4.3 Description of PrognAus for Windows 2.2

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Abstract. Users of forest growth simulators are often faced with specific problems requiring a growth simulator with specific capabilities. Because of the great variety among the existing growth simulators, it is not always an easy endeavour to find an appropriate one. In this situation a standardised description is very helpful. The description of the growth simulator PrognAus for Windows 2.2 follows the recommendations of the German Association of Forest Research Institutions for the standardised documentation and further development of forest growth simulators. It should facilitate the comparison of various growth simulators and help potential users to find the appropriate simulator for their specific needs.

4.3.1 Model Approach

The growth simulator PrognAus for Windows 2.2 is based upon the implementation of the individual-tree growth model PrognAus (*Prognosis for Austria*) which is comprised of a distance-independent individual-tree basal area increment model (Monserud and Sterba 1996; Hasenauer 2000), an individual-tree height increment model (Schieler 1997), an individual-tree mortality model (Monserud and Sterba 1999), and an ingrowth model for trees exceeding the 5-cm diameter at breast height (DBH) threshold (Ledermann 2002a). Treatments, i.e. thinning and harvesting, are based on tree species, DBH classes, and tree attributes. The growth models are independent of age and predict the increment directly, i.e. they do not follow the potential growth concept. Site factors such as elevation, slope and aspect, depth of soil and humus horizons, relief, soil moisture class, soil and vegetation type are included in the growth equations as continuous and dummy variables. Figure 4.4 represents a flow chart which graphically shows the conceptual framework of the simulator and its components. *Configurations* depend on the data set and should only be changed if the data set changes. *Options* can be changed before/after each simulation run.

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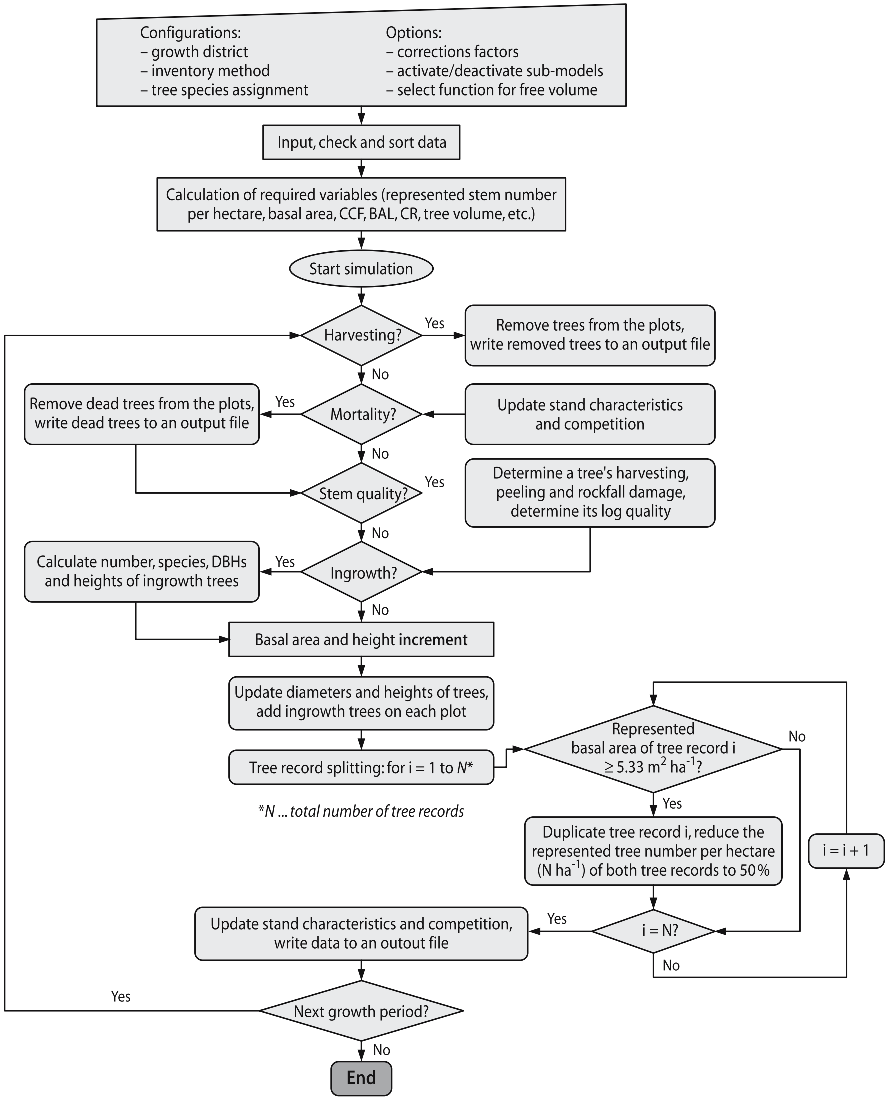

