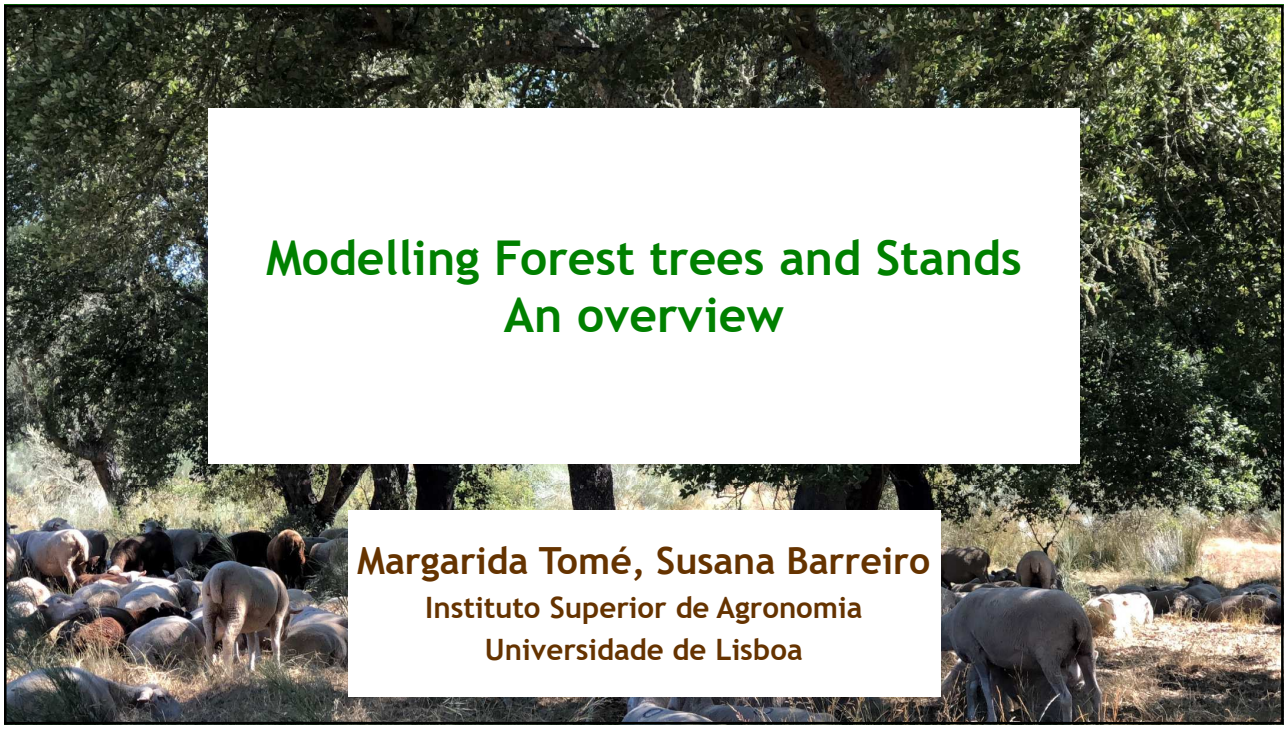

Modelling Forest trees and Stands
An overview

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Summary

- Why do we need forest growth models?
- What is a forest growth model (FGM)?
- The FORMODELS database
- What is a forest simulator?
- What is a decision support system?
- Are present forest growth models able to support forest management decisions of today?

▪Why do we need forest growth models?

To support the increasingly complex forest management…

▪Forestry and forest management

▪Forestry

- ✓ Forestry is the science, art, business, and practice of conserving and managing forests and forest lands in a way that
  - provide a sustained supply of **forest products**
  - maintain the forest **health and vitality**
  - provide any **other forest values** desired by the forest owners

(adapted from Ford-Robertson, 1971)

▪Forestry

- ✓ Forestry is the science, art, business, and practice of conserving and managing forests and forest lands in a way that
  - provide a sustained supply of **ecosystem services** desired by the forest owners and the **society** in general
  - are **resilient** to the increasing occurrence of **hazards**
  - are adaptable to **climate change**

(modified from Ford-Robertson, 1971)

Forestry implies decisions about the relationship between the man and the forest, in particular about the way man modifies the forest in order to achieve his objectives

FOREST MANAGEMENT

Forest management decisions are not easy…

- Every forest activity, undertaken at any point in time during the life of the stand, has impacts on its future health and vitality and on the ecosystem services provided over time
- There is no optimum sequence of silvicultural operations, they depend on the objective for each stand and landscape (there are no “recipes”)
- Objectives may change over time (and have changed during the last decades…)
- Many times there is the need to take into account rules established at a higher level (e.g. forest policy) in the day to day management

Forest management decisions

↓

The need to evaluate, on the long term, the impact of alternative management options under a changing environment

↓

FOREST GROWTH MODELS

- **What is a forest growth model?**

What is a forest growth model?

- ✓ It is a simplification of the dynamics of a forest stand allowing the simulation over time of the characteristics of:
  - trees, stands
  - other characteristics of the ecosystem

How do we build a forest growth model?

- ✓ Stages in model development:


Selection of the model type (e.g. empirical, process-based, tree level, stand level, etc)


Data collection


Designing the structure of the model (e.g. selecting the variables and defining their relationships)


Evaluation of the model


Implementation of the model in a computer program/integration of the model in a forest simulator

▪What is a forest growth model?

