# Forest models for the future

combining physiology and statistics

moving from the stand to the landscape

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# Summary

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- ✓ Forest models, forest simulators and platforms for forest simulators
- ✓ Present challenges in forestry
- ✓ Evolution of forest models
- ✓ Forest models for the future
  - how to build them
- ✓ The need for forest simulators

# Forest models and simulators

# Forest model

- ✓ A dynamic representation of the forest and its behaviour, at whatever level of complexity
- ✓ It is based on a set of **modules** that together determine the behaviour of the forest
- ✓ The forest is defined by the values of a set of **state variables**
- ✓ It takes into account the forest responses to changes in the **driving variables**

# State variables

- ✓ Variables that characterize the forest at a given moment :
  - *e.g.* dominant height, total volume, biomass (total and per tree component), soil water, individual tree data
- ✓ Two types of state variables:
  - **Principal variables** – growth modules
  - **Derived variables** - indirectly predicted from the values of the driving variables
- ✓ The forest model predicts the evolution of state variables in time (forest dynamics)

# Driving variables

- ✓ Variables that are not part of the forest but that influence its behaviour:
  - **Environmental** variables (*e.g.* climate, soil)
  - **Human induced** variables/processes (*e.g.* silvicultural treatments)
  - **Risks** (*e.g.* pests and diseases, storms, fire)

# Model modules and components

- ✓ Modules
  - Set of equations and/or procedures (sub-models) that led to the prediction of the future value of a state variable
  - Algorithms that implement driving variables (e.g. silvicultural treatments, impact of pests and diseases)
- ✓ Components
  - Equation or procedure that is part of a model module

# Types of modules

- ✓ Modules can be briefly classified as
  - Initialization modules
  - **Growth modules, the "real" forest growth model**

    (principal variables – need for process-based approach)
  - Prediction modules (derived variables)
    - Wood quality, erosion, biodiversity (probability of the presence of a certain species), non-wood products, ...
  - Modules for silvicultural treatments
  - Modules for hazards

# The need for initialization modules

- ✓ When do we need initialization modules?
  - When forest inventory does not measure all the state variables (concept of minimum input)
  - In the simulation of new plantations
  - For the simulation of regeneration
  - In landscape and regional simulators after a clear cut
  - ...

# Forest simulator

- ✓ **Computer tool** that, based on a set of forest models, makes long term predictions of the status of a forest under certain **forest management alternatives** and **scenarios**
- ✓ Forest simulators usually predict, at each point in time:
  - Wood and non-wood products from the forest
  - Sustainability indicators (environmental, economic, socio-cultural)
- ✓ Model application to practice requires that it is implemented on a simulator