Fig. 4.4. Flow chart of the individual-tree growth simulator PrognAus for Windows 2.2

4.3.2 Range of Application

The individual-tree growth simulator PrognAus for Windows 2.2 can be used to evaluate silvicultural treatment scenarios, and for making forecasts of forest stands and forest inventories, respectively. It is used for research and to determine the annual allowable cut for forest enterprises.

4.3.3 Validity

All sub-models of the simulator were developed from data of the Austrian National Forest Inventory (ANFI). Thus, the validity of the simulator refers to the whole forested territory of Austria. The simulator can be applied to even- and uneven-aged mixed stands of common Austrian tree species, and to all types of commercial and pre-commercial thinnings and harvesting strategies as represented in the data of the ANFI. The input data are limited to trees larger than or equal to 5 cm in DBH (1.3 m); a maximum DBH was not defined.

4.3.4 Input

The input data are independent of area shape and size, and must be provided in an ASCII file or in an MS ACCESS database. Missing information must be generated outside the growth simulator. The number of tree records is not limited, but is rather determined by the computer's available RAM. The requirements for the input data are according to the instructions of the ANFI (Forstliche Bundesversuchsanstalt 1981).

4.3.5 Program Control

The individual-tree growth simulator PrognAus for Windows 2.2 provides an interactive program mode and a semi-batch mode. Furthermore, it is designed for interactive and algorithmic stand treatment referring to DBH classes, tree species, and tree attributes. Both the basal area increment model and the height increment model can be modified by a multiplier; an external change of the actual model coefficients can be done in an ASCII file. Changing the equations is not possible. The simulator provides the opportunity to save interim results; the continuation based on these interim results is possible.

4.3.6 Output

The output of the simulator comprises tree lists of remaining, harvested, and dead trees for each 5-year period. All tree lists can be exported to an MS ACCESS database. For a given stratum, the simulator also provides the development of several stand characteristics such as volume per hectare, stem number per hectare, basal area per hectare, annual increment, harvesting and mortality, quadratic mean diameter, mean height (Lorey), mean tree volume and mean height/diameter ratio, and, finally, the development of the quadratic mean diameter and mean tree volume of the harvested trees. All these characteristics can be obtained at the forest enterprise level or any other substratum (e.g. age class, management district). Structural characteristics at stand or forest enterprise level are limited to distributions of DBHs, species, and tree attributes. Economic parameters in terms of commercial assortments with regard to log size and log quality classes, costs of harvesting (felling + skidding), and the contribution margin (CM, revenue minus costs) are also provided by the simulator. The visualisation features are limited to charts of DBH, species, and tree attributedistributions, and to charts presenting the development of stand characteristics.

4.3.7 Growth Model

Data for estimating model coefficients were available from the ANFI comprising more than 30,000 sample trees. The log-linear basal area increment model was developed by Monserud and Sterba (1996) and Hasenauer (2000):

$ln(BAI_5)=f\,(DBH, CR, BAL, CCF,$ elevation, slope, aspect, thickness of *F*-humus and *H*-humus horizon, soil depth, relief, soil moisture, vegetation type, soil type, growth district)

where

BAI_5	basal area increment of a 5-year period;
DBH	diameter at breast height;
H	total height;
CR	crown ratio;
BAL	basal area in larger trees (Wykoff 1990);
CCF	crown competition factor (Krajicek et al. 1961);
F-humus	semidecomposed, fragmented organic matter and humus;
H-humus	amorphous organic matter without mineral material.

The height increment model by Schieler (1997) is a simple linear model:

$$ih_{11}=f\,(DBH, H, id_{11})$$

where ih_{11} is the height increment of an 11-year period and id_{11} is the DBH increment of an 11-year period.

The simulator contains a static crown ratio model (Hasenauer and Monserud 1996):

$CR=f\,(DBH, H, BAL, CCF,$ elevation, slope, aspect)

and a mortality model (Monserud and Sterba 1999):

$$P_5=f\,(DBH, CR, BAL)$$

where *P5* is the mortality rate of a 5-year period.

