ANALYZING THE DEVELOPMENT OF REGENERATION UNDER CROWN COVER: INVENTORY METHODS AND RESULTS FROM 10 YEARS OF OBSERVATION

Heinz Utschig
Chair of Forest Yield Science, Munich
Hohenbachernstraße 22
D-85354 Freising, Germany

ABSTRACT

Between 1983 and 1986 5 trials with 20 plots (12.4 ha in total) were established in mixed stands with beech, oak and pine in Bavaria. These plots represent different states of the long term development of regeneration under shelterwood.

Height development is an important indicator for interpreting the effects of shading and competition in the regeneration. The influence of the old stand was described as crown competition for light. Looking for causalities the function of v. Bertalanffy provides as a first approach to interpret height growth in the regeneration in dependence on the old stand.

The results of this observation are a first step for modelling and simulating the development of the regeneration under crown cover in mixed species stands.

INTRODUCTION

In German forestry we know a lot about the development of tree species in pure stands. The institutes of forest yield science have a wide network of log term experimental plots which are for example the database for interpreting different silvicultural treatments (Wiedemann, 1949; Assmann and Franz, 1963). Only few mixed stands are in long-term observation. By the change from pure stands to mixed stands and the change from regeneration in a short period to a long-term regeneration system this database seems no longer be sufficient (Pretzsch, 1992). In respect of regeneration under shelterwood we recognise a lack of knowledge about growth reactions of the old trees and about development of regeneration under crown cover (Franz, 1987).

MATERIAL

Between 1983 and 1986 5 long term trials with 20 plots (12.4 ha in total) were established in mixed stands of beech, oak and pine in Bavaria. These plots represent different phases of the long-term development of regeneration under shelterwood. The different trials were designed as growth series, from the old growth with closed crown cover to the phase of beginning regeneration up to the final phase of complete regeneration with a mean height of 10 to 15 m and some hold-over trees (fig. 1). Now these plots were assessed for the second time during the last three years. In the old stand height, dbh, crown dimension, stem position and the quality of the stem were assessed.

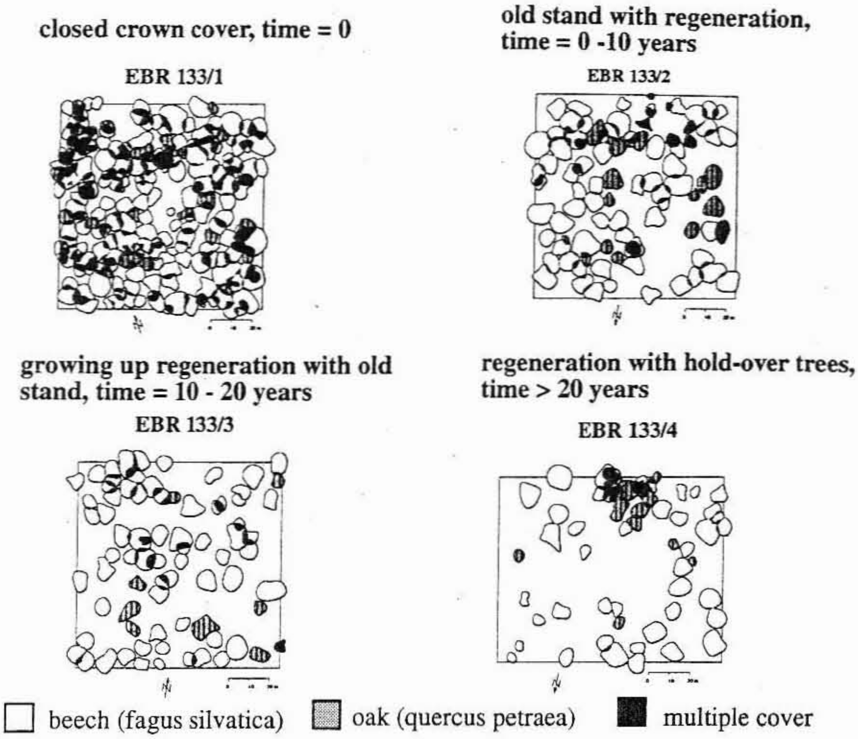

Figure 1: Part of the growth series Ebrach 133, plot 1 - 4 in beech stands with different scales of crown cover.

