Introduction to modelling forest dynamics

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Interdisciplinary Summer School on Forest Ecosystems

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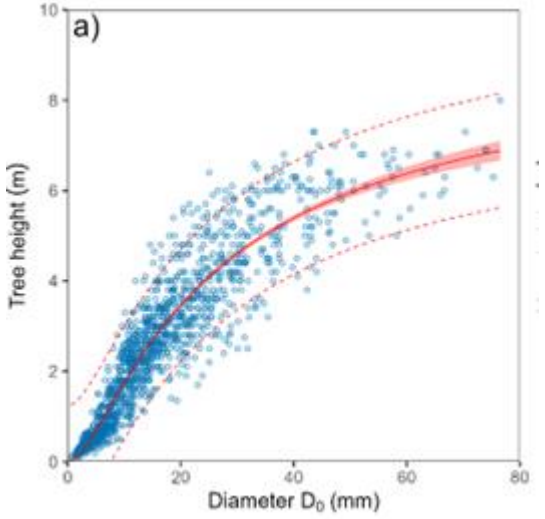
Model

Models of vegetation dynamics

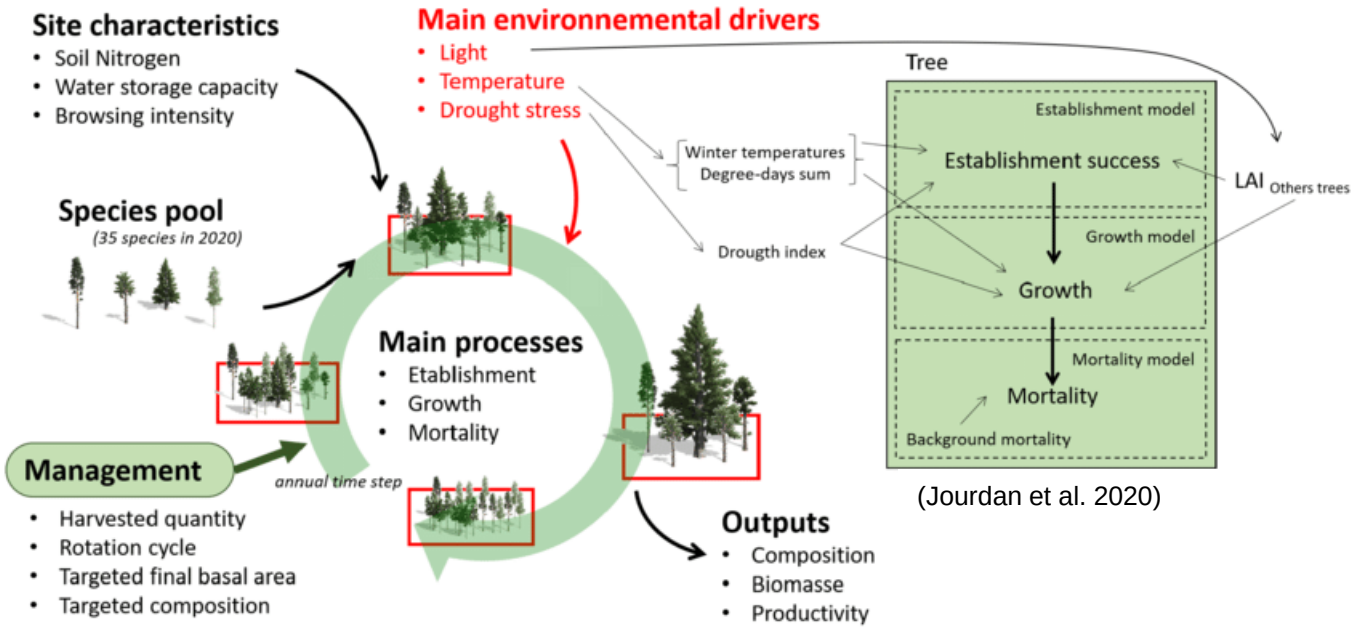
Model = a simplified representation of reality
= a simplified description, especially a mathematical one,
of a system or a process, to assist calculations and predictions

Simple models – relationships between two variables, e.g. diameter and height



(Konôpka et al. 2023)

Complex models simulate multiple processes and interactions in ecosystems



(Jourdan et al. 2020)

