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Integration of the Forest Growth Simulator SILVA in Practical Forest Management

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Abstract

Forest growth is a dynamic system depending on different conditions. In forestry science growth models like SILVA are used to research system feedbacks. Possible applications for forest growth simulators are the optimisation of silvicultural management strategies, calculation of climate change impacts, landscape visualization, and the prognoses for sustainability of growing stock and economic sustainability. SILVA3 is designed as a platform-independent client-server-architecture embedding connections to different data sources like forest inventory data bases. The benefit of integrating SILVA in forest planning processes is shown in a case study.

1. Introduction

Forest stands are dynamic systems governed by pronounced feedback effects. Forestry managers take advantage of these responses by carrying out thinnings, in order to achieve revenue and to enhance the development of the remaining stand. From a system-theoretical aspect these measures must, however, be considered an external kind of interference, which in turn leads to the question of the system limits. Forest growth simulators like SILVA can model those feedback effects and system limits and are proven to be a very effective tool for simulating the dynamic response of forests to a large variety of management scenarios. A comprehensive forest ecosystem management oriented to the principles of stability and sustainability and taking equally into account the forests' economic and social effects and benefits, there is still a great lack in necessary and fundamental information. This information gap can be closed by usage and processing of forest inventory data.

2. Forest Growth Simulator SILVA

The Forest Growth Simulator SILVA has been developed since 1989 under the guidance of Prof. Dr. Hans Pretzsch at the Chair of Forest Yield Science at Technische Universität München, Germany. In the distance-depending individual-tree approach a forest stand is regarded as a 3-dimensional system of single trees influencing each other mutually (Pretzsch, 2001; 2002). The site-growth-model is able to simulate forest growth depending on different site factors. The user has the choice of different alternatives of stand treatment regarding thinning concepts, intensities and intervals. Their effects on stand dynamics can be simulated in time steps of five years up to the maximum of 145 years. During the simulation height and diameter increment, crown dimensions, and tree mortality are calculated for every individual tree depending on site and competition. The results are split in three groups, covering timber production, economical and structural characteristics.

The growth model is used in different ways:

- Optimisation of silvicultural management strategies

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- Prognoses for sustainability of growing stock, assortment and economic sustainability (Pretzsch, 2005)
- Impacts of Climate Change and the selection of tree species
- Landscape visualization (Pretzsch & Seifert, 2000)
- Evaluation of ecological effects with structure and genetic diversity indices (Pretzsch, 2003a; Röder et al., 2005)
- Decision support system in forest and landscape management, for education of students, foresters and landscape managers, and for scientific purposes (Pretzsch 2003b)

The model functions of SILVA are based on statistical analysis of a very extensive data base, covering the tree species Norway Spruce (Picea abies), Silver Fir (Abies alba), Scots Pine (Pinus sylvestris), Douglas Fir (Pseudotsuga menziesii), Common Beech (Fagus sylvatica), Sessile Oak (Quercus petraea) and Black Alder (Alnus glutinosa). While the parameterisation is suitable for central European conditions, SILVA is used in Denmark, Switzerland, Germany, Slovak and Czech Republic.

3. SILVA software architecture

Due to experiences in the practical use of SILVA, the software is permanently in development. An analysis of the former SILVA version, which was developed as stand-alone application in Delphi, lead to a totally revision of the source code and to a re-design of the software architecture. The new architecture should ensure a flexible extensibility and adjustment on the practical and scientifically workflows. The following demands were defined (Seifert et al., 2005):

1. Modularity

With the aim of an efficient modular software system it should be able to combine the different programme elements. This allows the simple configuration of specific calculations for economical and ecological questions, while the maintenance of the basic programme components is very easy.

2. Platform-independent Client-Server-Application

The separation of server and client increases the availability, scalability, security and flexibility of the technical software solution (Haas & Schreiner, 2002).

3. Integration of analysis and prognosis in one technical solution

Users highly demanded for standardized analysis in forestry practice, for example in the line of medium-term forest company planning, as well as a prognosis tool in one software solution. The purpose of the integration of analysis and prognosis in the same application is the straight flow of data and information and the compability of the mathematically functions in analysis and prognosis.