METHODS

The complete measurement of the old stand and the regeneration (fig. 2) is the database for the analyses.

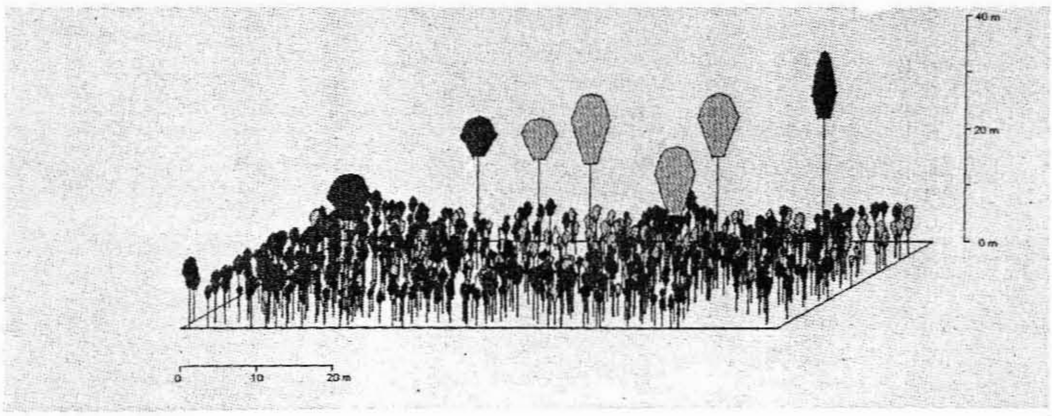

Figure 2: Structure of the plot Ebrach 133/7 in a 80m x 15m section, the plot is in the phase of growing up regeneration with old stand.

For analyzing the regeneration the whole plots were partitioned into 2.5 m squares to get local information about the regeneration. On each quad the number of trees per species and damages were registrated. Related to the highest tree per quad all trees which have reached at least 80% of the height of the top-height tree were additionally measured, species, dbh, height and quality were assessed.

RESULTS

We collected data from more than 6000 quads (2.5 m squares) of regeneration and from over 1500 beech, oak and pine trees of the old stand.

We got three different levels of information: ad first descriptive statistics to show the distribution of characteristically features, at second comparing two surveys to analyse the stand development and at third a database to design models for simulating the development of regeneration under crown cover.

Descriptive statistics

One example is the structure of height in the regeneration. On the one hand we get local information for each quad (fig. 3). The variability of height in the regeneration can be described. If we assign the top height of each quad to a height class we get different proportions related to the regeneration interval. If we compare two surveys - in figure 3 from 1983 and 1993 - for one plot it is possible to show that with this methods of measurement structure in regeneration can be exactly recorded.

Stand dynamics

The comparison of two repeated assessments allows to describe the stand dynamics. The height increment on each quad gives a local information about the development of regeneration (fig. 4). The distribution of the height increment indicates the global development and the homogeneity in the regeneration.

The growth dynamics in the regeneration can be quantified. In figure 4 the development of maximum height in the regeneration of each quad is described for one plot. On about 50% of the quads regeneration was grown up more than 5 m during the last 10 years. This shows the growth dynamic in this stand with an average crown cover of the old stand from about 40%.

After describing regeneration we looked for dependencies between old stand and regeneration. In figure 5 the heights of oak and beech on the same quad are compared. If oak is higher than beech the height difference is greater than zero, if beech is higher than oak, the height difference is less than zero. This relations are plotted in dependence on the shading of the overstory. It is surprising, that oak, as a typical light demanding tree species, shows on these stands a height increment similar to beech, if the crown cover of the quad is less than 40%. Also in more shaded areas there is a hard competition between oak and beech and oak hasn't lost the struggle.

First linear models were tested, but it was not satisfying. We tried simple functions to start describing dependencies between influence factors (crown cover, starting height, density etc.). In calculations for regeneration under crown cover the standard error is often higher and the coefficient of correlation is often lower than in pure stands. Figure 6 shows in which relation to the factors starting height and scale of shading from the overstory, height in the regeneration is growing up.

