Using Capsis for connection with wood quality

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ABSTRACT

Capsis (de Coligny et al., 2004 ; http://capsis.free.fr) is an object-oriented software environment designed for hosting a wide range of forest dynamics and stand growth and yield models. It has been designed together by scientists from various French research organizations since 1994. Each model can have its own underlying stand (and if needed tree) description, thus very different kinds of models can be integrated: from stand models to distance-dependent or independent tree models with or without spatialization. Capsis can host heterogeneous models up to the region level and provides libraries to study spatial structures, biomechanics and tree genetics. For a given model and after having loaded a root step from an inventory file or through virtual generation, the user can create different scenarios by alternating growth sequences calculated by the model and silvicultural interventions.

The project is organized in three circles: (1) a single developer in charge of designing and maintaining the generic core application, but also dealing with animation, coordination and technical support ; (2) forest growth and dynamics scientists who create the models and implement them into the platform ; (3) end users who use these models for their activities. Every scientist can join the project on condition that he/she accepts the Capsis Charter.

Several models have recently been adapted for wood quality issues. PP3 (Meredieu *et al.*, 2005) is a distance-independent tree growth model with a whole-stand growth regulation for pure even-aged stands of Maritime pine (*Pinus pinaster*) in southwest of France. With a stem taper model, a juvenile wood description coupled with a cross-cutting model, impacts of silvicultural scenarios on grading of logs can be studied. We will consider coupling Capsis and WinEpifn (Meredieu *et al.*, 1999) to improve outputs in near future.

Fagacées model simulates the growth of sessile oak (*Quercus petraea*) and common beech (*Fagus sylvatica*) for various conditions. A stem taper was developed (Dhôte *et al.*, 2000) and can for example assess the impact of silviculture on ring width all along the stem of the tree. The same work is in progress for beech based on a taper equation from Trincado and Gadow (1996).

For Aleppo pine (*Pinus halepensis* Miller), the main coniferous species in the French Mediterranean region, a tree distance-independent growth model is coupled with a branching model allowing for simulation of branch diameter (maximum value and distribution for each branch level) along the crown in relation to silviculture. Further relationships describing crown size and branch length will be implemented in order to contribute to fuelwood simulation on shaded fuel breaks.

1. INTRODUCTION

The evaluation of wood quality can be studied by simulation with forestry growth models. They can offer a great flexibility by calculating numerous different silvicultural scenarios and thus produce various situations for wood quality evaluation.

The Capsis software hosts about 25 such forest growth or dynamics models. These models have been progressively integrated by co-development between their authors and computer scientists since year 2000 (for Capsis version 4) into an homogeneous modelling platform.

With its interactive, multi-operating system (Java language) and multi-language graphical user interface or by using its script mode, it is easy to run various simulations and to export the results in appropriate file formats for connection with other tools, including wood quality tools.

Section 2 details the special features Capsis offers to ease such connexions. Sections 3 discusses three wood quality related studies around Maritime pine, Oak and Beech, and Aleppo pine.

2. CURRENT STATE OF CAPSIS

The Capsis platform (fig. 1) was designed around an open architecture in order to accept models of different kinds (de Coligny *et al.*, 2004). The first models integrated were stand level or distance-independent tree models dealing with growth and yield of one single species on a plot of about one hectare (Dhôte, 1991, 1994 ; Meredieu *et al.*, 2001, 2003).

Forestry researchers now also develop other kinds of models, either individual based or heterogeneous (several species), sometimes dealing with seeds and pollen flows on areas of hundreds of hectares. These more recent models often include regeneration and mortality, they deal with various competition indices, sometimes with tree genetics or biomechanics (Courbaud *et al.*, 2003 ; Ancelin *et al.*, 2004 ; Dreyfus *et al.*, 2005).