4. Flexible connection to different data sources

In the course of the further development connections to different data sources like forest inventory data bases, forest trial plot data bases and geographical datasets should easily be integrated.

5. High user-friendliness and easy learnablity

An expert graphical user interface, which allows the flexible input of settings, was developed for experienced users like scientists. For basic users like forest practitioner and students a discrete user interface was designed, preventing them from the total complexity of the growth model.

The centre of the technical concept of SILVA 3 (Figure 1) is a server application, which is developed in C++. It is responsible for the calculations, while the client acts as graphical user interface. The communication between server and one or more clients are done by an integrated SOAP interface. The graphical user interfaces, both the expert and the basic mode, are developed in Java, which allows different operating systems for server and client. The expert GUI is a composition of icons, symbolizing different work flow operations like import of data, stratification of forest stands, calculations and presentation of the results. The user can define the arrangement and the combination of the icons according to the specific analysis or prognosis demands. This work flow with all settings can be saved as so-called “user object” and then re-used for comparing investigations. The basic GUI uses such standardized user objects.

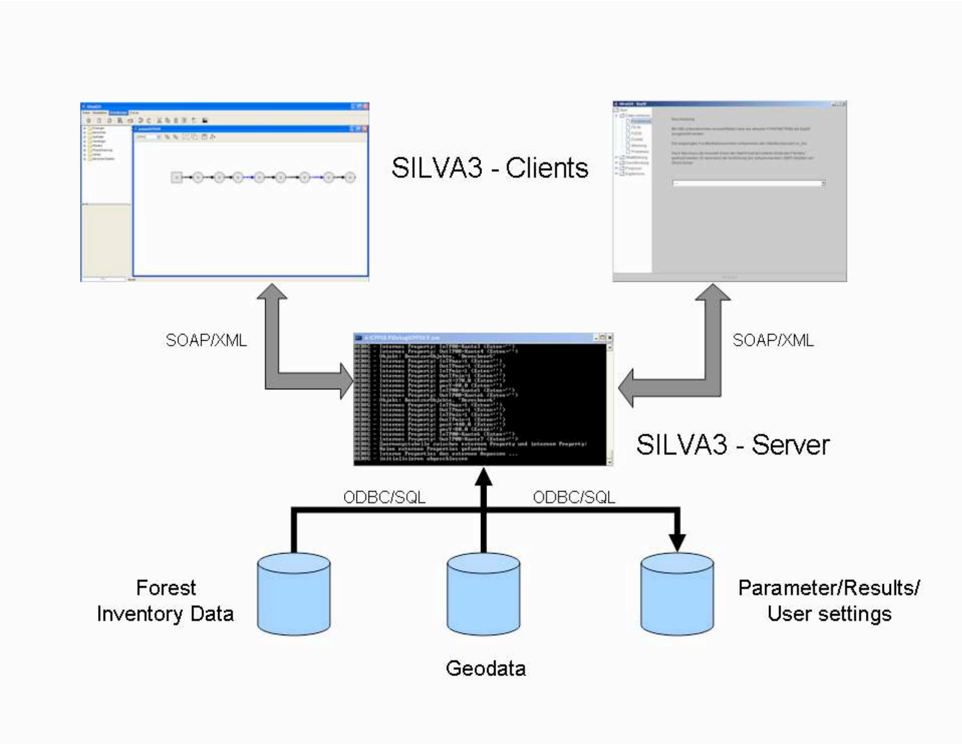

Figure 1: SILVA 3 software architecture

Connections to databases are possible by the utilisation of the Oracle, ODBC and DB2-CLI Template Library[2], geodata can be imported and analysed with the aim of the Geospatial Data Abstraction Library[3], a widespread library in the geospatial open source scene. Furthermore a WebGIS application with the UMN MapServer[4] for selection of forest stands or inventory plots and presentation of analysis results with interactive maps is realized.