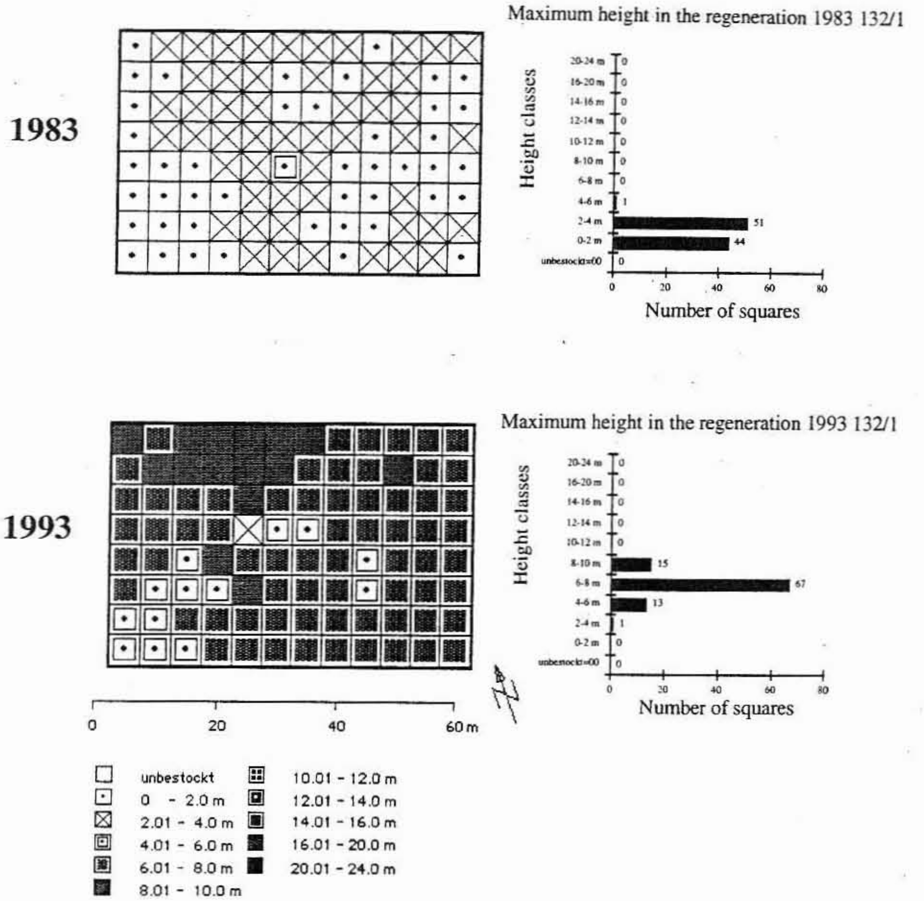

Figure 3: Structure of height for the plot Ebrach 132/1 (growing up regeneration with old stand). The maximum height for each quad (left) and the distribution of height for the whole plot (left) is illustrated.

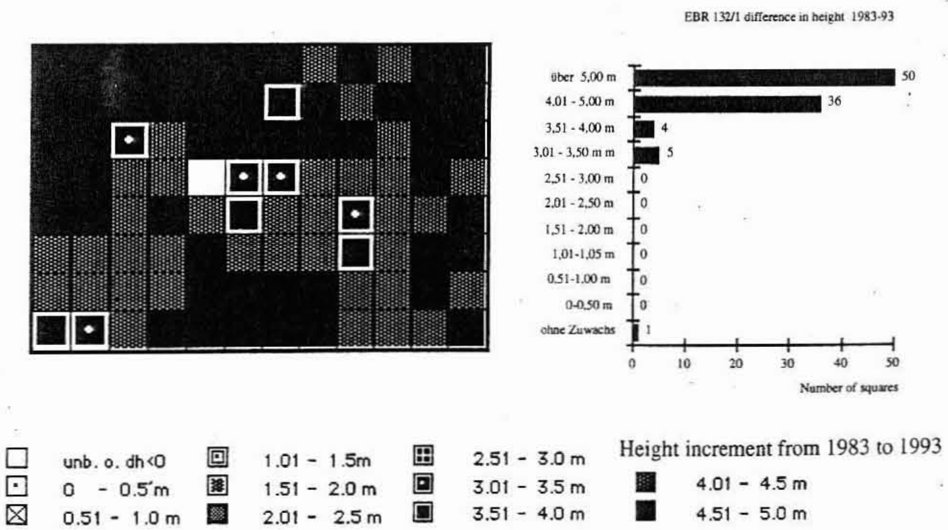

Figure 4: Dynamics of height growth in the regeneration, local height development (left) and the distribution of height increment for the whole plot (right).

