A grammar based model for juvenile Scots pines as an aggregation of LIGNUM

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Introduction

The idea was to create an individual based model which simulates the growth of trees in the understorey of a gap as an aggregation of LIGNUM (Perttunen et al.1998). The new model is implemented with an L-system. The aggregation is obtained by using individuals with simplified crown structures as in Pretzsch (1992a). That means that the tree crown is represented by an irregular pyramid with eight corners. This method is often used in tree stand simulation tools for predicting tree growth (cf. Nagel et al. 2000 and Pretzsch 2000). The LIGNUM-canopy version is used in simulation runs for trees in the understorey of a gap. The results of the simulation of juvenile trees are aggregated and integrated into the new model which is implemented using L-systems similar to the approach of Prusinkiewicz et al. (2001). For implementing and interpreting the L-systems the software GROGRA (Kurth 1999, Kurth and Sloboda 1999) is used.

Aggregation of the light model

In the simulation runs the canopy version of LIGNUM is used. LIGNUM-canopy simulates a juvenile tree and its behaviour under a light regime which is influenced by a gap, using a detailed radiation model. GROGRA uses a hemispherical covering ratio between the maximum number of sky sectors and the actual number of sky sectors which are not shaded by another segment (CR), thus making a much simpler and more efficient calculation. Another version of the function additionally weights the shaded sector with sin(phi) where phi is the inclination angle of the incoming radiation (WCR).

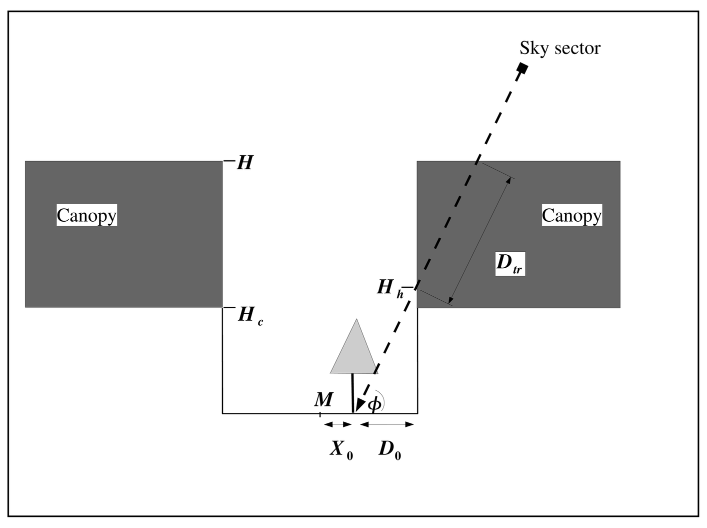

Fig. 1: The figure shows the representation and calculation of the light reduction which is caused by a Scots pine roof in LIGNUM-canopy. H = height, Hc=crown base, D=travel distance through canopy, Hh intersection height, X0 = distance from the gap centre (M), D0 = distance to the edge of the gap.

$$RAD = \frac{\sum PAR_i}{PAR_{tot}}$$

$$CR = 1 - \frac{\sum CR_i}{CR_{tot}}$$

$$WCR = 1 - \frac{\sum \sin(\phi_i) \cdot CR_i}{\sum \sin(\phi_i)}$$

Fig. 2: Calculation of both covering ratios. RAD = radiation income, CR = covering ratio, WCR = weighted covering ratio.

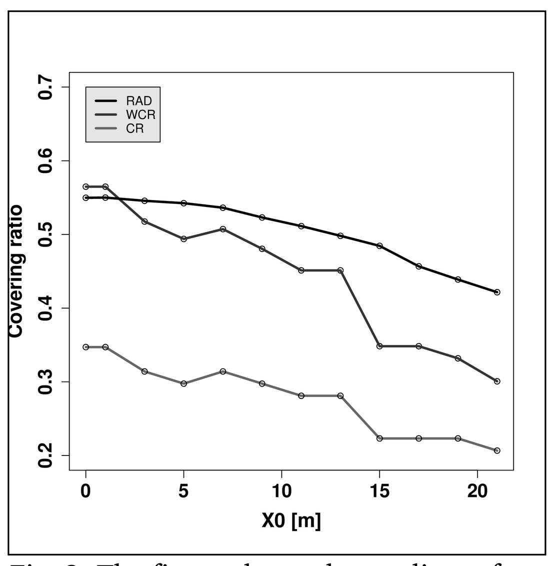

Fig. 3: The figure shows the gradient of RAD, CR and WCR along the radius of a gap with a radius of 20m. X0 = gap radius.

Aggregation of the LIGNUM tree

Within the gap the incoming radiation depends on the distance of the tree to the centre of the gap. The closer the tree is to the edge the smaller is the incoming radiation. The parameters height, height of the crown base, diameter and mean crown extension are investigated in relation to that distance. All parameters - except the crown base - can be approximated using linear regressions with age and distance as independent variables.