- ✓ It is a simplification of the dynamics of a forest stand allowing the simulation over time of the characteristics of:
  - trees, stands
  - other characteristics of the ecosystem
- ✓ A dynamic representation of the forest and its behaviour (at whatever level of complexity)
- ✓ The forest is defined by the values of a set of state variables (N, hdom, G, V, W, Wshrubs, soil characteristics, etc)
- ✓ The model is able to simulate the evolution of forests over time (evolution of state variables) and its responses to changes in the driving variables

▪State variables:

- ✓ Set of variables (stand and/or tree variables or some ecosystem pools) that characterize the forest at a given moment and whose evolution in time is the result (output) of the model:
  - Principal variables (direct output of the growth module of the model)
  - Derived variables (indirectly estimated from the other variables)

▪Driving variables:

- ✓ A set of external variables that control (drive) the system:
  - Environmental variables (e.g. climate and soil variables)
  - Management related variables (e.g. silvicultural treatments)
  - Disturbances related variables (e.g. pests and diseases, storms, fire)

Sometimes the separation between state and driving variables is not straighforward

▪What is a forest growth model?

- ✓ It is a simplification of the dynamics of a forest stand allowing the simulation over time of the characteristics of:
  - trees, stands
  - other characteristics of the ecosystem
- ✓ A dynamic representation of the forest and its behaviour (at whatever level of complexity)
- ✓ The forest is defined by the values of a set of state variables (N, hdom, G, V, W, Wshrubs, soil characteristics, etc)
- ✓ The model is able to simulate the evolution of forests over time (evolution of state variables) and its responses to changes in the driving variables
- ✓ The model is based on a set of (sub-)models or modules that together determine the behaviour of the forest

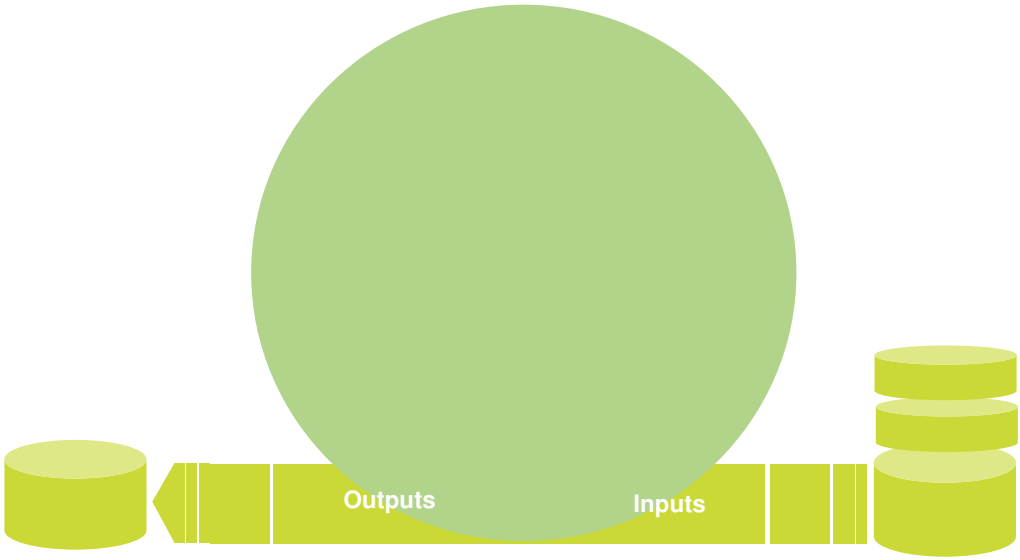
▪Model Module:

- ✓ A set of equations and/or procedures that led to the prediction of the future value of a principal variable (dynamic) or to the estimation of the value of a derived variable (static)

▪Model structure:

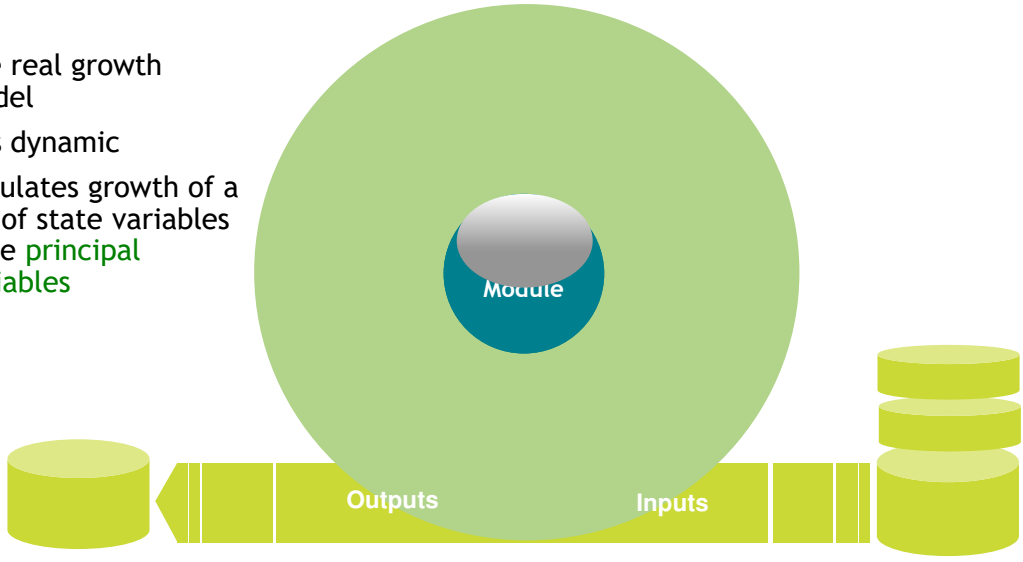
- ✓ A growth model includes a set of modules:
  - Growth module (that predicts growth of principal variables)
  - Management module (that drives growth predictions reflecting the impact of silvicultural treatments
  - Calculation (that estimates the derived variables and distributions)
  - Initialization module
- ✓ The links needed to adequately connect the modules (flowchart and/or algorithm)