# Spatial scales

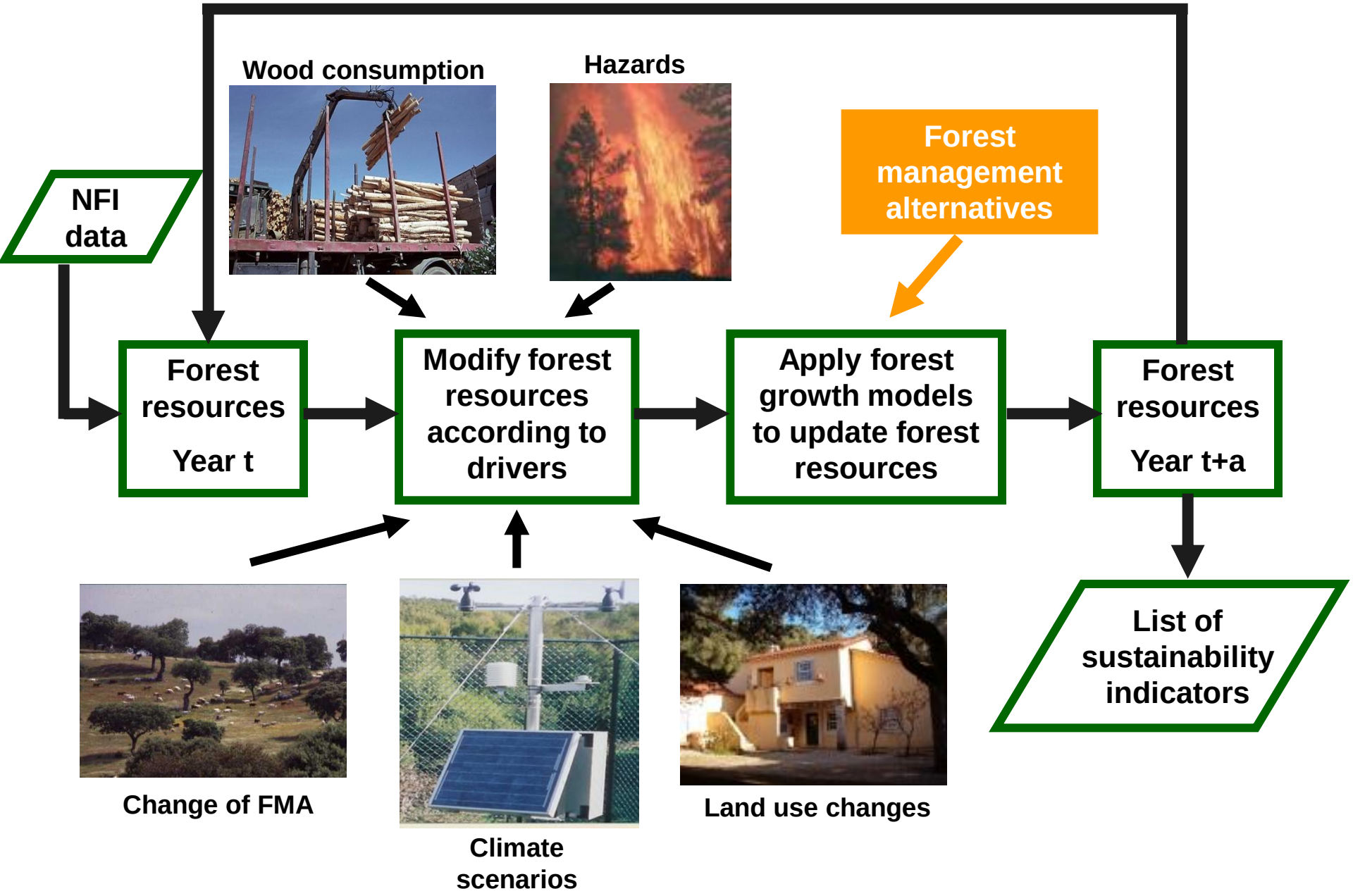
- ✓ Stand simulator
- ✓ Forest simulator
- ✓ Landscape simulators
- ✓ Regional/country simulators