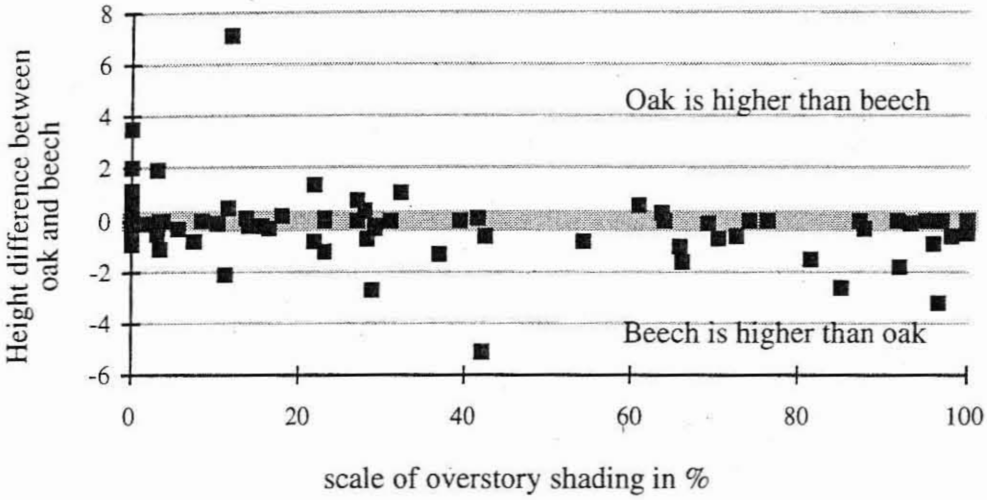

Figure 5: Height relations of oak and beech for each quad is shown in dependence on canopy density.

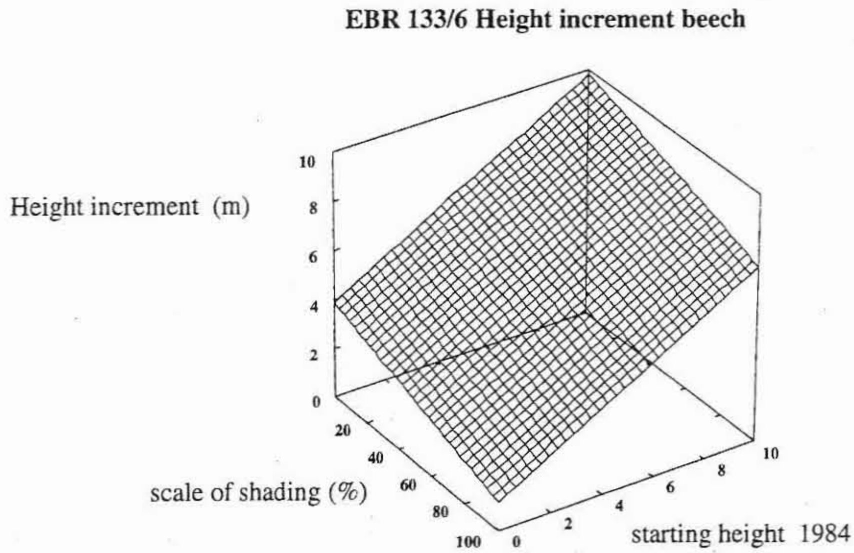

Figure 6: Graph of the regression: height increment = f(starting height and scale of shading) ($R^2 = 0.37$).

Modeling the development of regeneration

At the chair of Forest Yield Science in Munich the growth model SILVA 2 was developed by Pretzsch (1992, 1993). This model is a single tree distance dependent growth model for pure and mixed stands (fig. 7). We are very interested in launching a regeneration module to this growth simulator for the prognosis of more than one rotation period. I can only show the first steps in modeling the development of regeneration under crown cover.