All models are wrong, but some are useful

Forest dynamics

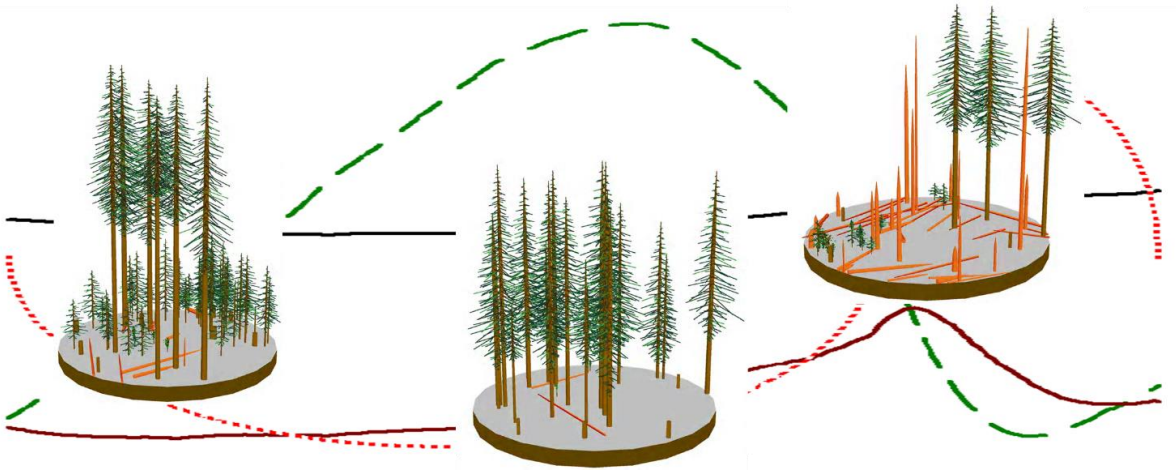
Forest dynamics

= changes of a forest ecosystem due to the underlying physical and biological forces

- occurs at different spatial and temporal scales:

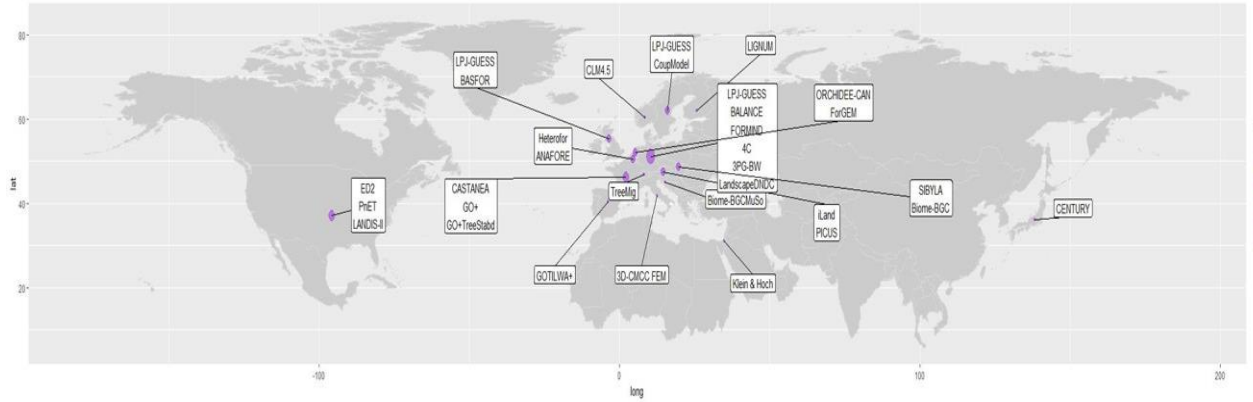
1) the dynamics caused by individual-level processes - tree growth and mortality,

2) the dynamics of the mosaic of forest stands caused by disturbances:
    - natural (forest fires, hurricanes etc.)
    - anthropogenic (silvicultural operations)