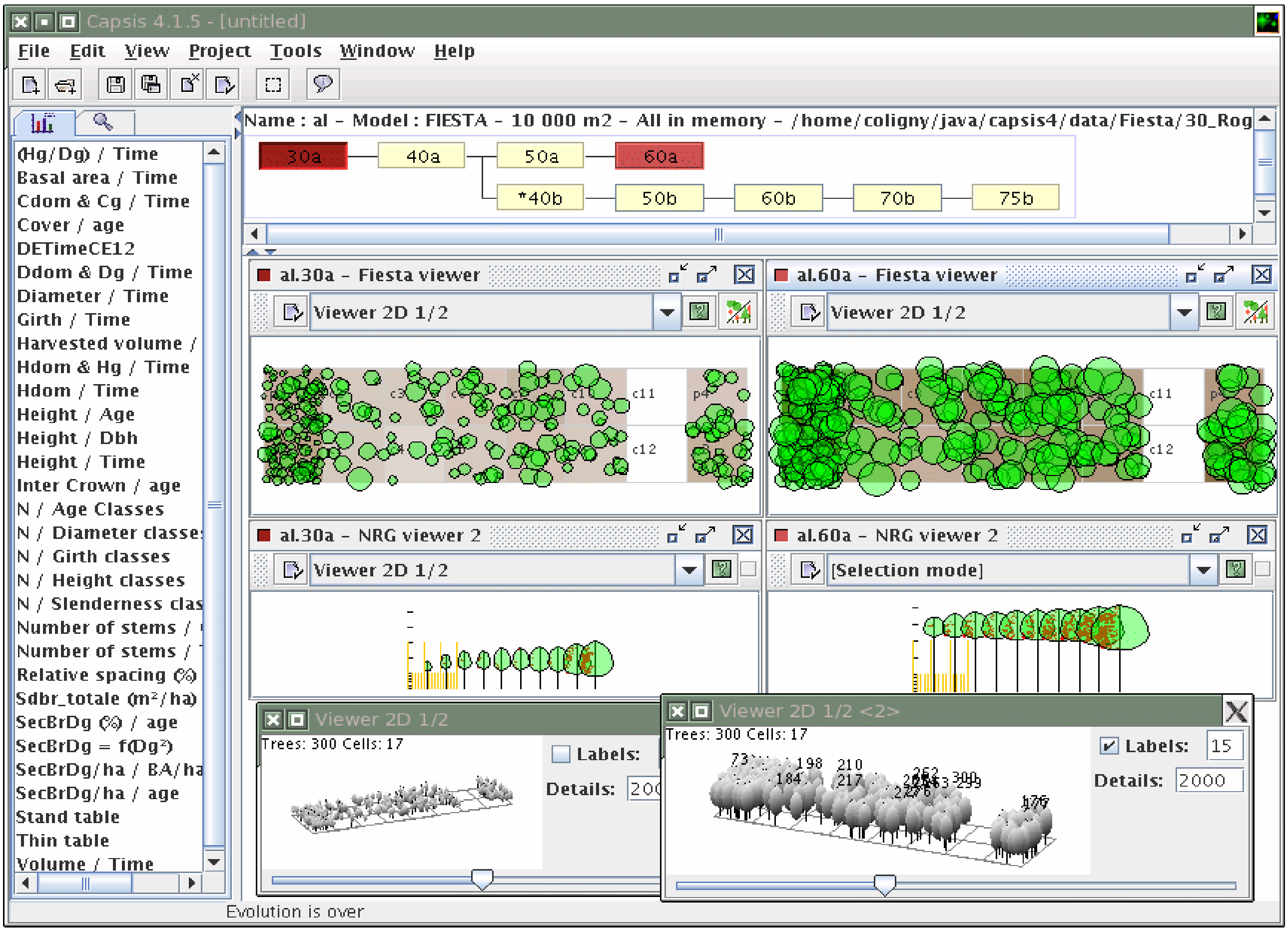

Fig. 1. A general view of Capsis in interactive mode (here in English and under Linux).