[2] http://otl.sourceforge.net/
[3] http://www.gdal.org
[4] http://mapserver.gis.umn.edu/

4. Processing inventory data

The information potential of expensive forest inventories based on a raster sample design by far is not yet deployed for planning and controlling of forest enterprises. Combining a forest inventory data base with the growth simulator SILVA ensures the best possible use of inventory information for silvicultural planning and sustainable resource management. The concept of using inventory data for planning contains the following steps:

- Data import

Initially, there are inventory data from raster sample plots which may be used for decisions on stand, enterprise or superior regional levels. These data a stored in a data base which contains stand state characteristics, site information like geomorphology and soil as they are needed as an input for SILVA.

- Clustering

By aggregating the inventory data to particular stand and site units and passing respective initial characteristics of the classified enterprise units to drive the growth model SILVA may be used to simulate the forest development within these enterprise units.

- Thinning concept

Different treatment alternatives and management strategies may be tested and optimised.

- Prognosis

Depending on the demands the state of single inventory plots, the forest development within particular stand or enterprise units, or the development of a total enterprise may be simulated with the model.

- Results

Results of respective simulation runs may also be stored in the data base. Possible treatment actions and predicted development referring to the classified enterprise units give a practical decision support and form an important basis for planning.

In either case, with this concept it is possible to make inventory data available to silvicultural decision-makers, because the data may be processed by a growth model and applied to scenario analyses and development predictions.

5. Case Study

As already mentioned SILVA is the denomination for a distance dependent single tree forest growth simulator which has been developed within the last two decades. The latest development efforts lead in a software solution which is called SILVA3 in which the growth driving functions are equivalent with the ancestor SILVA 2.2, but which is technically completely different as described before.

SILVA3 is especially developed for the use in forest management for operational and strategic planning. For operational purposes management plans or timber production prognosis can be derived for single stands, forest enterprises and landscape units (Pretzsch et al., 1998). In general, this is executed on a short or medium-term perspective. In strategic planning, which normally covers long term periods, Silva helps to develop management guidelines for certain tree species or stand types under particular site conditions (Pretzsch et al., 2002).

Because of the advances in technical development and software ergonomics SILVA3 is in demand by numerous forest enterprises which vary in size, staff and economic and ecologic aims. They have in common that their managers are convinced that the use of modern forest planning instruments is necessary to show the effects of their silvicultural efforts. For them the use of modern, reliable planning instruments, which can show them the consequences of planned silivcultural activity before realization, is synonymic with a guaranty for sustainability.

In the following section a case study for the application of SILVA in practical forestry is given. This first example shows the use of SILVA on forest estate level. This study was done for the former Bayerische Staatsforstverwaltung, which was one of the biggest forest landowners in Central Europe. (Since, 2005 the state forest area in Bavaria is managed by a commercial enterprise called Bayerische Staatsforsten, which is completely under possession of the government of Bavaria). Within this study a scenario analysis for the former Forstamt Starnberg with SILVA was done with the aim of validating the natural usage quotas to ensure the sustainability on forest estate level. Forstamt Starnberg was a forest estate 30 km in the south of Munich in Bavaria with a size of 3498,16 ha.