**Frequently connected to a GIS**

- ✓ **Large scale** simulators

- ✓ Decision support systems

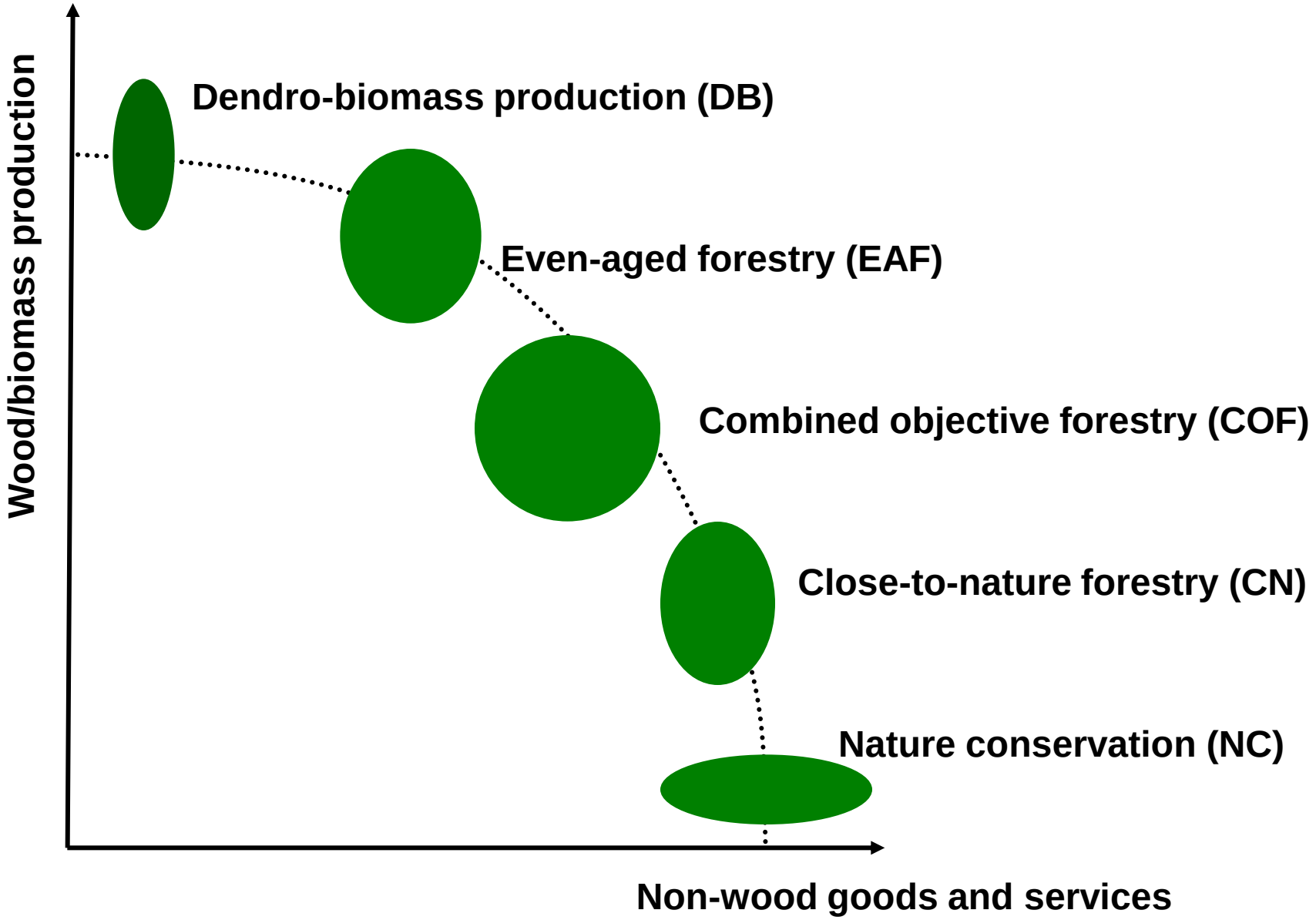
  (imply some type of optimization)


Wood consumption
Hazards
NFI data
Forest management alternatives
Forest resources Year t
Modify forest resources according to drivers
Apply forest growth models to update forest resources
Forest resources Year t+a
List of sustainability indicators
Change of FMA
Climate scenarios
Land use changes

# Forest simulator - FMAs and scenarios

- ✓ **Forest management alternative** (FMA)
  - Sequence of silvicultural operations that are applied to a stand during the projection period
- ✓ **Scenario**
  - Conditions (climate, forest policy measures, forest management alternatives, etc) present during the projection period

# Forest management alternatives:



# Platform for forest simulators

- ✓ **Computer interface** that facilitates the implementation, under the same framework, of several forest simulators
  - CAPSIS (France)
  - sIMfLOR (Portugal)

# Present challenges in forestry

# The global change environment

- ✓ Forest management faces several **challenges**
  - Environmental (mainly climate change and the associated increase of hazards)
  - Economic (increasing requirement and variability of high quality wood and non-wood products)
  - Social (increasing use of forests for the general welfare of urban societies)
- ✓ **Flexibility for the forest management**

  Forest should be continuously monitored and forest **management adapted** to the current situation and environment

# Forest models should be able to

- ✓ Simulate forest dynamics and products under a changing environment
- ✓ Provide an enriched output
  - Size distribution of wood logs, wood quality, non-wood products and services, sustainability indicators
- ✓ Simulate the occurence and impact of hazards
- ✓ Simulate the impact of improved genetic material and intensification of silviculture
- ✓ Simulate several forest management alternatives and transition between them

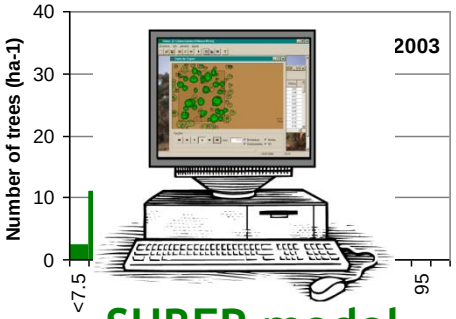
# Forest management alternatives - thinnings

- ✓ Thinning algorithms are an essential part of the simulation of FMA's:
  - DB – no thinning
  - EAF (SM) – thinning is simulated by reducing the stand variables
  - EAF (TM) – thinning algorithm based on the estimation of the probability of each tree being thinned
  - COF and CN – thinning algorithm applied to tree groups or d classes
  - NC – just sanitary thinnings