Forest growth model

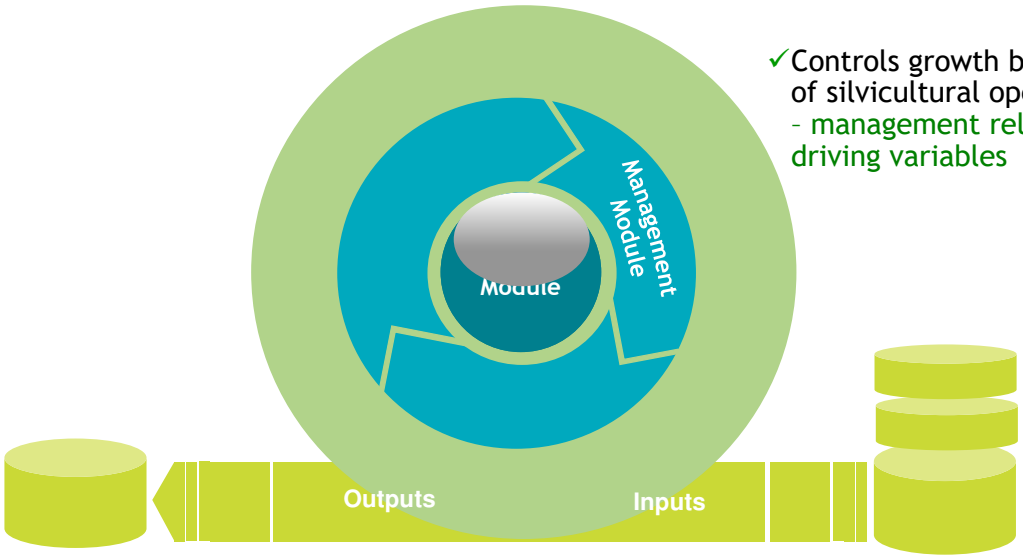


Forest growth model

- ✓The real growth model
- ✓It is dynamic
- ✓Simulates growth of a set of state variables - the principal variables



▪Forest growth model



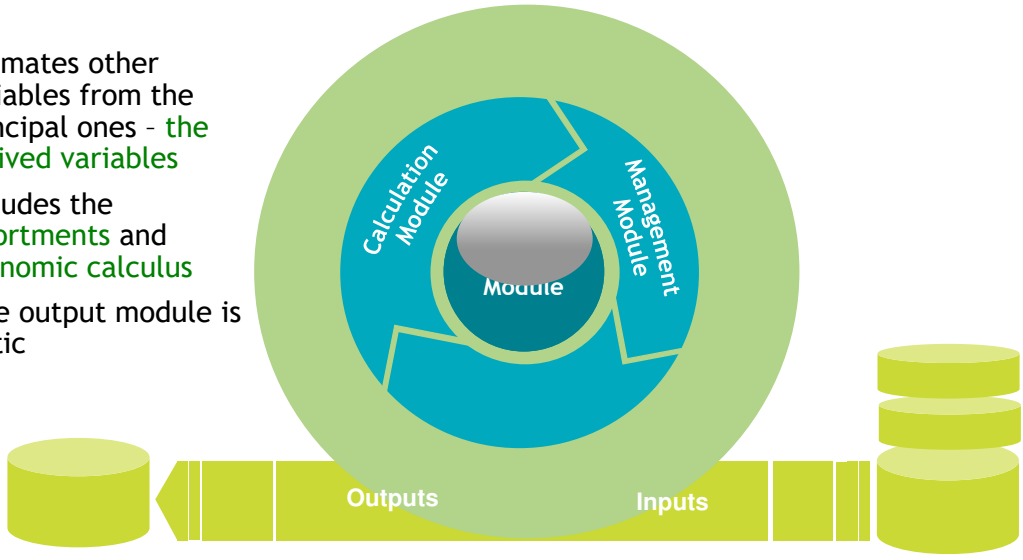
✓Controls growth by a set of silvicultural operations – management related driving variables

▪Forest growth model

✓Estimates other variables from the principal ones – the derived variables

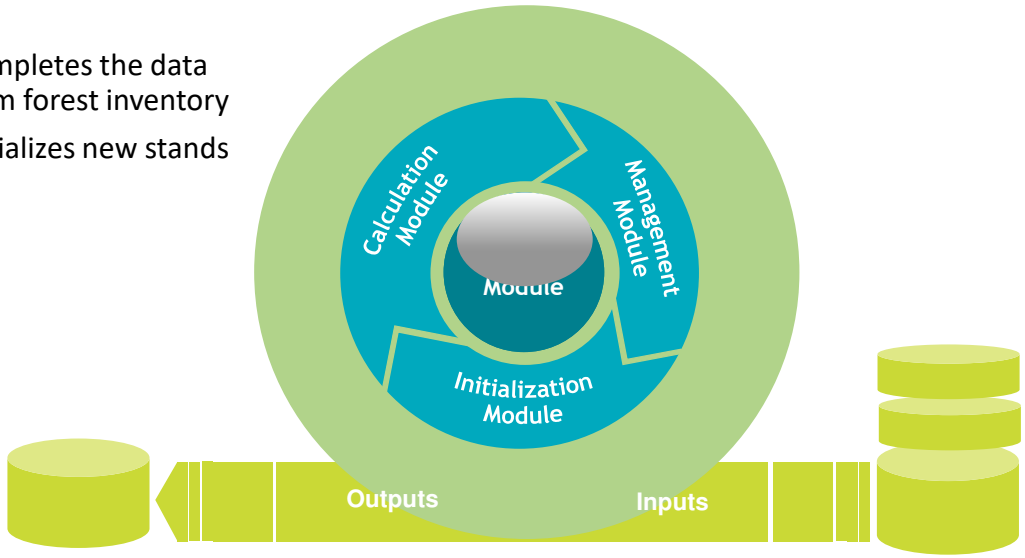
✓Includes the assortments and economic calculus