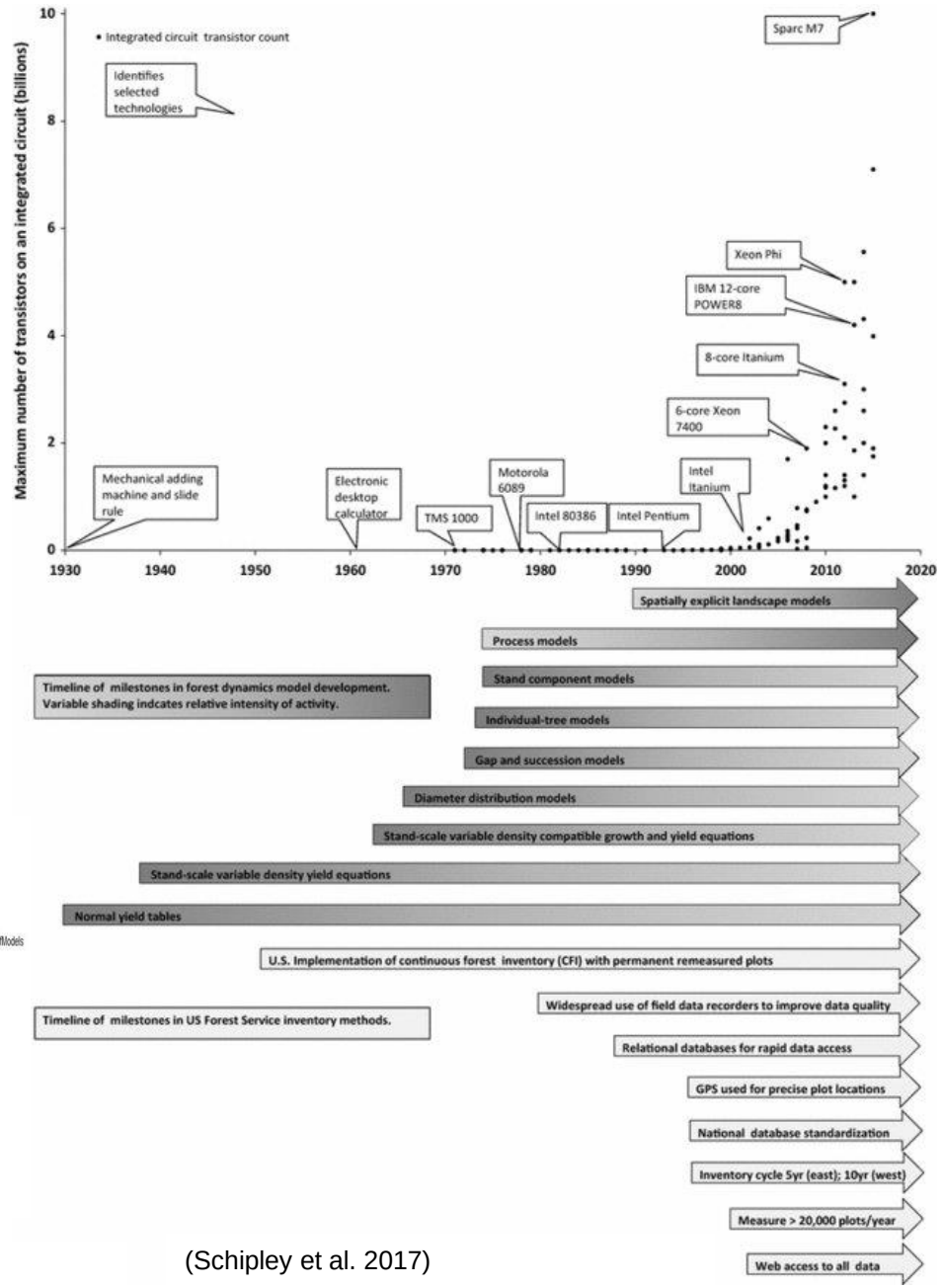


Models of vegetation dynamics

1950



(Merganičová et al. 2019)



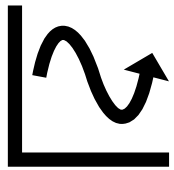
(Schipley et al. 2017)

What are models for?

To **understand** and analyse the behaviour of the system,
relationships,
processes,
interactions in the system

To check the **impact** of
environmental conditions,
management,
disturbances

} on forest dynamics



To make **predictions** of forest development under different
climate
management
disturbance

} scenarios

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What are models for?

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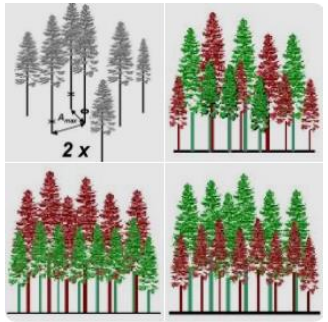
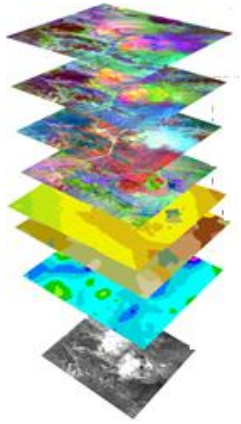
Link of modelling to other disciplines

Plant physiology

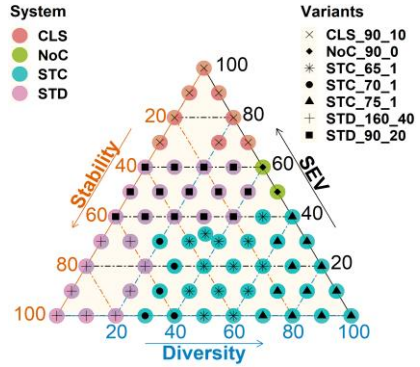
Silviculture



Remote sensing

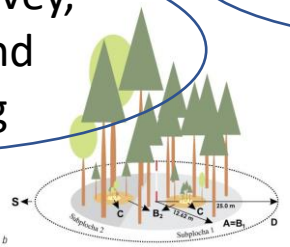


Modelling ecosystem dynamics

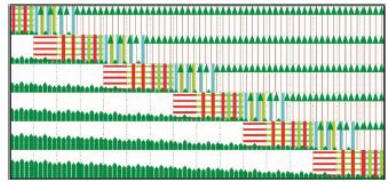


Nature protection

Ecosystem survey, inventory and monitoring



Management planning



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Types of models

➢From the point of **applied principles**:

