be about fl. 55 per cbm. If these trees could be used for plywoodlogs the price may still be higher.

If important changes of this type occur the optimum regime will show a much higher rate of return compared with the actual regime.

Other conclusions and considerations:

1) The graphs and data only represent estimates. This article is written in the first place to demonstrate the possible advantages of the method, and not to give exact results. A further checking of graph II is possible by collecting data of unthinned plots of different densities, by making comparisons with a greater variety of thinned plots with different regimes, and by measuring free-growing trees in parks or nearly free-growing trees along roads.

A weak point in the deduction of the D.B.H./age graph is the position of the line for free-growing trees. This is also true, when actual C.C.T. data are available. The points for the calculation and construction of this line are only available at early ages, when competition has not yet started. The extra-polation of the rest of the line makes it less reliable. When a graph is deducted for a species for which no C.C.T. data are available, only the beginning point is known (just after reaching breast height). The rest of the line is assumed to be in the same position as the nearest graph of the most similar species and site-quality.

This shows the importance of obtaining at least a few data on the size of free-growing trees before definitely advising on an optimum regime. The prediction of other regimes than the optimum is possible with a high degree of accuracy, because the correct inclination of the lines is easy to deduct.

2) Graphs II and IV show clearly, that a long post-ponement of thinnings and specially of the first thinning can have a very adverse effect, not only on the rate of return, but also on the reaction to thinning, which under high coefficients of competition is much lower.

If extrapolation to find the lines for very high densities and the reaction to thinning for these densities should be correct, it can be shown, that with densities in the order of 10,000 to 20,000 s.p. ha and a late first thinning after 15 years saw timber size cannot be reached any more, even under intensive later thinnings. There are perhaps some indications, that this kind of extrapolation is not reliable, because natural selection can take the place of thinning to some extent. On the other hand the aspect of many Pinus silvestris stands in Holland are an indication that this might be the cause of poor growth in many cases.

3) Objections can exist against the adoption of an optimum thinning regime. The more open stands may produce weed-growth, wind-damage or heavy branches, and perhaps in some cases adventitious shoots. However it is not sure, that weed growth and wind damage will increase; the higher vitality of the remaining trees may have the opposite effect. Heavy branches cannot be a serious problem, because pruning has to be done anyway, and the first two logs in a tree represent at least 80 % of the volume and a still higher percentage of the value.

4) A much wider initial espacement can reduce the plantation cost and the cost of the first thinnings and have at the same time a favourable effect on early growth. It is even possible that a very wide espacement, for instance 3×3 m with 1111 stems per hectare and occasional soil preparation during 15 years until the first thinning is more economic.

It seems advisable to establish some C.C.T. series adapted to local conditions and in connection with experiments on initial espacements and planting methods. It is almost sure, that this will lead to a much better rate of return.

Literatuur:

1. O'Connor, A. J. 1935. Forest Research with special reference to planting distances and thinning. British Empire Forestry Conference, 1935.
2. Marsh, E. K. Some preliminary results from O'Conner's correlated curve trend (C.C.T.) experiments on thinnings and espacements and their practical significance. Commonwealth Forestry Conference Australia and New Zealand 1957. Union of South Africa.
3. Laar, A. van en J. van Soest. De groei van de douglas in Nederland. Ned. Bosbouw Tijdschr. 30 (4) 1958 (118—129).