To comply with this diversity, each model is integrated into Capsis as a module containing its own scene description and evolution algorithms. This way, models can have their own stand properties, possibly with custom tree properties and additional geographical cell levels to deal with very large areas. They can also have their own simulation step, initialisation process, generation of the initial situation strategy with virtual methods and particular inventory files. They can manage additional models to deal with competition (radiative balance, neighbourhood), natural or artificial disturbances (gaps, integrated management) or internal quality (branches, taper).

Some particular features which have been added or enhanced in the Capsis platform for the last two years can ease the connection of the hosted models with downstream models.

The exportation extensions can be used to create custom files from every step memorized in the simulation history. Such files can then be read by another simulation tool for analysis. This is the easiest way to exchange data between Capsis and another simulator or statistical / graphical tool.

The Capsis grouping system has been enhanced. It can handle groups of trees or ground cells by combining several criteria which are implemented in extensions. It is thus possible when needed to build new filters for new criteria (sizes, locations, species, values or thresholds for some properties...). The group system can deal with the complementary and complex groups can be created by combining simple or other complex groups. This feature can help select some target objects to be monitored closer in the various Capsis extensions (ex: export only some trees).

The dynamics models in Capsis now propose a list of calculation protocols for which they have an implementation (ex: basal area, volume, root biomass...). Extensions can thus ask questions to the models in an unified way.

Small viewers have been added to answer selections in Capsis main viewers. Such tools can for example draw a tree taper or show a table of properties for the selection.

A device has been designed and implemented to memorize cut or dead trees on the step just following the event. This status map is available for individual based models as well as distance-independent tree models. Trees are memorized with their properties and groups of such trees can be passed to some calculation protocols to compute properties at the group level (*e.g.* basal area or mean diameter of the cut trees or a particular species or a range of size or age...).

Many simulations can be run without interactivity by using the script mode. This can help to run very long processes or also to repeat a great number of simulations with a stochastic factor or changing each time the initial parameters according to a simulation plan. Intermediate or final states can be saved in custom files during the script progress in order to be analysed afterwards outside the platform. Scripts can use export formats, groups, calculation protocols and the status maps exactly as if the simulation was run interactively.

All these features can help connecting the models inside Capsis with other models or simulators. Thus, some work has been done recently around wind risk with the ForestGales simulator (Cucchi *et al.*, 2005) and tree architecture with the AMAPsim 3D model (Meredieu *et al.*, 2004). Connections with wood quality models has also been made, especially for three dynamics models : Maritime pine, Oak and Beech, and Aleppo pine.

3. FROM GROWTH MODELS TO WOOD QUALITY

3.1. The PP3 module for Maritime pine

The PP3 module implements a distance-independent tree growth model specifically adapted to the simulation of the growth of Maritime pine stands in France (Meredieu, 2002). This model makes it possible to compare the growth of trees subjected to various forestry scenarios. Maritime pine is a significant forest species in France, taking up about 1 357 000 ha, with an annual crop of 7.5 Mm^3 for varied uses, including paper, packing, sawing and furnishing. In addition to the production of their stand, it was therefore important to provide the managers with information about the quality of the wood produced.

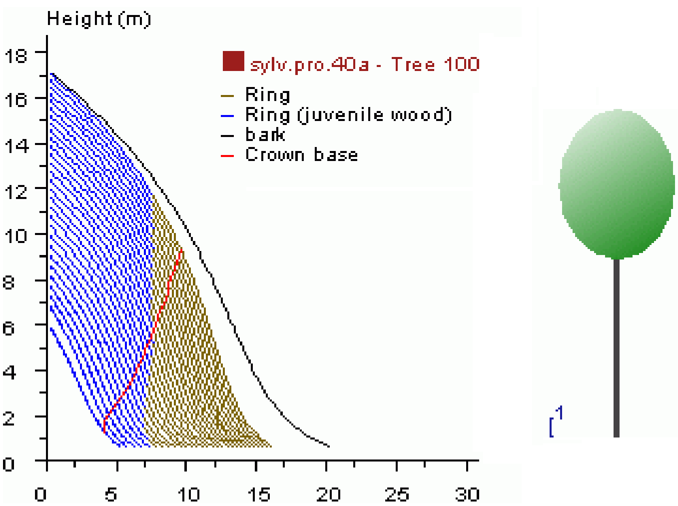

Fig. 2. Ring profile visualisation and schematic crown (level of living crown)
for one PP3 tree example (40 years old)

A significant work has begun to describe the various basic properties of wood affected by silviculture *via* the ring width all along the tree profile (fig. 2). Currently, the stem profile as well as the juvenile wood zone are calculated in the course of time for each tree of the stand. This partitioning under the bark is fundamental to include and understand the heterogeneity of the properties, particularly the wood density.