✓ The output module is static



▪Forest growth model

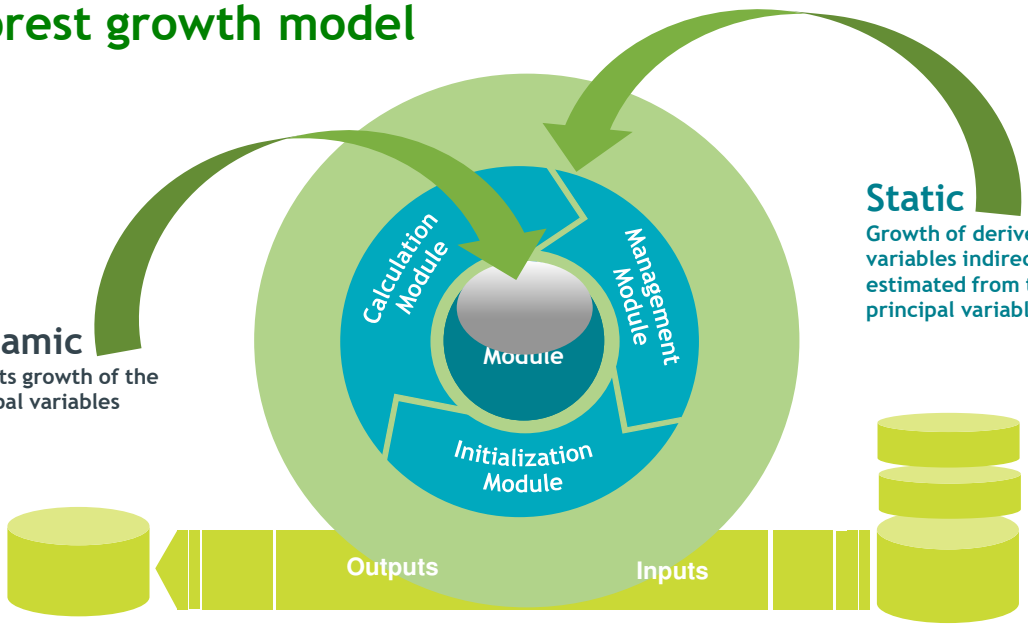
- ✓Completes the data from forest inventory
- ✓Initializes new stands



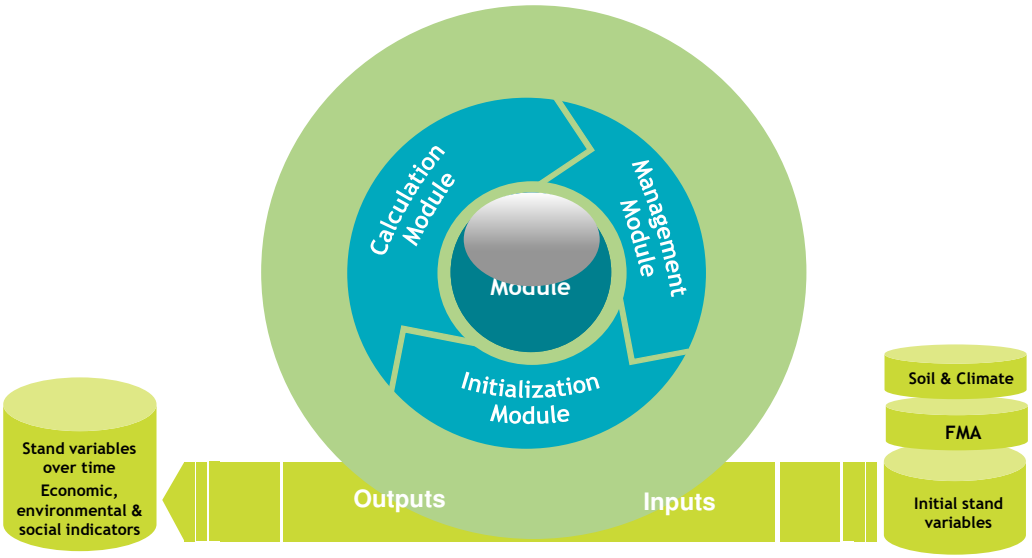
▪Forest growth model

Dynamic
Predicts growth of the principal variables

Static
Growth of derived variables indirectly estimated from the principal variables



Forest growth model



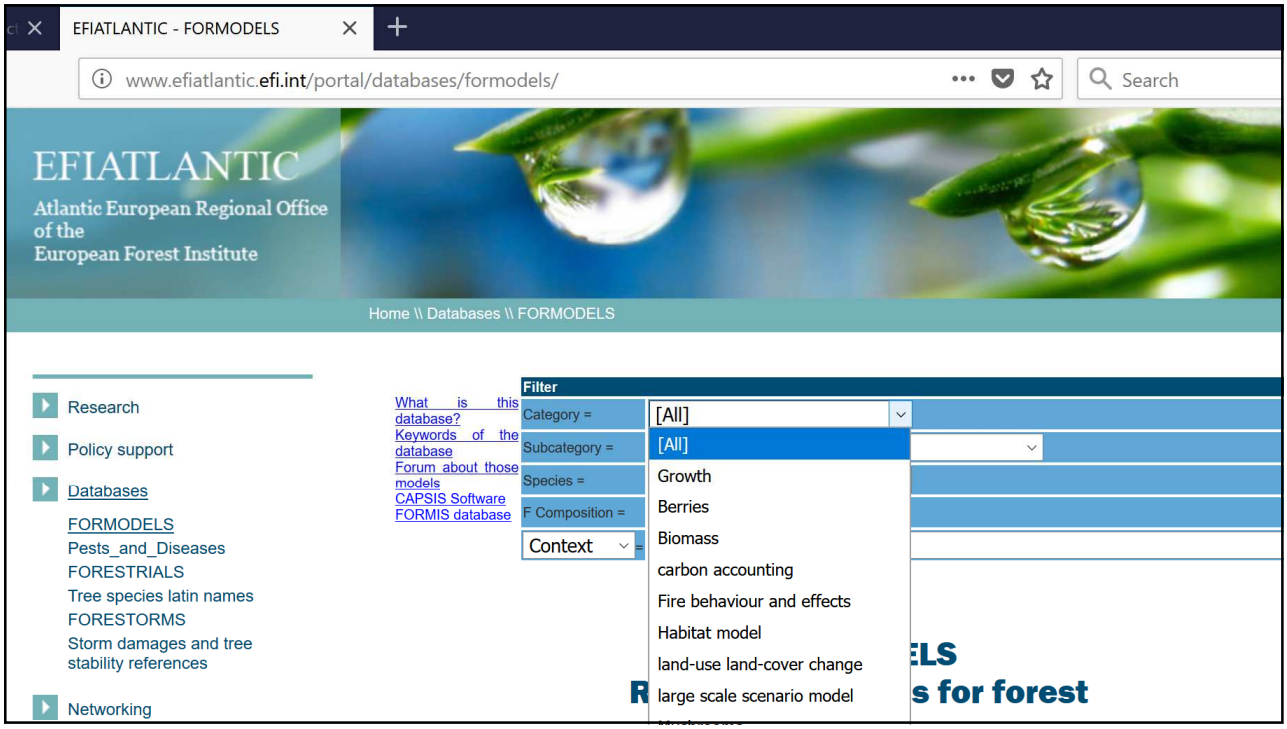
What is a forest growth model?