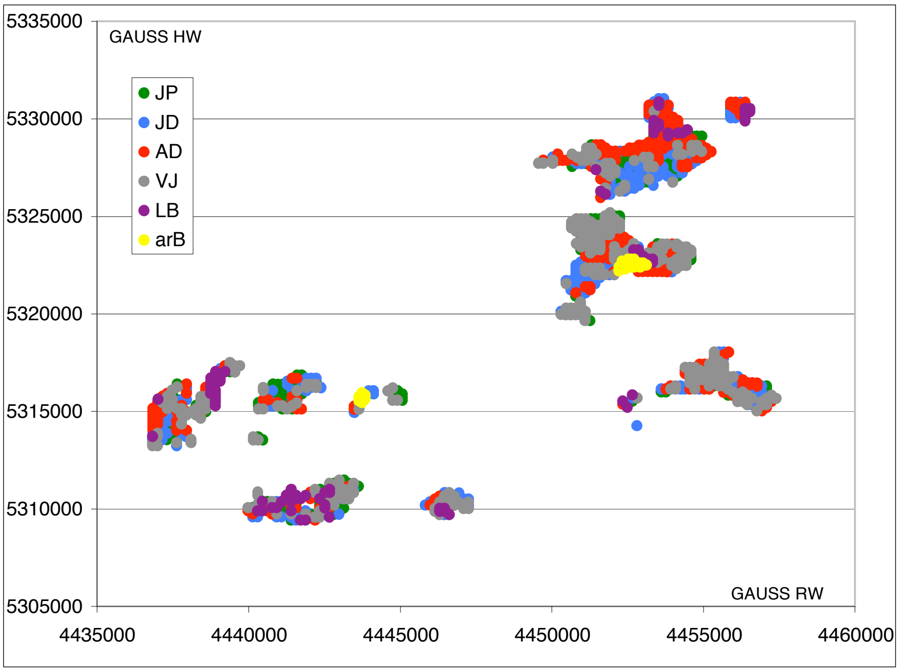

Figure 2: Geographical distribution of forest sample plots in Forstamt Starnberg. The different colours show the different treatment units (“Nutzungsarten”) assigned to each plot in stand wise planning process within forest planning campaigns in Bavaria.

Forest management planning in Bavaria is a process which is basically subdivided into two steps. The first step is a forest inventory in which permanent or temporary installed sample plots are measured. In the second step, based on the analysis of the preliminary forest inventory, a stand wise planning process follows, in which forest planning experts assess the coming treatment and the potential of harvesting volume stand wise.

The introduced case study for Forstamt Starnberg was done after the stand wise planning process. The main question of the forest planning experts was, if the calculated usage quota of 36000 Efm/ ha/ year would enables a sustainable usage within the next years and decades. This question came up because the in forest inventory process calculated increment of volume (so-called “ertragsgeschichtlicher Zuwachs”) only laid by 9,9 Efm/ ha/ year. The calculation of increment of growth by comparison of yield table values led to a calculated increment of growth of 10,8 Efm/ ha/ year. Both values open a possible usage range between 34631,78 Efm/ ha/ year and 37780,13 Efm/ ha/ year. Because of changing growth conditions yield tables are nowadays no longer as reliable as in former times and partly no longer accepted by forest experts or authorities. This was the reason to calculate additional with a modern, reliable planning tool a third possible usage quota to ensure the natural planning results by forest experts.

To check if a usage quota of 36.000 Efm/ ha/ year would also enable a sustainable forest usage the forest inventory data of Forstamt Starnberg was stratified by aggregating the inventory plots of comparable stands with a comparable structure and growth behaviour. Forest stands with such properties are grouped within so-called "Nutzungsarten" which is an indication for forest experts how to treat these kind of stands. Figure 2 shows the geographic distribution of inventory plots on this so-called Nutzungsarten. For the Nutzungsart JD, which characterizes young stands where especially elite trees were selected and assisted by silvicultural treatment, for mainly broadleaved, coniferous and completely mixed stands subdivisions of strata were assigned. The same thing was done for the stands in Nutzungsart AD, in which the preliminary already promoted trees can develop big crowns and mature. In this way 11 strata (c.f. table 1) were assigned. For this strata SILVA scenario analysis were done. For each strata three variants were assigned. The first variant was a so-called "Nullvariante" which shows what would happen if no silvicultural usage would be done within the coming decades. The second variant is called "Planungsvariante" which shows the results of the real forest planning of forest experts. The third variant is the so-called "Extremvariante" which is defined by a maximum imaginable silivcultural treatment in each strata.