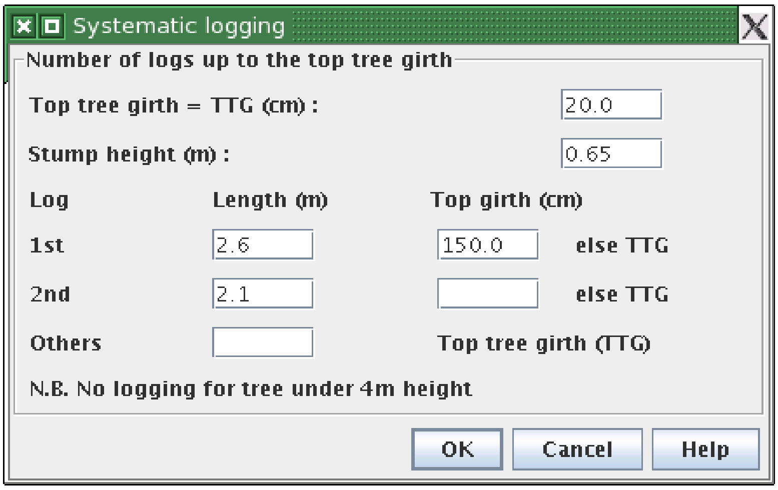

Fig. 3. Dialog box to choose criteria for systematic logging with the PP3 module

A first system of logs cutting was implemented in Capsis: it makes it possible to define a model of logs cutting based on criteria of length and top tree girth (fig. 3). For a given forestry scenario, this tool can simulate logging of the thinned trees during the scenario and of the trees at the time of final cut. A data file can be built, containing values to help analyse the scenario: a number of logs, volume over and under bark, volume of juvenile wood in the various logs...

Thereafter, we plan to integrate information concerning knottiness *via* a more detailed description of the crown increase (at present time just height of the living crown), to allow a zoning of the different types of nodes (adherent nodes, black nodes...), and a description of the branching (level and angle of insertion, diameter of the branches) to get finally a more precise description of the size of the nodes.

3.2. The Fagacées module for Sessile Oak and Common Beech

The Fagacées model is a growth model for Sessile Oak and Common Beech. It is a distance-independent model to simulate high forest, even-aged stands.