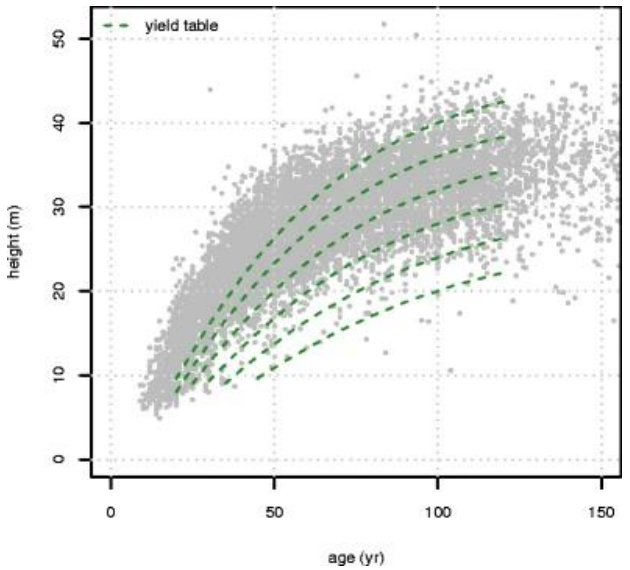
- *Empirical models*

- *Process-based (physiological) models*

Types of models

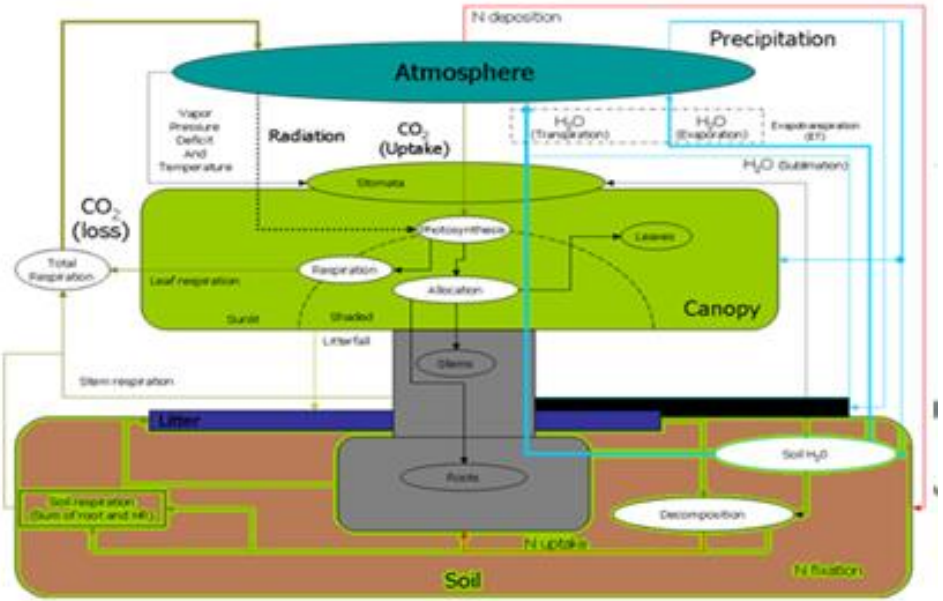
➢From the point of **applied principles**:

- *Empirical models* = based on statistical relationships, derived from observed data
  e.g. yield tables

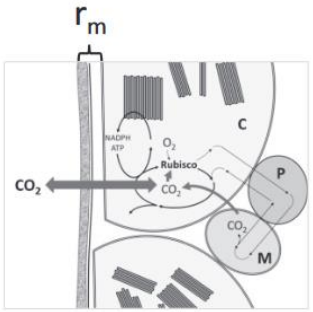


(Brandl et al. 2018)

- *Process-based (physiological) models* = based on mathematical description of processes in forests



Photosynthesis:



$$A = V_c - 0.5V_0\text{-}R_d$$

$$A = (C_i - C_c)/r_m$$

(Von Caemmerer 2013)

http://www.ntsg.umt.edu/project/biome-bgc

Types of models

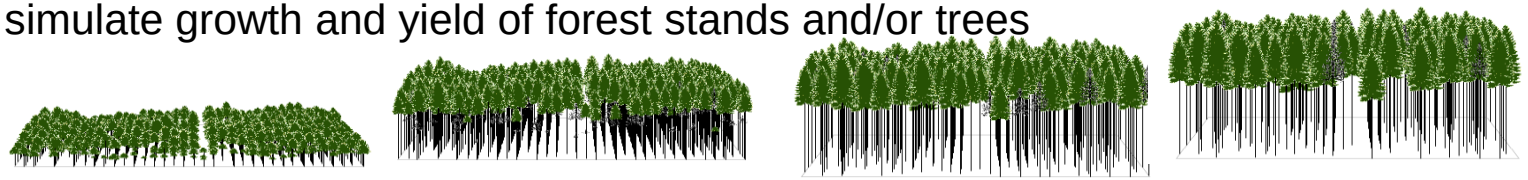
➢From the point of **modelled dynamics**:

- *forest growth models*
- *succession (gap) models*
- *functional-structural models*

Types of models

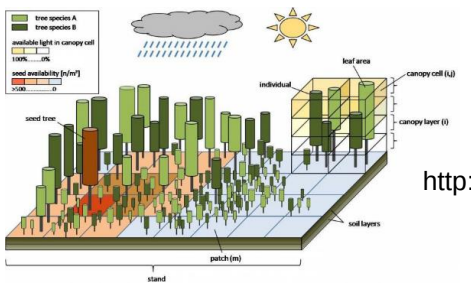
➢From the point of **modelled dynamics**:

- *forest growth models* - simulate growth and yield of forest stands and/or trees