# Forest management alternatives - transitions

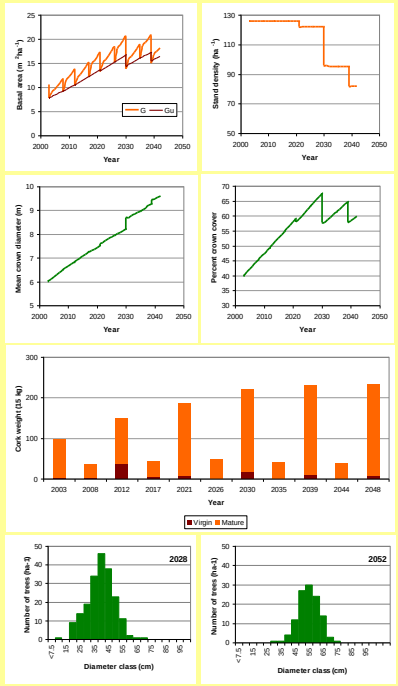
- ✓ There are diferent types of transitions between FMA's and its options:
  - Some can occur at any time
    - Different options of the same FMA
  - Some need an "intermediate" FMA and may not occur before a certain age
    - Even-aged to close to nature
  - Some can only occur after a clearcut:
    - Even-aged to dendro-biomass

# Forest management alternatives - transitions

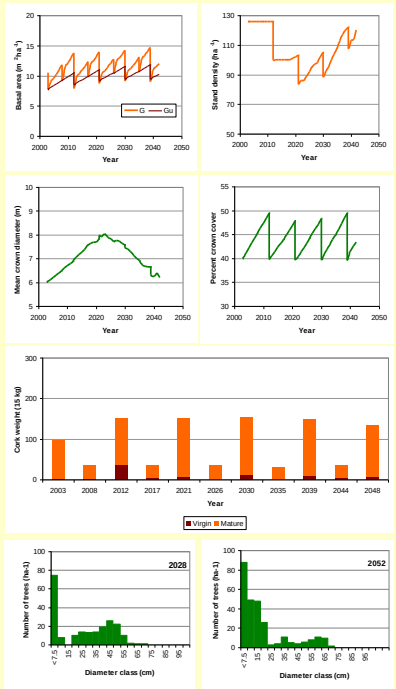



**SUBER model**

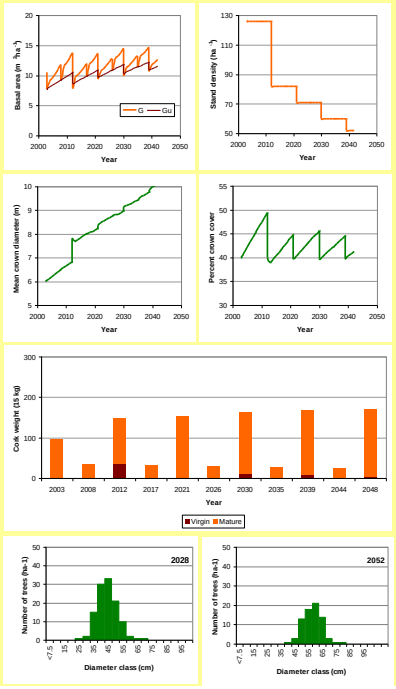
## COF (58%)