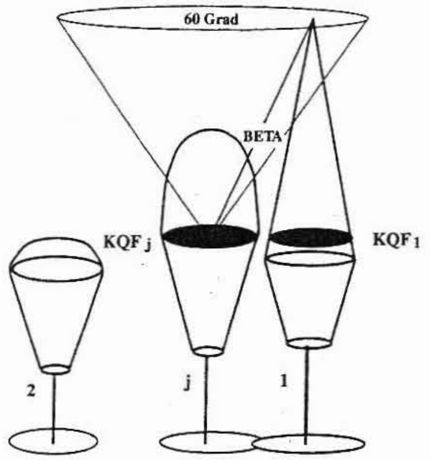

Figure 7: Definition of the crown competition index for light (see Pretzsch, 1992). The area of interference is defined by a cone of light for each tree.

In SILVA 2 the growth rate for each tree depends on three factors, the crown competition of light (CCL), the distance to the competing trees and the direction of competition. The factor CCL is defined as an area of interference described by a cone of light. The influence of the old stand on the regeneration is in this study also quantified by a cone of light, fixed in the centre of each quad in the regeneration. The factor CCL was calculated for all quads of a growth series in beech.

For modeling the height increment of regeneration, the growth differential equation of v. Bertalanffy (1) was used (from Kahn, 1994). Looking for causalities, this function provides for a first approach to interpret the growth reaction caused by the input factors.

$$\frac{dh}{dt} = \eta * h^{m} - \kappa * h \qquad (1)$$

h, k = constant of metabolism
= f(competition, canopy shading...?)

If we use the competition index CCL we can easily include the development of regeneration in our growth model. For one growth series in beech the index CCL was calculated for each quad. A model was formed (2) to explain the height increment (ZH) in dependence of CCL (KKL) and starting height in the year 1986 (HOS86).

$$ZH = (A + B * KKL)^{\frac{2}{3}} * HOS86 - (C + D * KKL) * HOS86 \qquad (2)$$

The results of the calculation you can see in table 1. We get a relative good fit to the data (R^2=0.49). In the plot (fig. 8) the reaction of height increment to increasing competition for light and starting height can be shown. Low regeneration is nearly independent on the density of crown cover, but as higher regeneration is growing up, the influence of crown cover becomes more and more important.

Table 1: Results of nonlinear regression with the function of v. Bertalanffy. Abbrevation: ZH=height increment, KKL=competition index, HOS86=starting height in 1986.

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DEPENDENT VARIABLE IS          ZH

ZH=(A+B*KKL)*HOS86^(2/3)-(C-D*KKL)*HOS86

   SOURCE    SUM-OF-SQUARES    DF   MEAN-SQUARE

 REGRESSION     5966.539740     4   1491.634935
   RESIDUAL      897.160497   626      1.433164

      TOTAL     6863.702800   630
  CORRECTED     1768.506150   629

      RAW R-SQUARED (1-RESIDUAL/TOTAL)          =       0.869289
CORRECTED R-SQUARED (1-RESIDUAL/CORRECTED)      =       0.492702


PARAMETER          ESTIMATE
       A           4.692725
       B          -0.000340
       C           1.681569
       D           0.001378
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The results shown in this paper are only a first step in describing and modeling regeneration, we must go on in this way. In addition to this aim we have to work out methods for description an reproduction of the horizontal distribution of the seedlings.