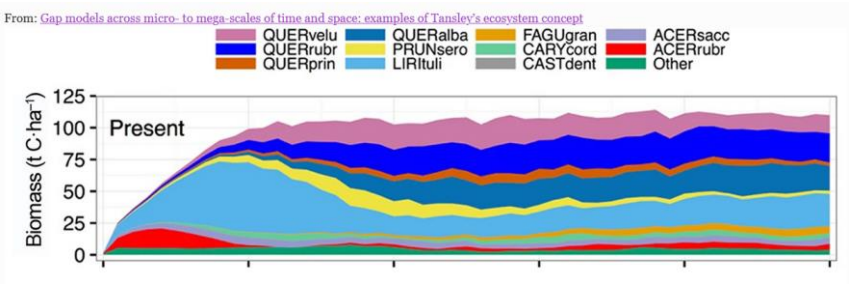


Year:	2000	2020	2050	2070
Age:	14	34	64	84

- *succession (gap) models* - simulate long-term development

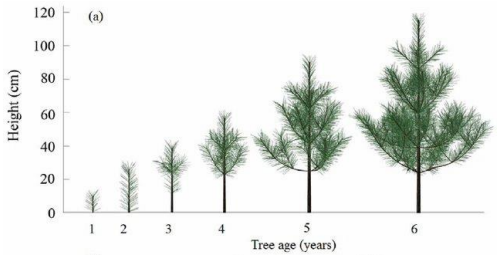


http://picus.boku.ac.at



(Shugart et al. 2020)

- *functional-structural models* - simulate growth of individual parts of trees – branches, twigs, buds



(Wang et al. 2012)

Types of models

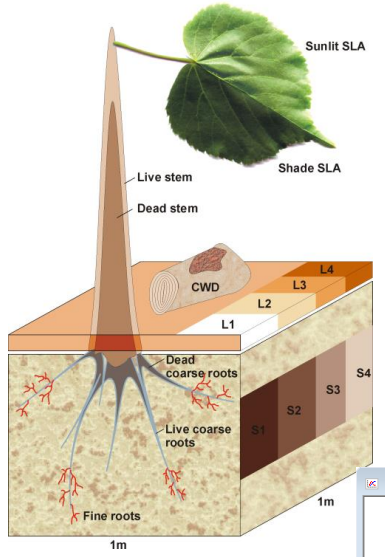
➢From the point of **spatial resolution**:

- *Stand scale models*
- *Cohort models*
- *Individual tree based models*

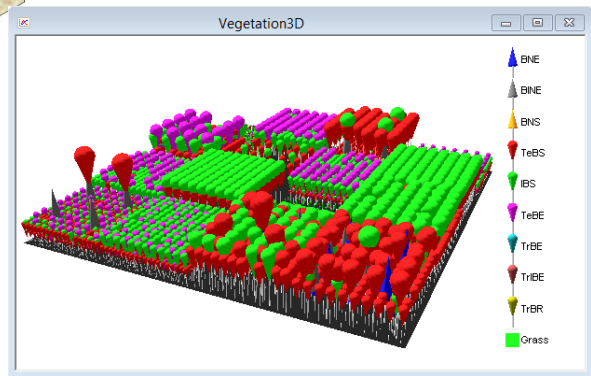
Types of models

➢From the point of **spatial resolution**:

- *Stand scale models* – the smallest simulated unit is a forest stand
  e.g. yield tables, big leaf models

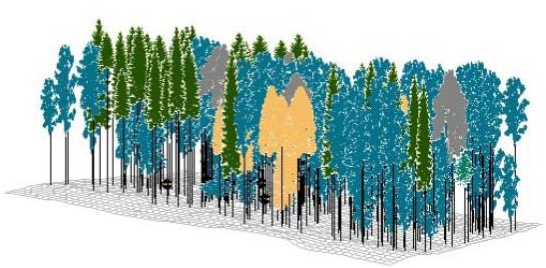


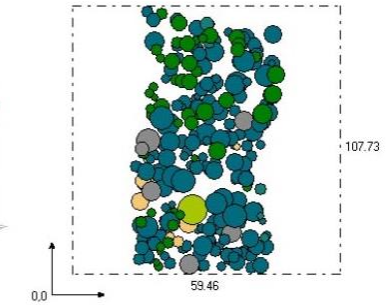
- *Cohort models* – cohort = a group of trees of same species, similar size and/or age, each cohort is represented by one individual



https://web.nateko.lu.se/lpj-guess/education/docs/graph.html

- *Individual tree based models* –
  distance-dependent
  distance-independent





https://etools.tuzvo.sk/sibyla

➢From the point of **temporal resolution**:

- *Models working at hourly to decadal level*

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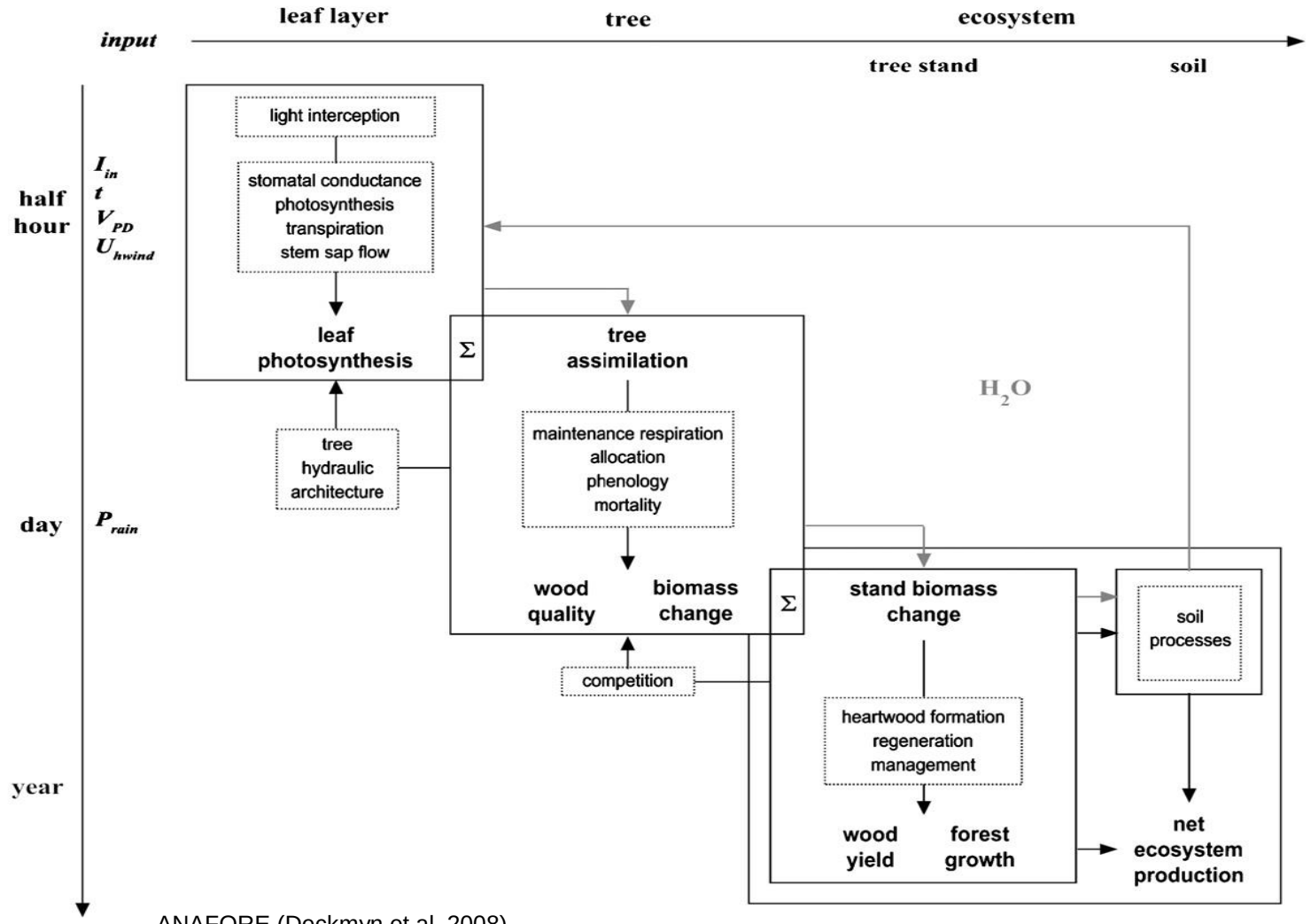
Hybrid models