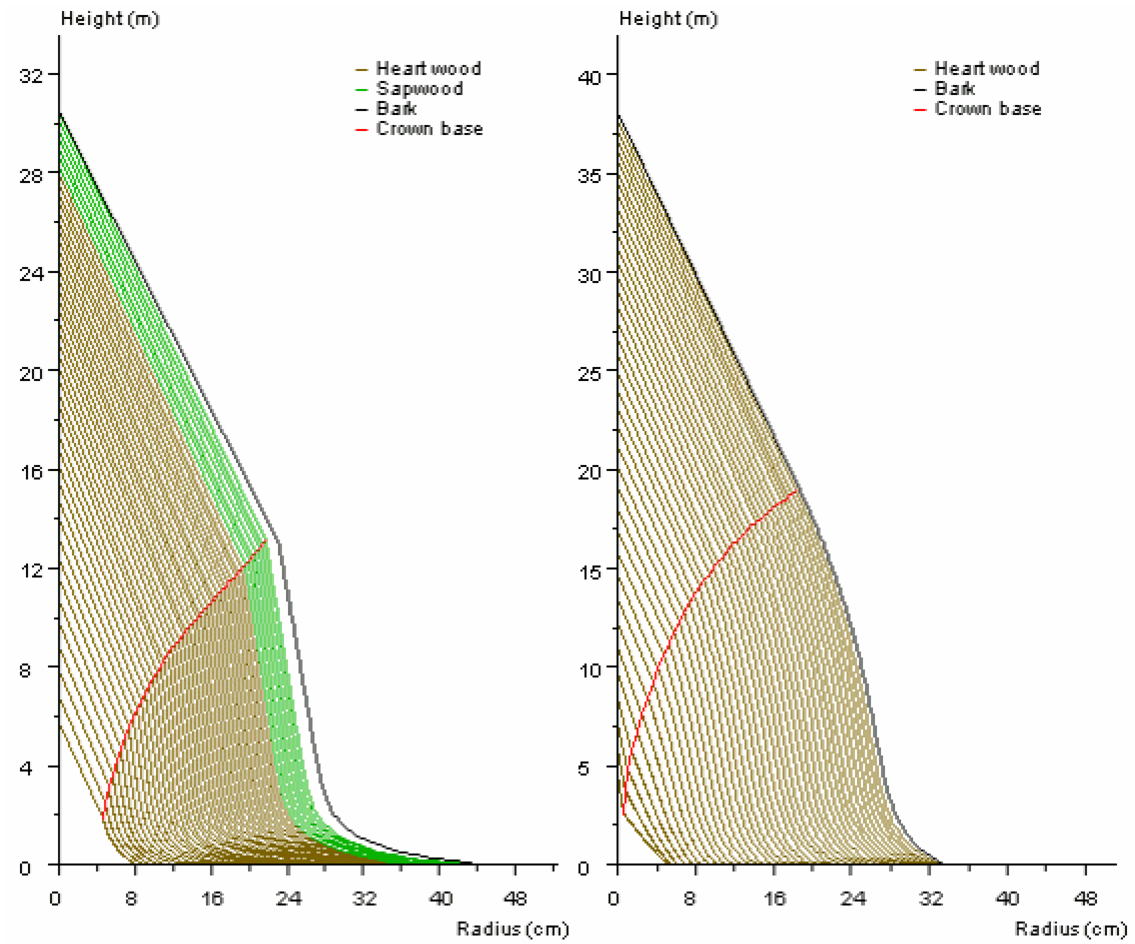

Fig. 4. Taper models for Sessile Oak (left) and Common Beech (right)

Knowing the diameters and heights for all trees at every simulation step, the taper can be calculated (fig. 4). For Sessile Oak, the taper model was developed by Dhôte *et al.* (Dhôte *et al.*, 2000). For Common Beech, Fagacées uses a taper model adapted from Trincado and Gadow (Trincado and Gadow, 1996).

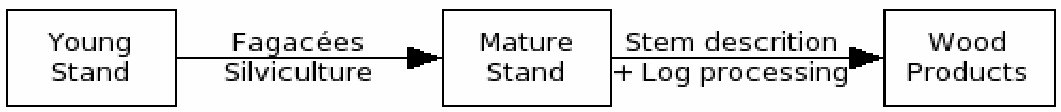

Fig. 5. Model chain

The stem taper is a part of the link between the trees in the stand and the wood products. This completes a model chain shown on figure 5. Several applications can be done, for example to assess carbon sequestration in wood products (cf. Le Moguédec, Nepveu and Bucket studies).

3.3. The Fiesta and NRG modules for Aleppo pine

For Aleppo pine (*Pinus halepensis* Miller), the main coniferous species in the French Mediterranean region, a tree distance-independent growth model is connected to a branching model and to crown height and radius relationships. The growth and mortality equations were achieved using data from 558 temporary plots from the French National Forest Inventory (5-year increment on every tree with dbh above 7.5 cm, data about dead trees …) (Dreyfus *et al.*, 2001) and a site-index relationship. The growth model allows for simulation of tree and stand growth (fig. 6) according to site conditions, age and thinnings either in closed stands or on shaded fuel breaks.