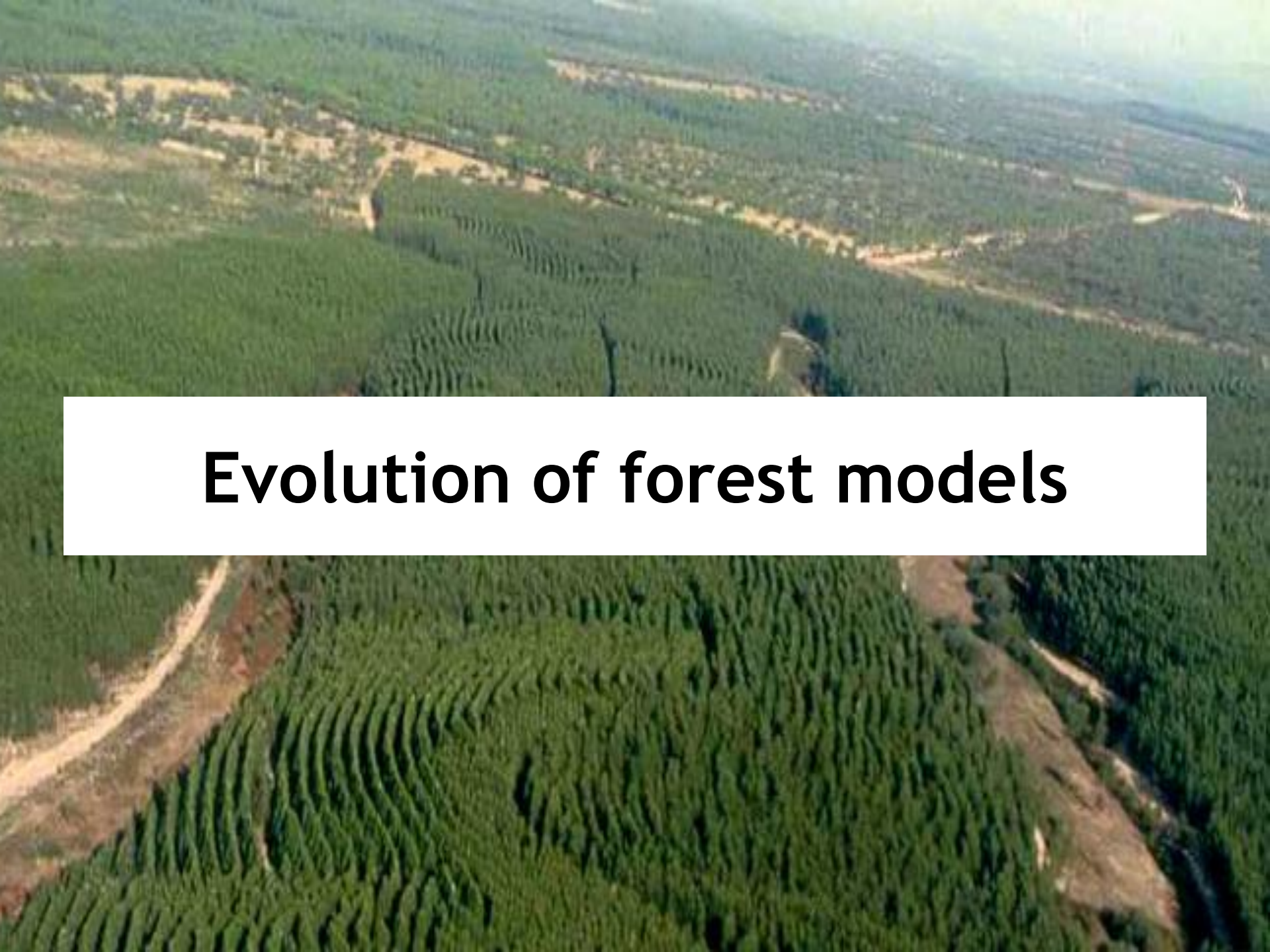



## CN (40%)

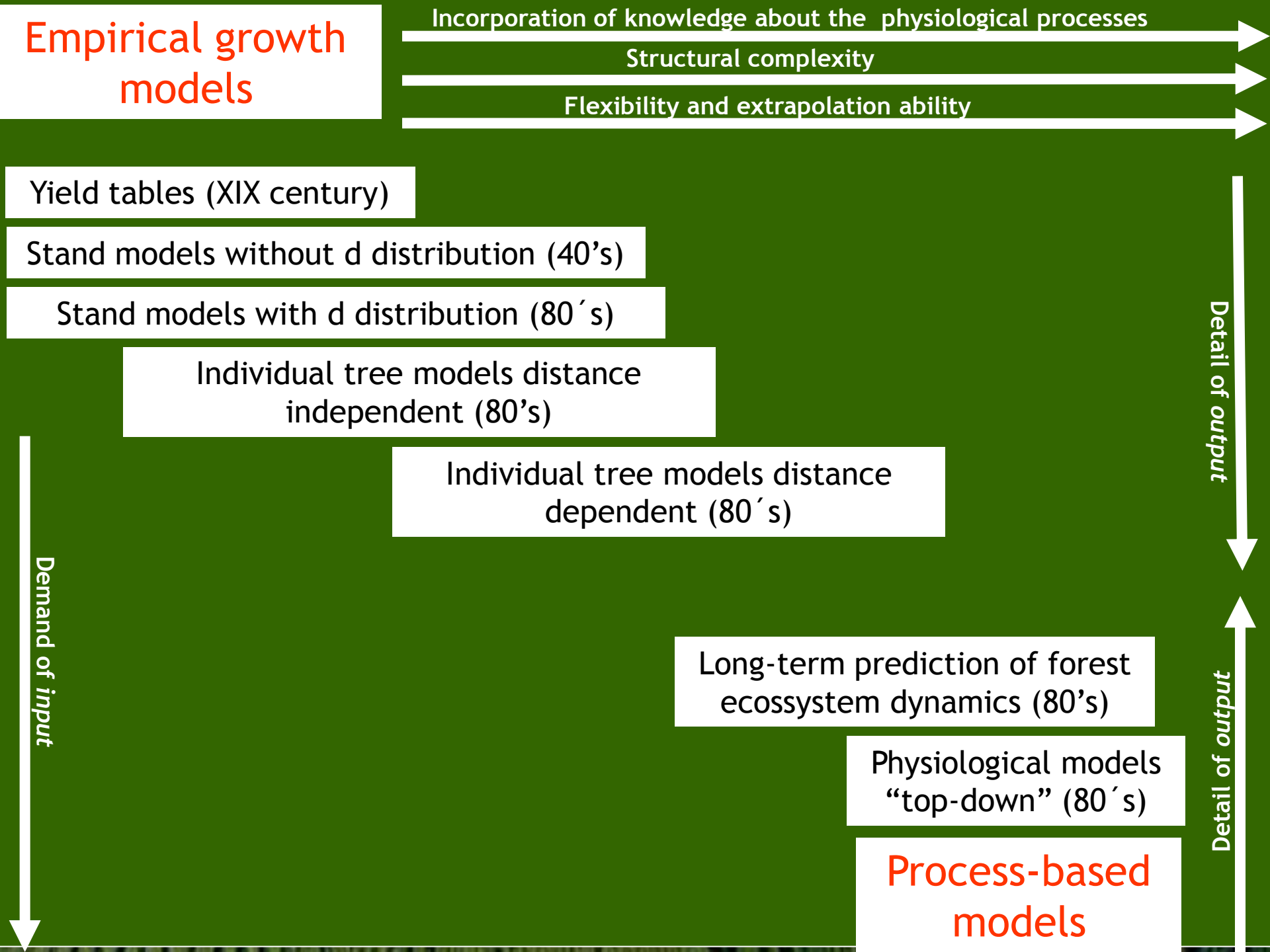



## COF (40%)





# Evolution of forest models


Empirical growth models
Incorporation of knowledge about the physiological processes
Structural complexity
Flexibility and extrapolation ability
Yield tables (XIX century)
Stand models without d distribution (40's)
Stand models with d distribution (80´s)
Individual tree models distance independent (80's)
Individual tree models distance dependent (80´s)
Detail of output
Demand of input
Long-term prediction of forest ecossystem dynamics (80's)
Physiological models "top-down" (80´s)
Process-based models
Detail of output

# Empirical growth and yield models

- ✓ The main driver is **site index**
- ✓ The **growth modules are statistically based** growth functions:
  - In more recent models difference equations derived by ADA or GADA procedures and that incorporate climate variables in the parameters
  - Site index curves and basal area as well as mortality are usually among the growth modules
- ✓ **High number of prediction modules** leading to a detailed output