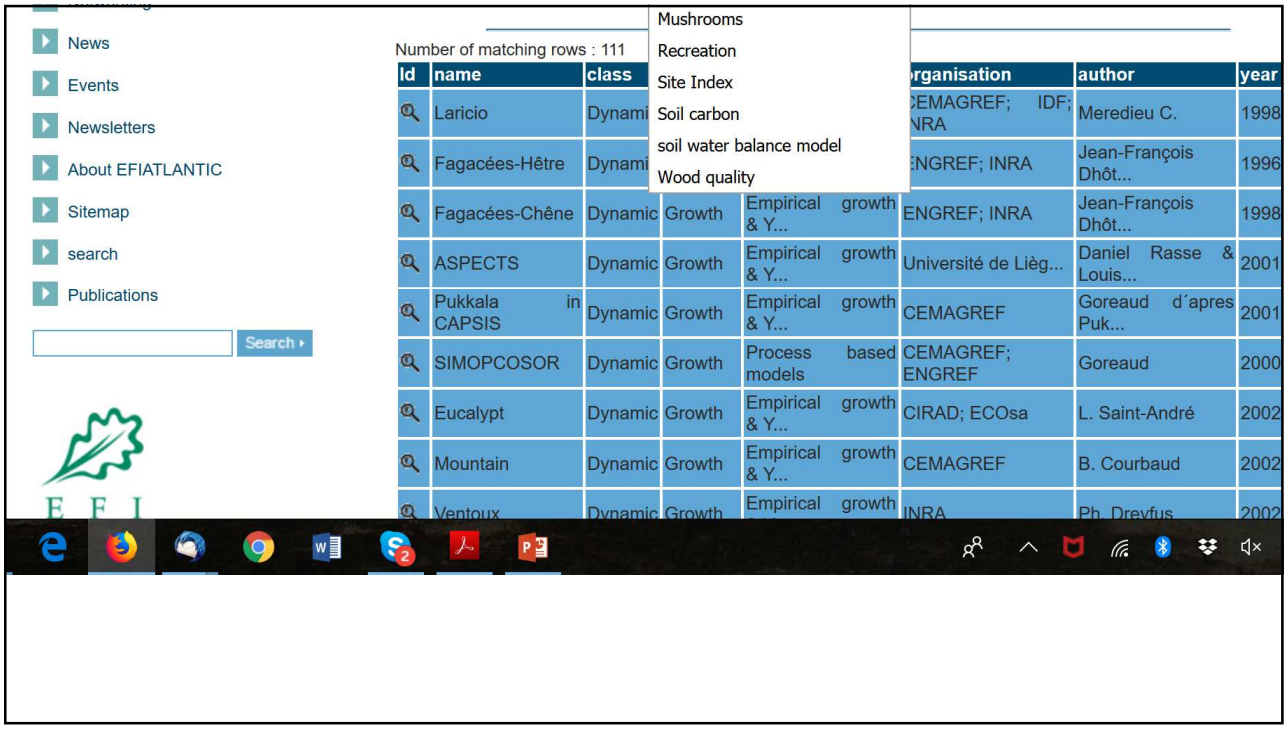
- A more formal definition of a forest growth model (FGM)

  ➔A dynamic representation of the forest and its dynamics, at whatever level of complexity, based on a set of sub-models or modules that together determine the dynamic of the forest as defined by the values of a set of state variables

  ➔The forest responses to changes in the driving variables are reflected by the predicted dynamic of the forest

