- 1

Introduction to process-based forest modelling

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Outline

- 1. Fundamental concepts
- 2. Modelling cycle
- 3. Overview of process-based forest models



M.C. Escher - Ascending and Descending, 1960



1. Fundamental concepts



Models: What are they?

- *Model* A **simplification of reality** constructed to gain insights into a set of attributes of a physical, biological, economic, or social system.
- Conceptual model A **hypothesis** regarding the important factors that govern the behavior of an object or a process of interest.
- Statistical model A numerical model built using observations within a probabilistic framework.
- *Mechanistic (or process-based) model* A numerical model that explicitly **represents the understanding** of physical, chemical or biological processes.
- Simulation model A numerical model that represents the development of a solution by **incremental** steps through the model domain.



Model components

- *Modules* or *sub-models* An independent or self-contained component of a model (e.g. Farquhar's C3 photosynthesis model).
- State variables The dependent variables calculated within a model, which often change over the simulation (e.g. soil moisture).
- Parameters Terms in the model that are **fixed during a model run** but can be changed in different runs (e.g. soil texture).
- *Constants* Terms that are **fixed values under all runs**, representing known physical, biological or ecological activities (e.g. the speed of light).



Model assessment

- Verification Examination of the implementation to ascertain that they
 truly represents the conceptual model and there are no inherent
 numerical problems.
- Qualitative assessment Uncertainty in model predictions that cannot be quantified (i.e. about the theory underlying the model or the model design).
- *Uncertainty analysis* Investigation of the **effects** of lack of knowledge or potential errors of **inputs** (e.g. climate forcing) **on the model output**.
- Robustness The capacity of a model to perform well across the full range of conditions for which it was designed.
- Sensitivity The degree to which the model outputs are **affected by** changes in input parameters.
- *Transparency* The clarity and completeness with which data, assumptions, and methods of analysis are **documented**.



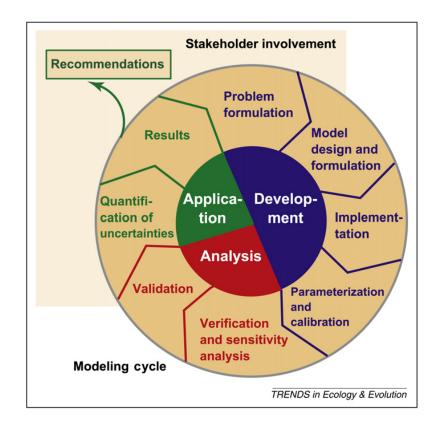


2. Modelling cycle



Modelling tasks: Development (1)

- 1. Problem formulation
 - Definition of objectives
 - Definition of the spatio-temporal physical domain
- 2. Model design and formulation
 - Data availability
 - Conceptual model
 - Use of existing vs. new model formulation
 - Compatibility with other modules
- 3. *Implementation*
 - Algorithmic design
 - Model coding (e.g. Python, C++)
 - Profiling and code optimization





Modelling tasks: Development (2)

4. Parameterization and calibration

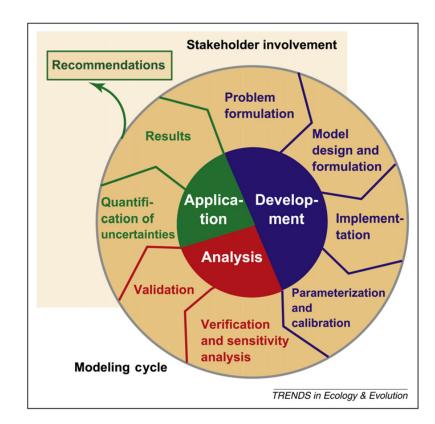
- Sources for direct parameter estimation
- Sources for parameter calibration
- Meta-modelling (estimation from the output of other models)

5. Model analysis

- Verification and qualitative assessment
- Sensitivity/uncertainty analysis
- Formal evaluation (validation)