In order to estimate the number, dimensions, and species of those trees that exceed the DBH threshold of 5 cm during a 5-year growth period, the simulator contains an ingrowth model (Ledermann 2002a) which on its own part comprises the following five sub-models:

$P_{Ing} = f$ (*QMD, BA, CCF, J1, J2, MAS,* elevation, slope, vegetation type, soil type, growth district)

$ln(N) = f$ (*QMD, BA, CCF, J2, MAS,* elevation, slope, aspect, growth district)

$P_{Spec} = f$ (*Spec, BA, CCF, MAS,* elevation, slope, aspect, soil moisture, soil type, growth district)

$DBH = f\ (N, BA)$

$H = f$ (*Spec, QMD, BA, CCF,* elevation, relief)

where

PIng	probability of ingrowth on a plot;
N	number of ingrowth trees on a plot (radius = 2.6 m);
P_{Spec}	probability of a specific tree species;
DBH, H	DBH and height of an ingrowth tree;
QMD	quadratic mean diameter;
BA	basal area per hectare
J1, J2	dummy variables for a specific development stage being present or absent on the plot;
MAS	management system (coppice forest, high forest, or protection forest);
Spec	dummy variable for a given tree species being present or absent on the plot.

Effects of thinning or harvesting are represented by parameters describing density and competition (CCF and BAL). Depending on the user's choice, the basal area increment model, the height increment model, the mortality model, and the ingrowth model can operate either deterministically or stochastically. All models are statistically fitted models. For estimating model coefficients simultaneous regression techniques and ordinary least square methods were used. Coefficients of probabilistic models were estimated by logistic regression using maximum likelihood methods. Both regression techniques and maximum likelihood methods were provided by SAS (SAS Institute 1989).

4.3.8 Additional Algorithms

Timber grading is based on the assortment tables according to Sterba et al. (1986) and Eckmüllner and Sterba (2002). Furthermore, the individual-tree growth simulator PrognAus for Windows 2.2 contains new models (Vospernik 2004) that allow timber grading in terms of log quality classes A, B, and C according to the Austrian national assortment guidelines (A stands for good quality, B medium quality, and C bad quality). Other algorithms refer to interactive or algorithmic stand treatments. The interactive stand treatment mode is based on species, tree attributes, and DBH classes, the width and the number (maximum 20) of which can be determined by the user. The algorithmic stand treatment mode comprises the following algorithms (Söderbergh and Ledermann 2003):

- removal percentages in defined DBH classes;
- target DBH;
- equilibrium curve;
- LOGIT models for tree removal;
- tree numbers.

In addition to these thinning/harvesting algorithms a snow breakage model is implemented in order to simulate salvage cutting. PrognAus can process both inventory data and data from entire stands. However, data from small plots lead to a differing resolution of the competition variable basal-area-in-larger trees (BAL) during a simulation run. Therefore, a special algorithm (Ledermann and Eckmüllner 2004) is implemented to avoid biased predictions of stand development.

4.3.9 Model Precision

Specifications regarding precision, bias and accuracy can be found in the following references: Monserud and Sterba (1996, 1999), Sterba and Monserud (1996, 1997), Schieler (1997), Sterba (1999), Hasenauer (2000), Sterba et al. (2001), and Ledermann (2002a).

4.3.10 Software and Hardware

The current version of the individual-tree growth simulator PrognAus for Windows 2.2 was released in January 2004. It was programmed in Visual Basic 6.0. An IBM-compatible PC with MS Windows 95/98-XP is required in order to run the simulator; a 300 MHz CPU and 64 MB RAM are recommended.

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4.4 The Individual-Tree-Based Stand Simulator SILVA

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Abstract. The forest growth simulator SILVA is single-tree based, tree-position-dependent and age-independent. The model's core algorithm evaluates the three-dimensional structure of forest stands in order to determine inter-tree competition. SILVA is parameterised with a large amount of data from long-term research plots in pure and mixed species forests, mainly from southern Germany. SILVA covers the tree species Norway spruce, Scots pine, silver fir, Douglas fir, common beech and oak. It includes a regeneration submodel and modules for conducting and visualising large regional scenario analyses based on inventory data.

4.4.1 Introduction

Since 1989, the Forest Growth Simulator SILVA has been developed at the Chair of Forest Yield Science, Munich, Germany, as an applicable tool for management, research and educational purposes (e.g. Pretzsch 1992, 2001). In this distance-dependent individual-tree approach a stand is regarded as a three-dimensional system of single trees influencing each other mutually. This approach permits the simulation of the development even of complex structured even- and uneven-aged pure and mixed stands, which is not possible by conventional means. As defined by its parameterisation data, SILVA is reliable for most German site conditions, par-

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