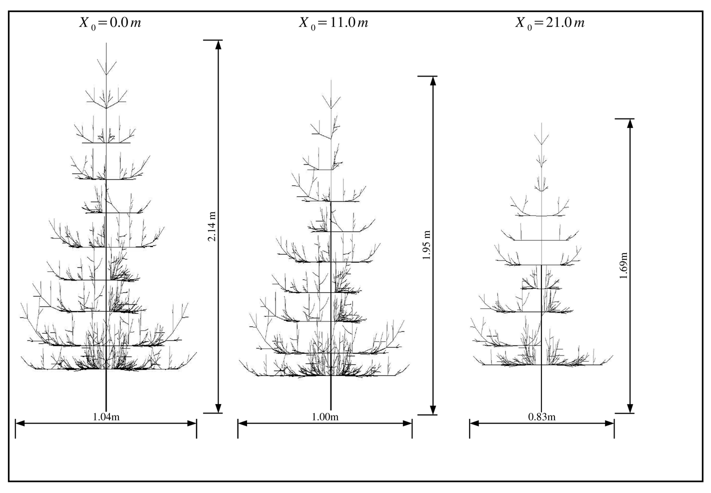

Fig. 4: The simulation result. Each tree is grown under a different light regime caused by different positions in a gap (see Dzierzon 2003).

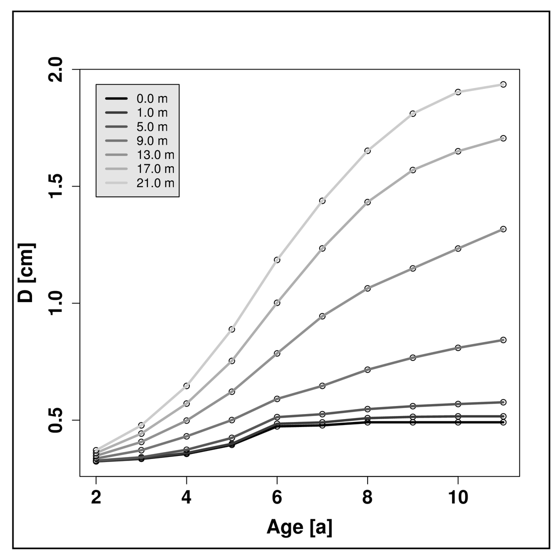

Fig. 5: The parametrization of tree growth which was used for aggregating the results of the complex model. The figure shows exemplarily the gradient of tree diameter (D) growth in relation to the position within the gap under the canopy (see Dzierzon 2003).

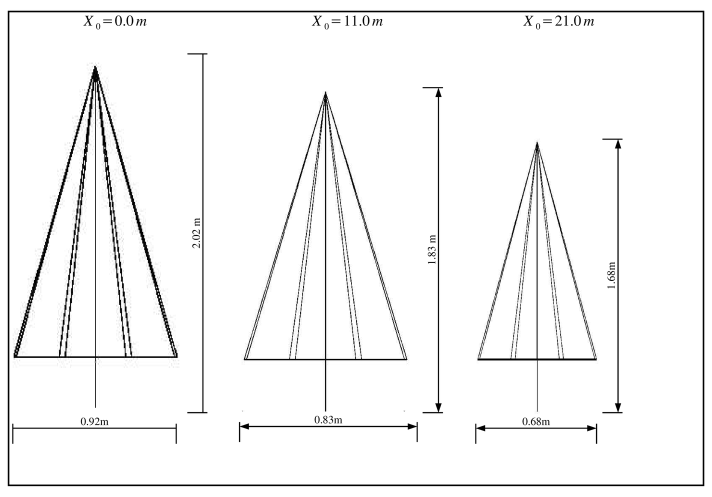

Fig. 6: The result of the aggregation process. The trees vary in relation to the position (X0) within the gap. The picture shows results from the L-System.

Results

The aggregation of the light model strongly differed between CR and WCR. Both are very differerent to the original RAD ratio. Compared to CR the WCR reacted more sensitive. The aggregation of the tree growth showed good relations between the parameters height, diameter and crown extension and light income represented by the covering ratio. The crown base behaved quite differently. It jumped after five years, hence there did not exist a correlation between crown base and the covering ratios.