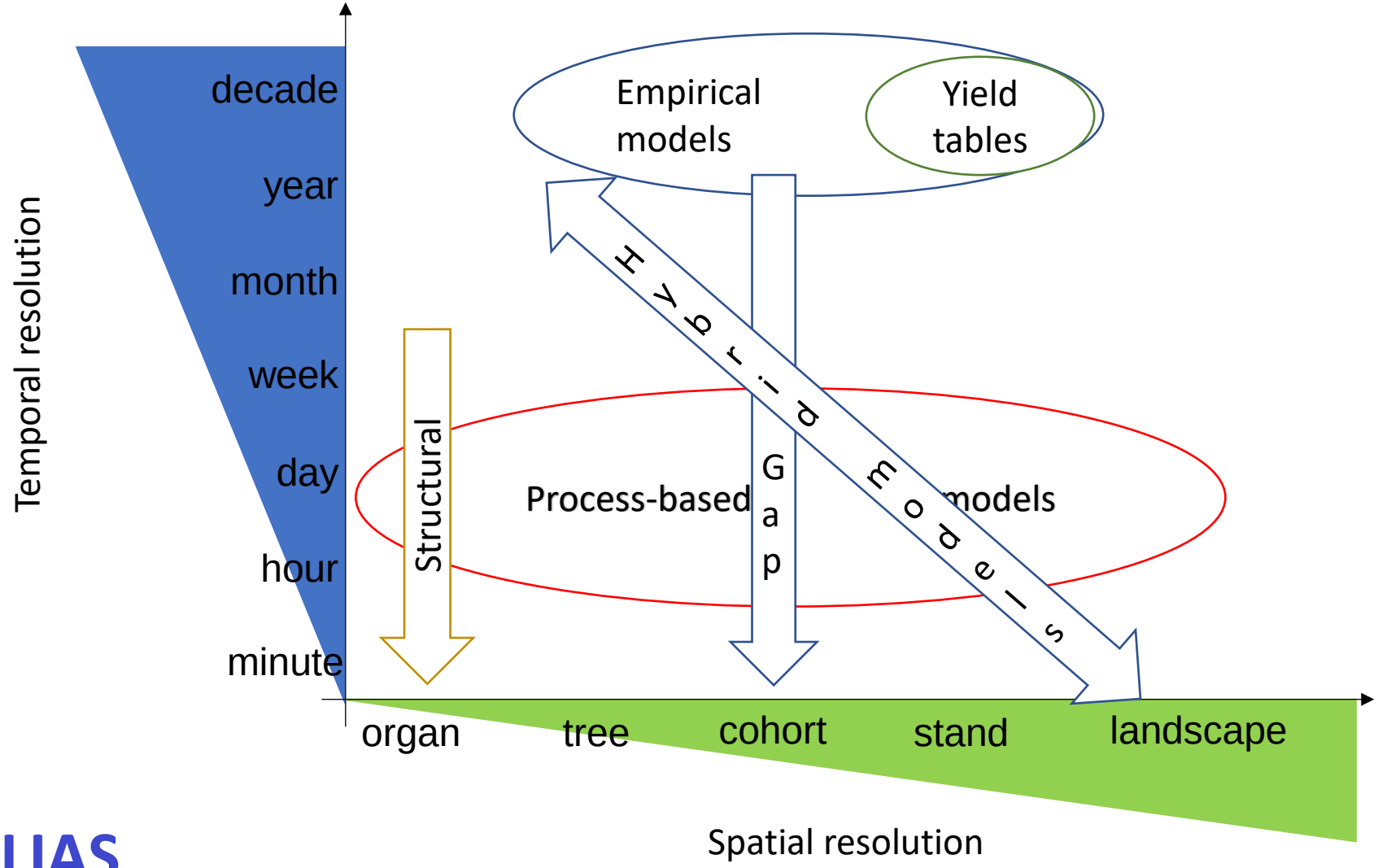
Hybrid models

= combine different principles and/or resolutions



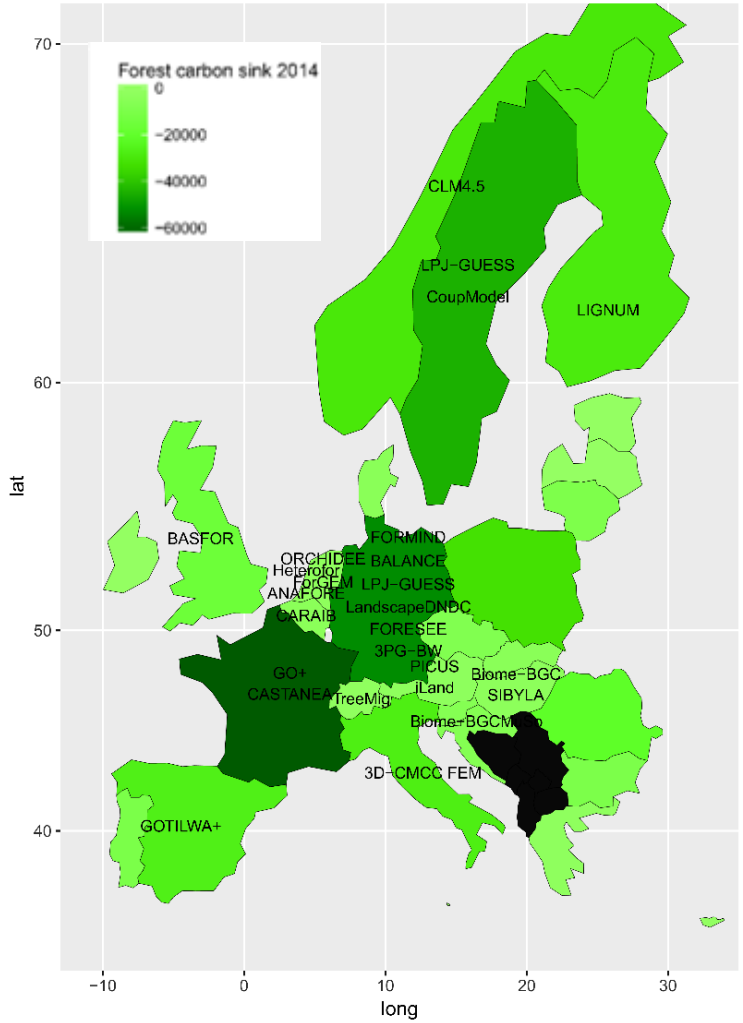
ANAFORE (Deckmyn et al. 2008)