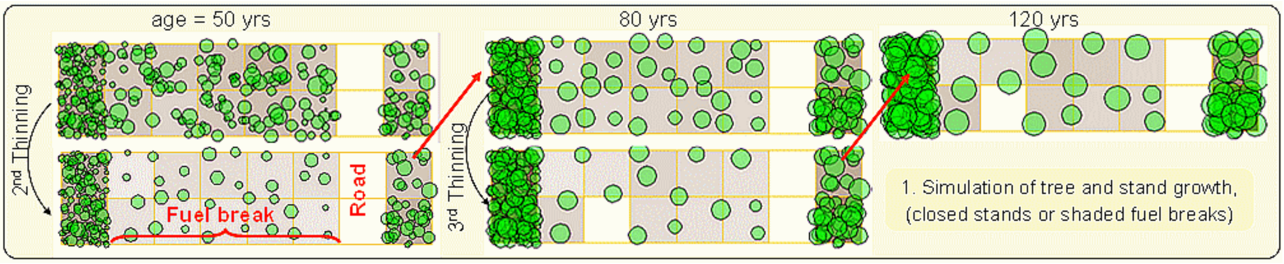

Fig. 6. Simulation of tree and stand growth

The allometric relationships in the branching model were obtained after stem and branch analysis of 32 trees (4 trees, from dominant to suppressed, in 8 plots ranging from height 5 to 20 m, age from 30 to 100 years, basal area from 6 to 44 m²/ha). For the crown radius relationships, 19 additional open-grown trees were measured.
The whole model (growth + branching and crown dimensions) allows for simulation of canopy cover and of branch diameter along the crown in relation to silviculture *i.e.* maximum diameter and branch diameter distribution for each level in the crown, for trees in each diameter class (fig. 7).

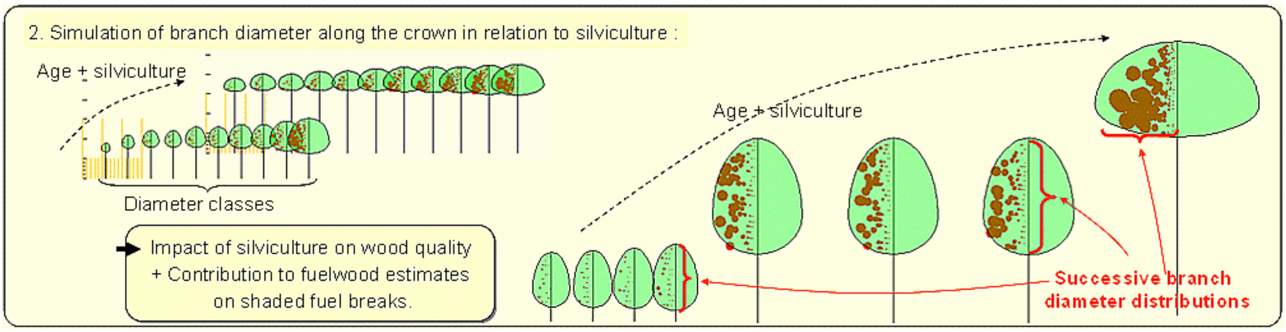

Fig. 7. Simulation of branch diameter along the crown as related to silviculture

Such simulations are useful both for estimating the impact of silviculture on wood quality and for contributing to fuelwood estimate on shaded fuel breaks. Further relationships describing branch length will be implemented in order to improve the fuelwood simulation.

4. CONCLUSION

Since 1999, Capsis project priorities have been first to enhance the previous Capsis platforms by rebuilding a platform opened to all kinds of models and at the same time to integrate such models in the software tool. Capsis now contains around 25 forest growth and dynamics models and new priorities can arise, like connecting these models to other tools or simulators dealing with wood quality. In this paper, we presented such connections concerning Maritime pine, Sessile Oak and Common Beech as well as Aleppo pine. These wood quality approaches will soon be completed by connecting models with downstream simulators especially devoted to log-making and sawing optimisation.

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