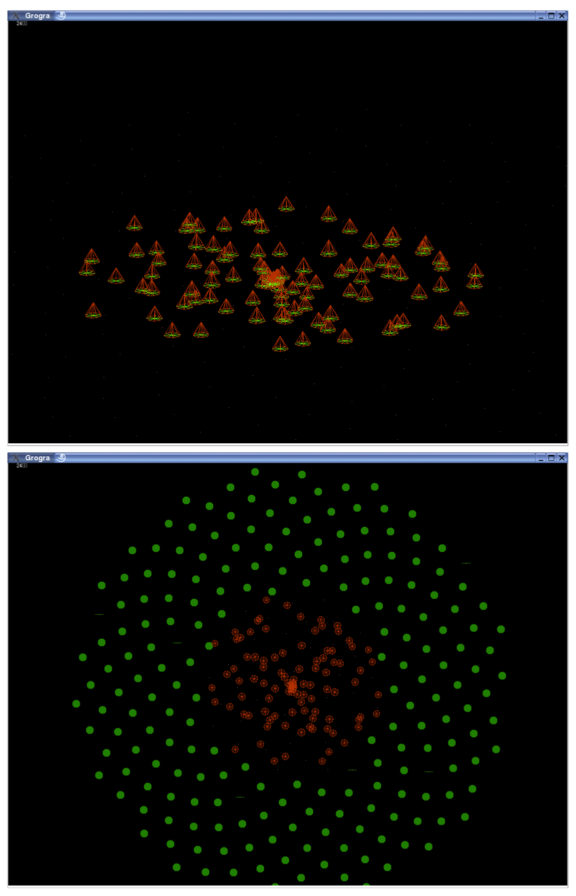

Fig. 7: The result after 24 time steps which is equivalent to 11 years. The result is visualized by the software GROGRA (Kurth 1999).

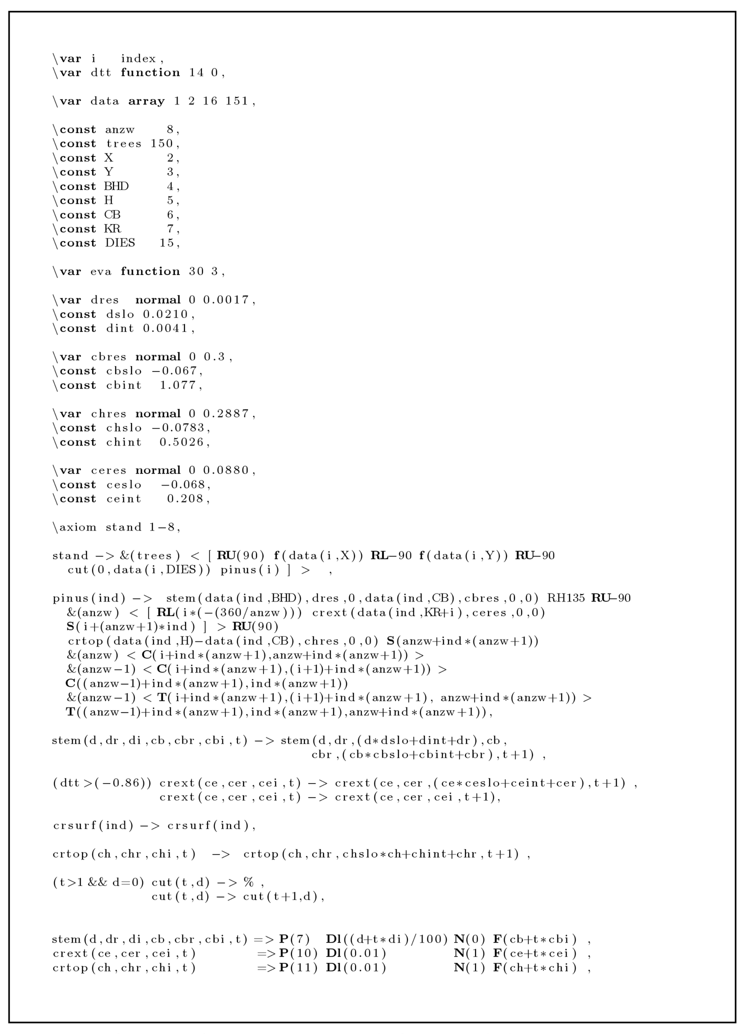

Fig. 8: The implementation of the model as an L-System. This L-system creates a representation of the aged stand (symbol palis) with the gap and 100 young Scots pine trees (symbol tree) growing in the gap. The surface of the crowns is represented by triangles. The light model referred to by the sensitive function 15 which is implemented as a procedural function (in C) in an extra file. The regularly-spacced objects in the lower picture mimick the surrounding aged stand.

Conclusions

A final assessment of the question if the simulation of juvenile trees was successful is not possible because the data for a quantitative validation are missing. However, the comparison between the model results showed no differences between the results and the resulting values of the aggregated version. In the whole view the aggregation was successful.

Even a correction factor could not avoid differences between the covering ratios. The gradient of the version using WCR is steeper. This results in smaller dimensions of all parameters in the aggregated version of the LIGNUM trees. A solution would be the integration of the more detailed light model from LIGNUM into the L-system specification of GROGRA.

The use of a rule based programming language in the form of the GROGRA L-systems specification extremely increased the transparency of the implementation work of modelling tree stands. It provides a transparency which cannot be provided by procedural or object oriented programming languages. The L-system contains 16 rules and 73 programming code lines.

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