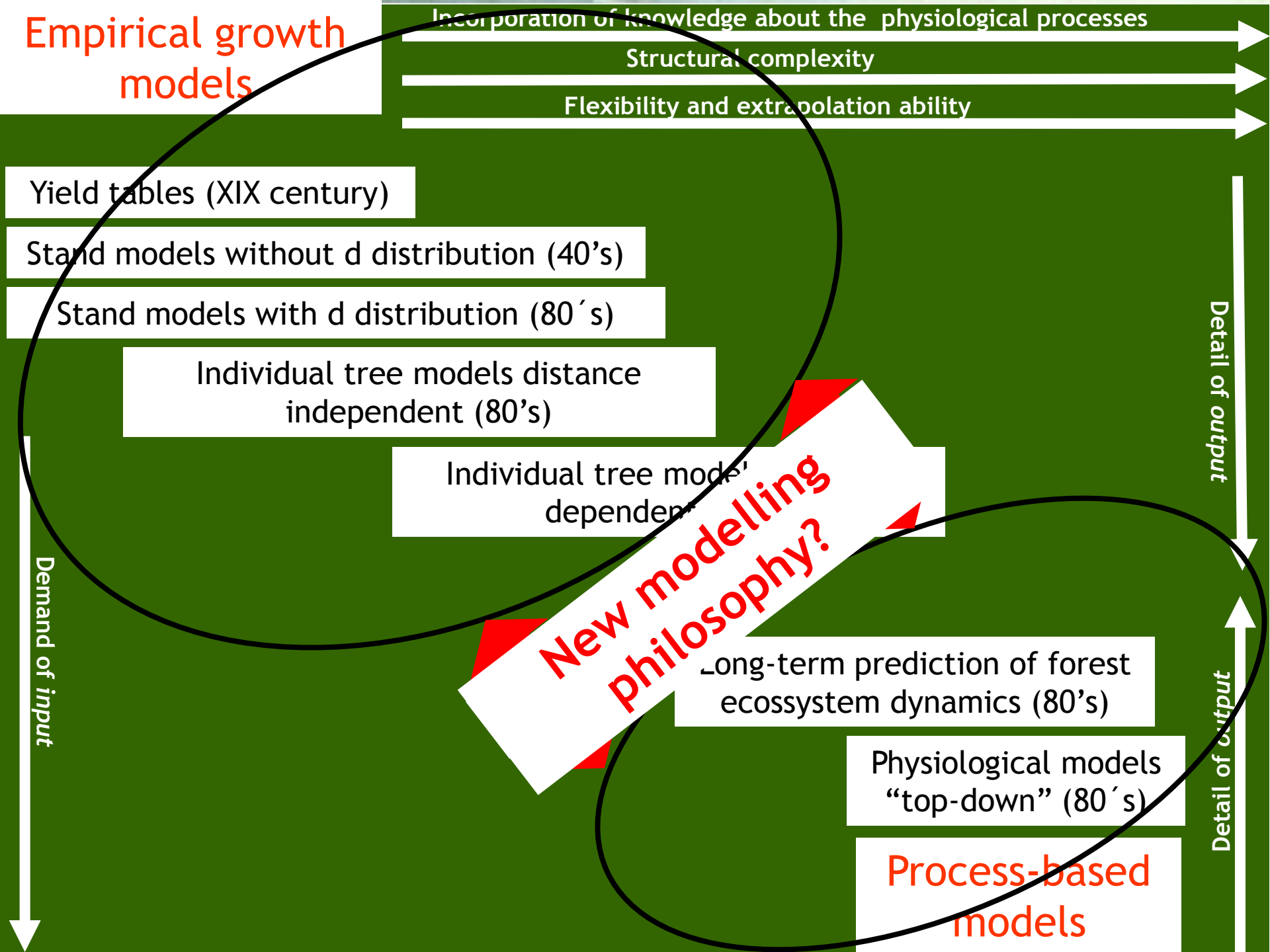
# Process based models

- ✓ Are driven by soil characteristics and climate
- ✓ The growth modules are, in some way, a simulation of physiological processes leading to the prediction of biomass growth
- ✓ Limited number of prediction modules
- ✓ High potential to simulate
  - Impacts of climate change, pests and diseases, genetic material, intensification of silviculture

# Forest models for the future how to build them?

# Are there models as required?

- ✓ No single model can meet all requirements of todays's environment and society!
- ✓ SO...
- ✓ The idea of combining different types of models and modelling philosophies emerged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New modelling philosophy?
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Process-based models
Detail of output
Demand of input
Detail of output

- ✓ **Should we build hybrid models?**
  - Models that combine parts from process-b[illegible] and empirical models

NO!

- ✓ **Or should we aim at developing "new" models that fulfill our requirements?**
  - Process-based growth modules added with prediction modules that were developed from data and statistical analysis
  - Developed by interdisciplinary teams of physiol[illegible] and traditional growth and yield modelers

YES!

# The need for forest simulators

## Do these new models fulfill all the requirements?

- ✓ No, some of the consequences of the global change environment can only be assessed at landscape, regional or higher spatial levels:
  - Simulation of hazards
    - The probability of occurrence is modeled at stand level
    - If occurring, the impact can be modeled at stand level
    - The real impact can only be studied at landscape or higher levels
  - The same is true for other issues, such as increasing wood demand, changes in forest management alternatives, land use changes


The
end!