6. Model application

- Simulation and documentation
- Quantifying uncertainty
- Evidence for decision

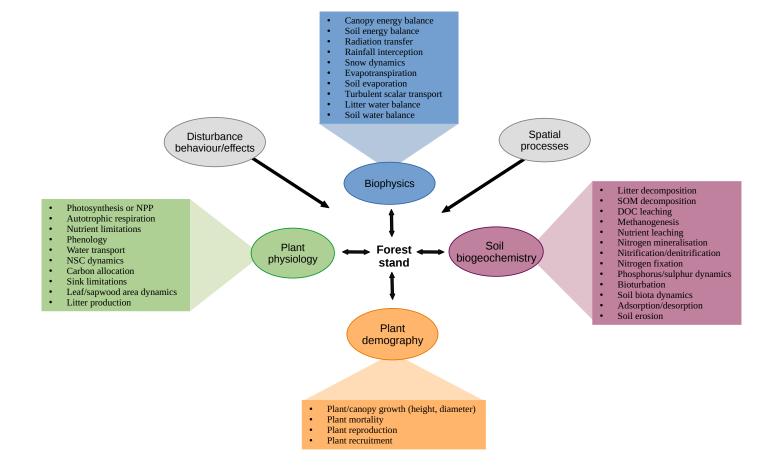




3. Overview of process-based forest models



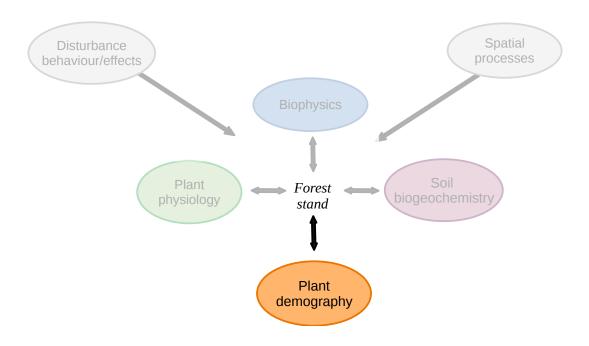
Processes





Forest gap models

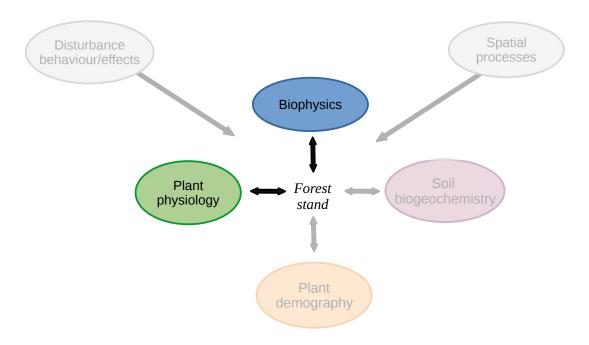
FORCLIM, FORCEEPS, GREFOS





Soil-vegetation-atmosphere transfer model

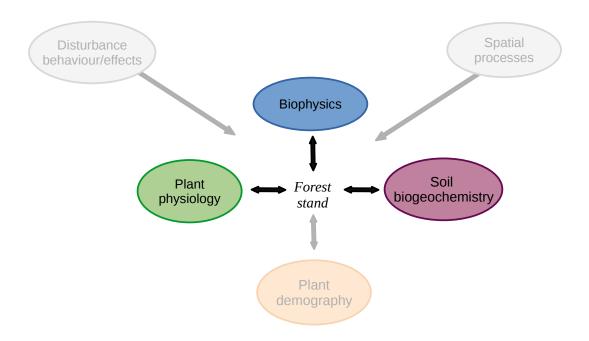
BILJOU, MuSICA, CANVEG





Forest biochemical model

CASTANEA, GOTILWA+, FOREST-BGC





Watershed ecohydrological model

RHESYS, ECH2O, Tethys-Chloris