- The FORMODELS data base

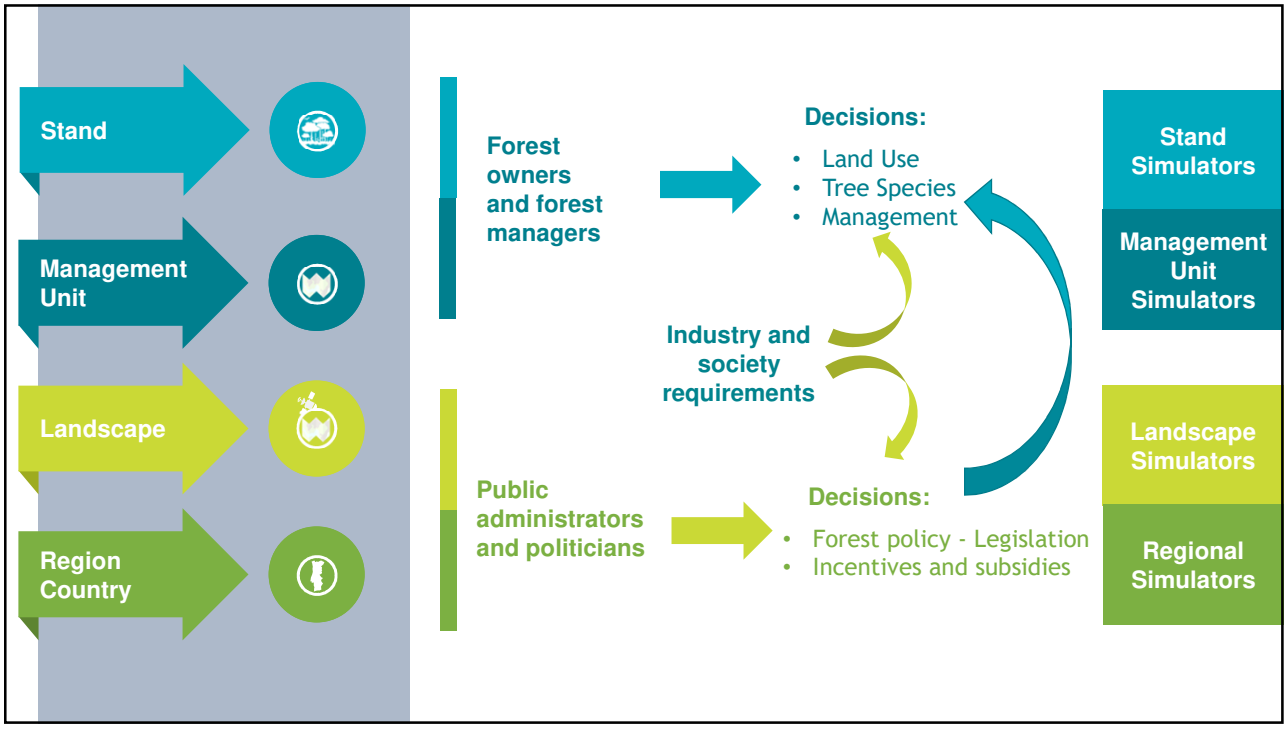




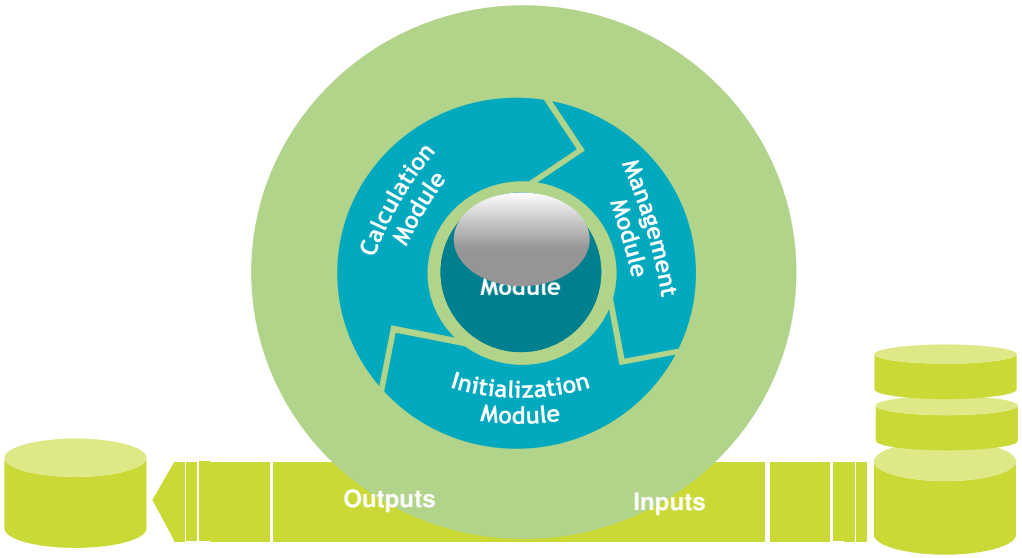
- **What is a forest simulator?**

▪What is a forest simulator?

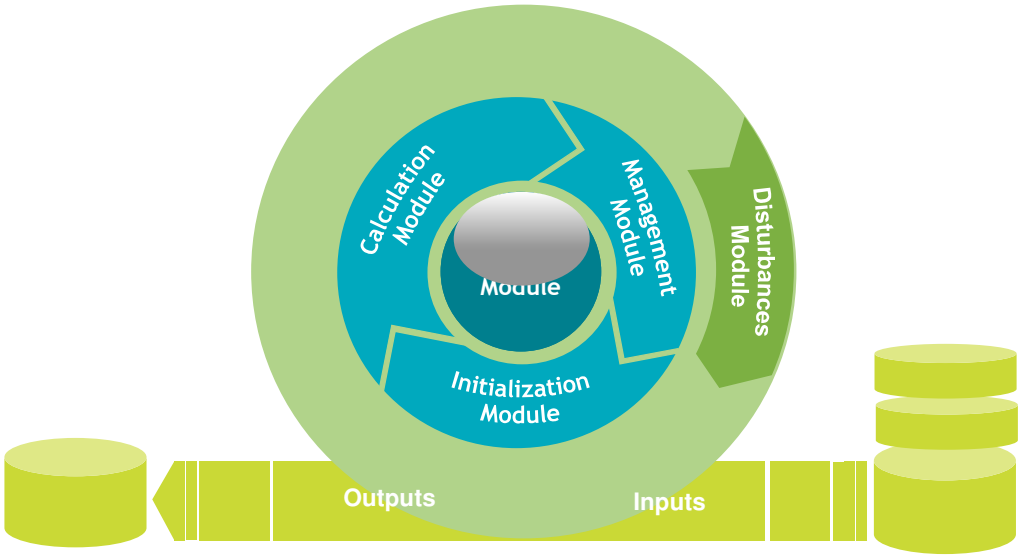
- ✓ Computer tool that, based on a set of forest models, makes long term predictions of the status of a forest under a certain scenario of management, climate, risks, forest policy
- ✓ Forest simulators usually predict, at each point in time, wood and non-wood products from the forest
- ✓ It is desirable simulators predict a large range of ecosystem services