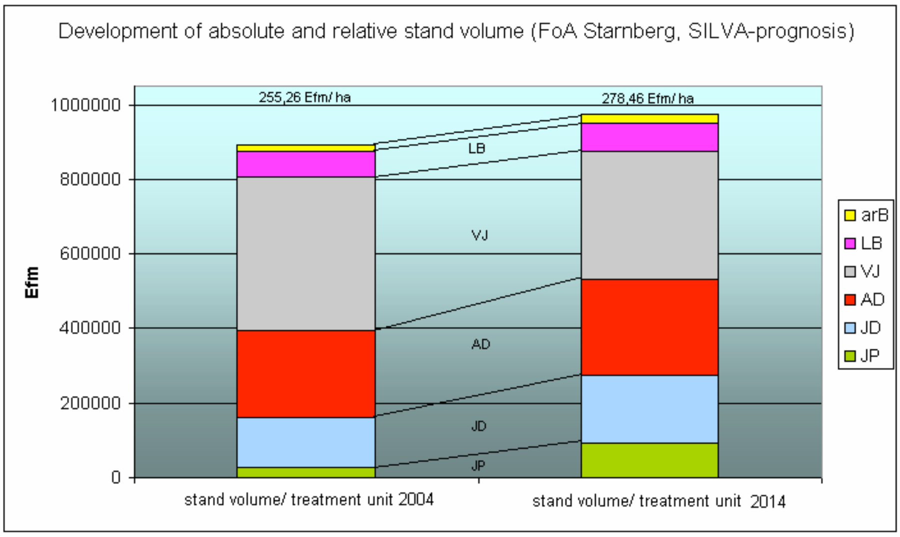

Figure 3: Development of stand volume (absolute and relative) in forest estate Forstamt Starnberg within the next 10 years according to a SILVA-prognosis for the real planned treatment ("Planungsvariante")

The results of the SILVA scenario analysis were aggregated on various levels. Table 1 shows the forecasted increment of volume within the whole Forstamt Starnberg for the so-called planning variants. The bolded number in last row shows that by SILVA an average increment of volume of about 11,9 Efm/ ha/ year is forecasted. This increment of volume leads to an accumulation of stand volume per hectare from 255 Efm/ ha/ year to 278 Efm/ ha/ year (Figure 3). Also according to the SILVA forecast the stocks of volume are build up between 2004 and 2014. These results were hints for the forest planning experts in the forest estate Forstamt Starnberg that the planned usage quota of 36.000 Efm/ ha/ year is a sustainable usage quota.

Table 1:
Results for increment of volume forecast of SILVA-calculations for Forstamt Starnberg

Treatment unit	Increment of volume [Vfm m.R. / ha/ y]	area [ha]	Forecasted increment of volume [Efm o.R./ ha + a] 2004-2014	Total increment of volume in forest estate [Efm o.R.]
JP	8,99	762,56	7,19	5484,33
JD broadlaeved	14,368	90,39	11,49	1038,98
JD coniferous	23,798	346,59	19,04	6598,52
JD mixed	19,619	332,61	15,7	5220,38
AD broadleaved	16,221	78,88	12,98	1023,61
AD coniferous	20,131	394,19	16,10	6348,35
AD mixed	15,019	260,33	12,02	3127,92
VJ	15,545	671,3	12,44	8348,29
idelle Vvj.	5,18	250	4,14	1036,00
LB	13,7	254,79	10,96	2792,50
a.r.B	13,26	56,52	10,61	599,56
SUM		3498,16	**11,90**	41618,44

6. Perspectives

The presented case study was an initial study. Meanwhile the application of the forest growth model SILVA is a standard within planning processes in Bavarian state forest. One important step for the integration in forest planning process was the design of a pattern-oriented database interface which enables the transfer of data of different forest inventory databases in SILVA with a low coding effort. To advance the applicability of this growth model for a bigger group of forest experts two user interfaces are actually designed. The first is a so-called expert user interface which enables e. g. the customizing of the SILVA model kit for different special questions on forest estate level. It is especially designed for SILVA experts which use the model very often and which are familiar with the huge number of possibilities of this growth model. The second user interface is designed for a bigger group of people, which use SILVA not so often, but wants to get the benefits of SILVA-calculations too. For this group the user interface is very simple designed, there are only few buttons which enable only a few number of choices for standard calculations on forest estate level.

At the end of 2007 the first experiences of the standard application of SILVA within the forest planning process in Bavarian state forest will lead to an evaluation process. At the moment it is planned that a simple GIS-interface should be integrated within both user interfaces to show the results of SILVA calculations in a way which is already familiar to the forest experts.

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