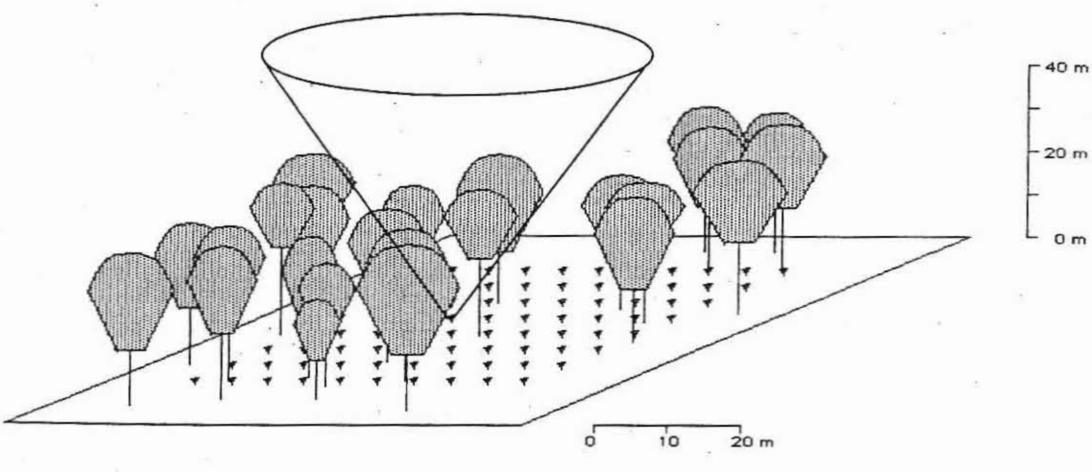

Figure 8: The influence of the old stand on the regeneration is quantified by a cone of light,fixed in the centre of each quad.

CONCLUSION

We have a lot of data out of the repeated assessments of the plots. They can be used for modeling the development of regeneration under crown cover. If we work with a competition index like it is used in the growth model SILVA2 we get a good approach to describe the effects of the old stand onto the regeneration. With the function of v. Bertalanffy we have a flexible instrument for modeling height growth in the regeneration.

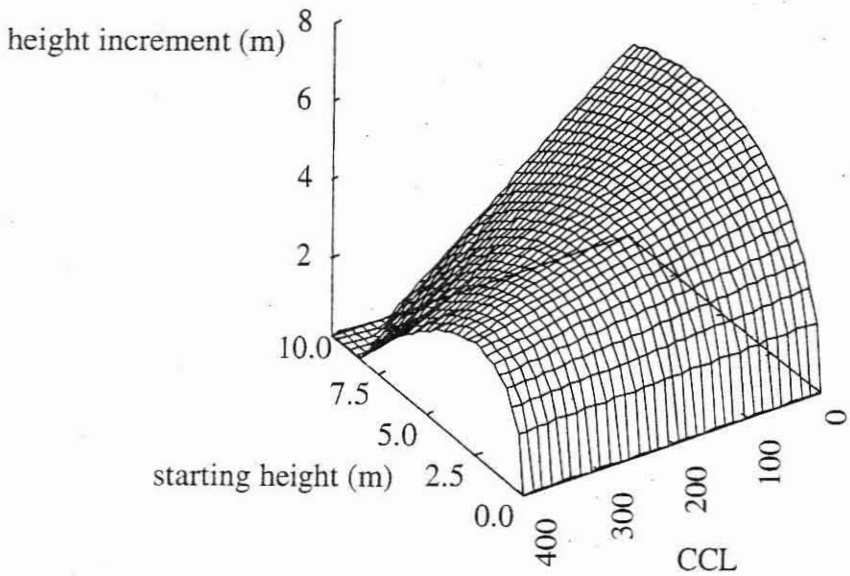

Figure 9: The function of v. Bertalanffy fitted to the data of a growth series in beech (Rothenbuch 634).

LITERATURE

Assmann, E. and Franz, F. 1963: Vorläufige Fichtenertragstafel für Bayern Institut für Ertragskunde der Forstlichen Forschungsanstalt München, 104 S.

Franz, F. 1987: Zum Aufbau eines neuzeitlichen Informationssystems für die Forstwirtschaft, Forstarchiv, 58. Jg., H. 4, S. 131-137.

Kahn, M. 1994: Modellierung der Höhenentwicklung ausgewählter Baumarten in Abhängigkeit vom Standort, Forstl. Forschungsberichte München Nr. 141, 221 Seiten.

Pretzsch, H. 1992: Konzeption und Konstruktion von Wuchsmodellen für Rein- und Mischbestände Forstl. Forschungsberichte München .Nr. 115, 358 Seiten.

Pretzch, H. 1993: Analyse und Reproduktion räumlicher Bestandesstrukturen, Versuche mit dem Strukturgenerator Strugen, Schriften aus der forstl. Fakultät der Universität Göttingen und der Niedersächsischen Forstlichen Versuchsanstalt, Band 114, 87 S., J.D. Sauerländer's Verlag.

Wiedemann, E. 1949: Ertragstafeln der wichtigen Holzarten bei verschiedener Durchforstung, Schaper, Hannover, 100 S.