▪Forest growth model / Stand simulator



▪Management unit and large scale simulators



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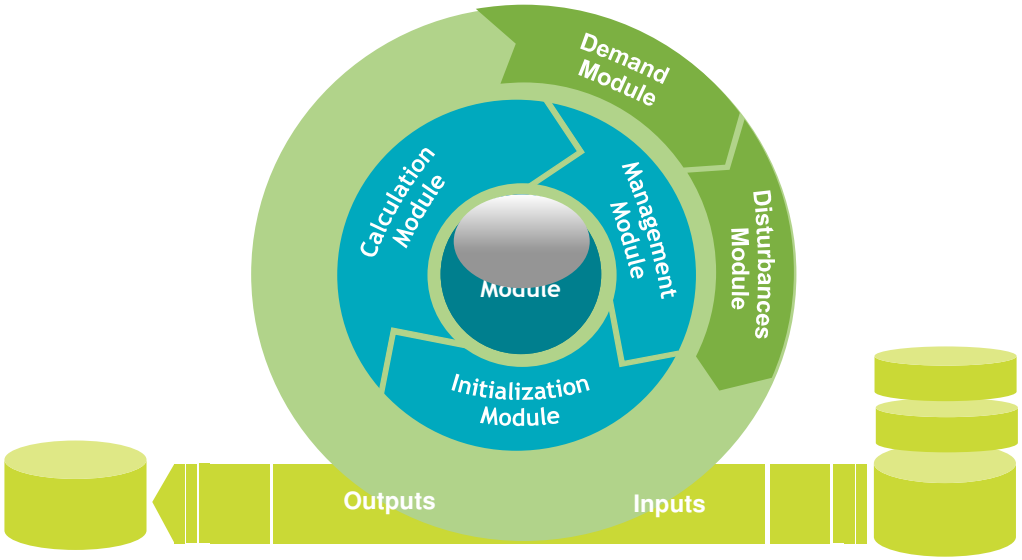

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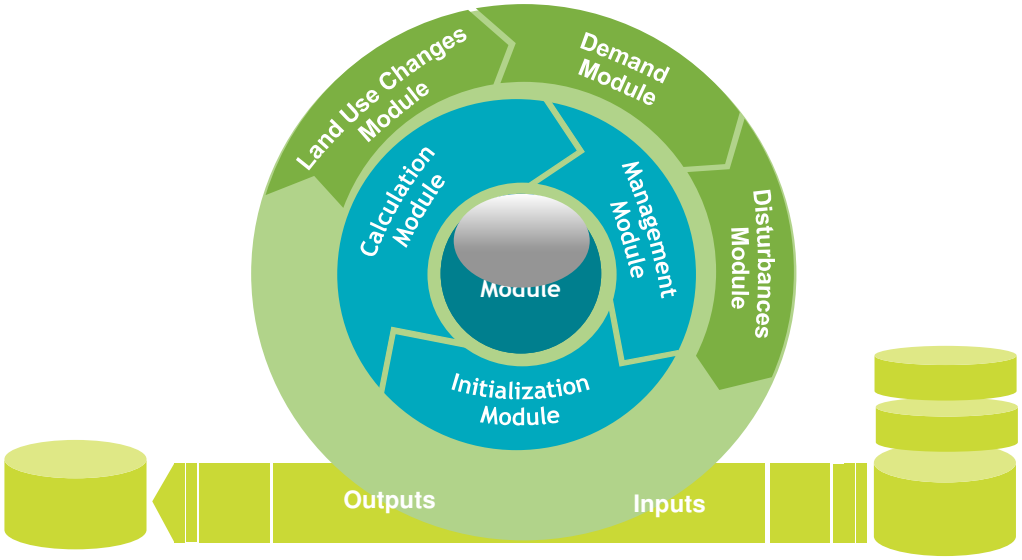
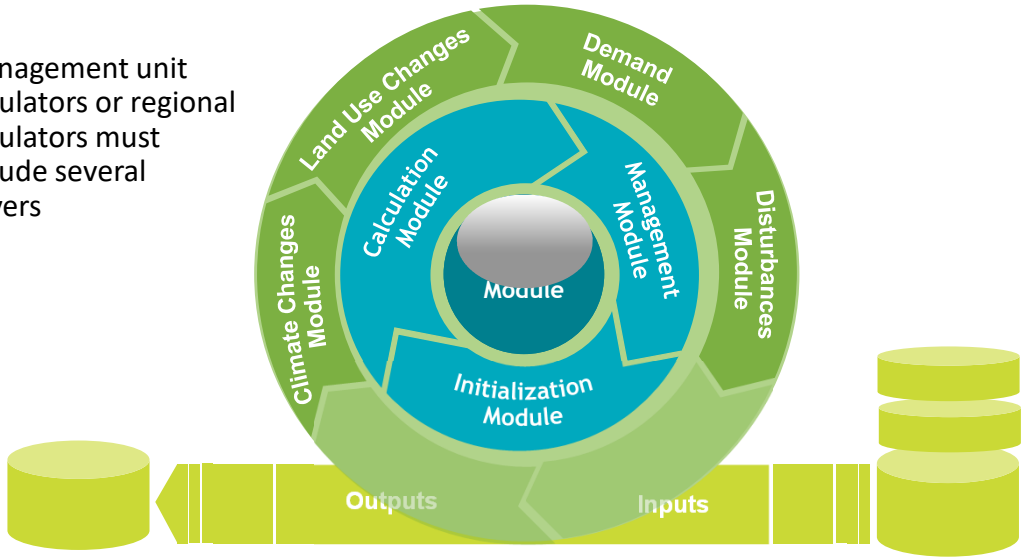
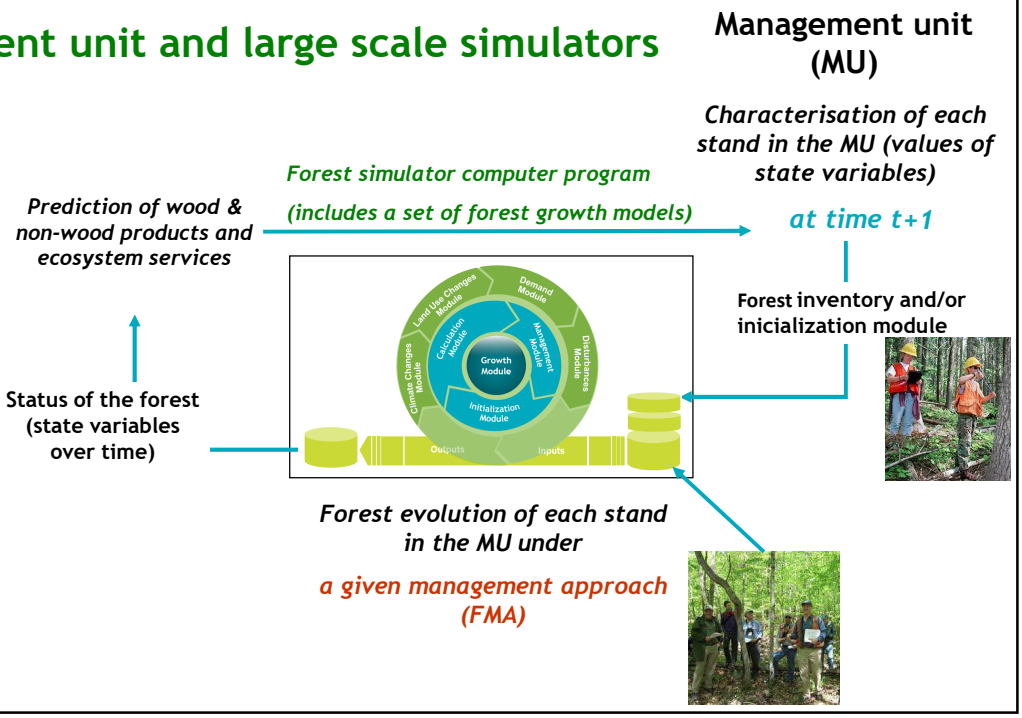


▪Management unit and large scale simulators

✓Management unit simulators or regional simulators must include several drivers



▪Management unit and large scale simulators



What is a Decision Support System?

Decision support system

- ✓ Simulator that includes optimization algorithms that point out for a solution – selection of a forest management approach for each stand:
  - Multi-criteria decision models
  - Artificial neural networks
  - Knowledge based systems

▪Decision Support System

Management unit (MU)

Characterisation of each stand in the MU (values of state variables)

Forest simulator computer program

(includes a set of forest growth models)

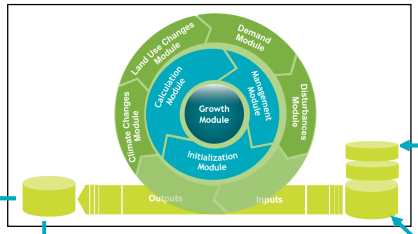
at time t+1

Prediction of wood & non-wood products and ecosystem services

For each of the FMAs

Forest simulator applied several times to each stand

Status of the forest (state variables over time)



Forest inventory and/or inicialization module

Forest evolution of each stand in the MU under

several management approaches (FMA)

Optimization and other OR techniques

$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} corkA_{ij}x_{ij} = CORKA_t,\ t =$$

$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} cones_{ij}x_{ij} = Cones_t,\ t =$$

Models and methods to select management options that may sustain conditions and outcomes of interest

(multiple criteria)

Decision Support System

▪Are present forest growth models able to support forest management decisions of today?

▪Present models need improvement

- ✓ There is the need for **more detailed, versatile forest growth models** that
  - can work using readily available forest inventory data as input
  - are able to give good predictions under climate change
  - take into account the genetics of the plant material
  - provide information on the effect of different silvicultural alternatives not only on tree growth but also on other forest products and services (indicators of MSFM)
  - provide reliable information on stand structure and wood quality
  - account for the possible occurrence of several damages

▪Present models need improvement

- ✓ Current models:
  - Do not include risk assessment such as storm damage, fire, pests and diseases
  - Concentrate output on the development of trees (do not give output on the impact of forests and forest management on soils and water use, biodiversity, recreational and amenity values, etc)
  - Do not simulate wood quality
  - Do not simulate the impact of genetic improvement
- ✓ There are models covering some of these aspects but generally these aspects are not covered

▪Present models need improvement

- Scientifically there is the need to improve the knowledge of the forest ecosystems to be able to predict stand growth and forest development under changing environmental and managerial conditions
- For forestry practice
  - there is the need to improve output quality regarding the level of detail as well as the accuracy of predictions
  - for instance good information on stand structure is essential to assess wood quality or to evaluate harvesting procedures and costs

▪The need to use MU forest simulators

✓ For instance modelling fire impacts includes several steps
- Predicting the probability of occurrence
- Once it occurs, predict the "propagation of the risk"
- Predict the impact (tree death, decrease in productivity, etc)

✓ It can only be done at MU/larger spatial scales and requires that the model includes new variables (such as height of shrubs, shrub biomass, height to the base of the crown, crown bulk density)

The integration of models into management unit / large scale forest simulators is a requirement of modern forest management

▪Final comments

▪Good decisions on forest management?

- ✓ Depend on good decision support systems that include:
  - – Forest inventory
  - – Forest models (give answers to what if? questions)
  - – Definition of the forest management approaches to test
  - – Evaluation of the results using optimization and other OR techniques
- ✓ Where must the research efforts be put?

Decision Support System

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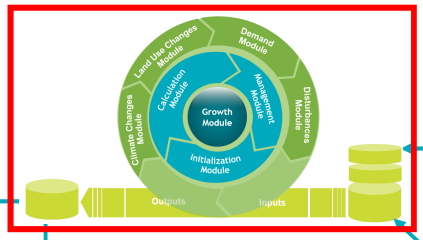

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