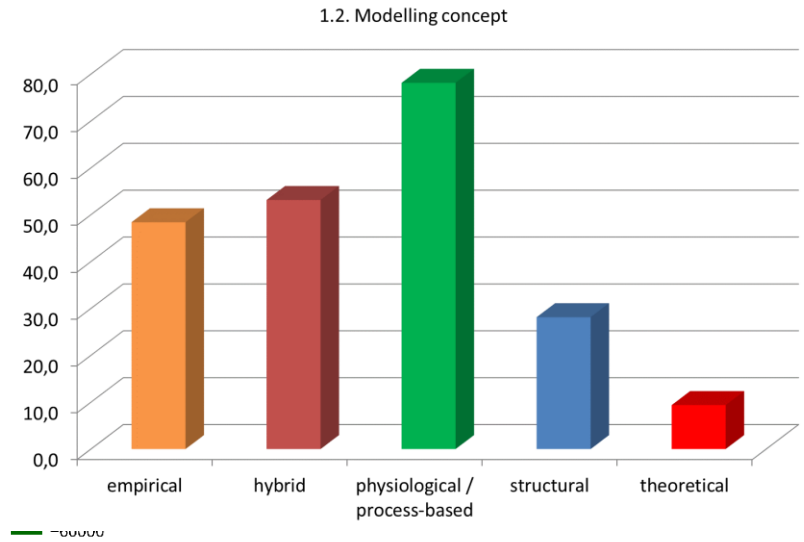
Types of models

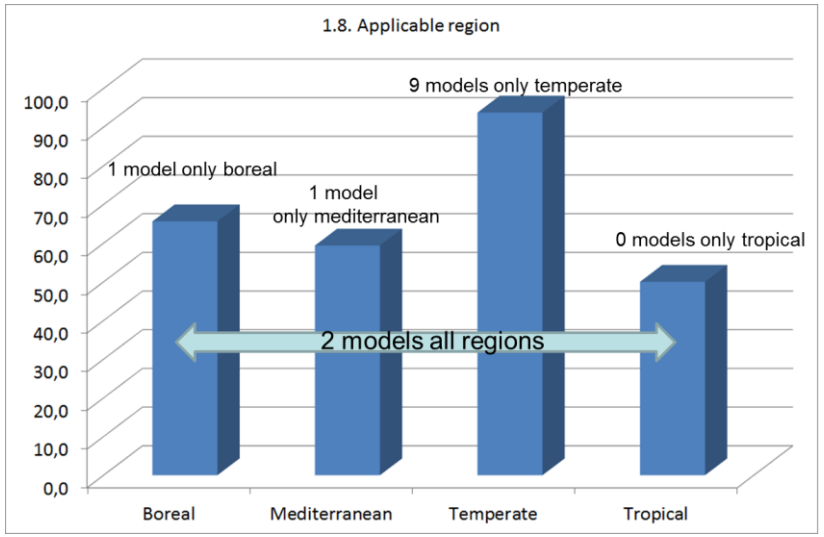


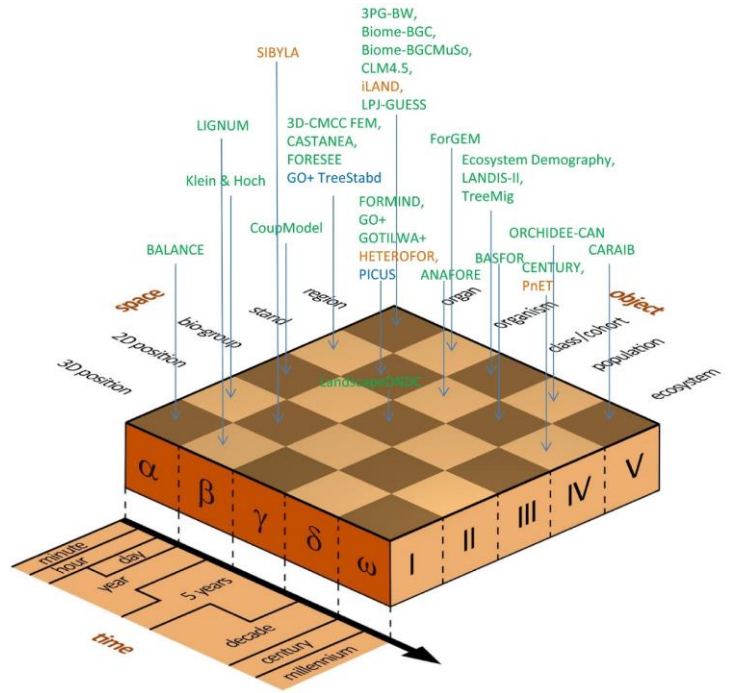
Models around Europe

31 models
16 countries

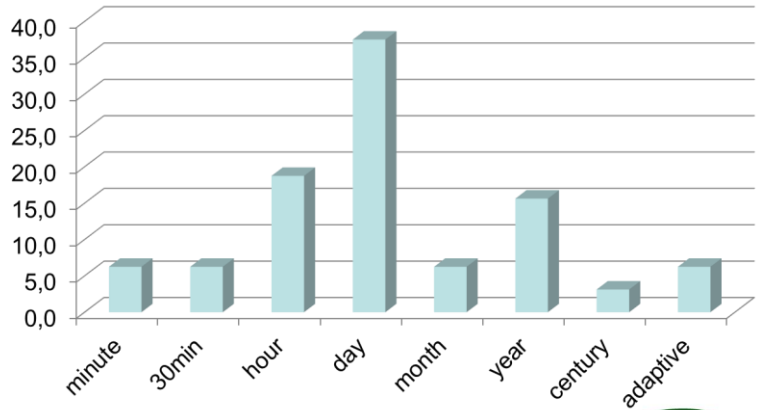








1.7. Shortest model time step



Merganicova et al. 2019

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What modeling studies can be done?

- **Model evaluation**: Compare model results to observations
  Evaluate simulated processes

- **Detection of climate change impacts**:
  Is the model able to simulate observed signals?

- **Attribution of climate change impacts**:
  Are the signals due to climate change or part of the internal variability of the system?

- **Projection of impacts of future climate change**

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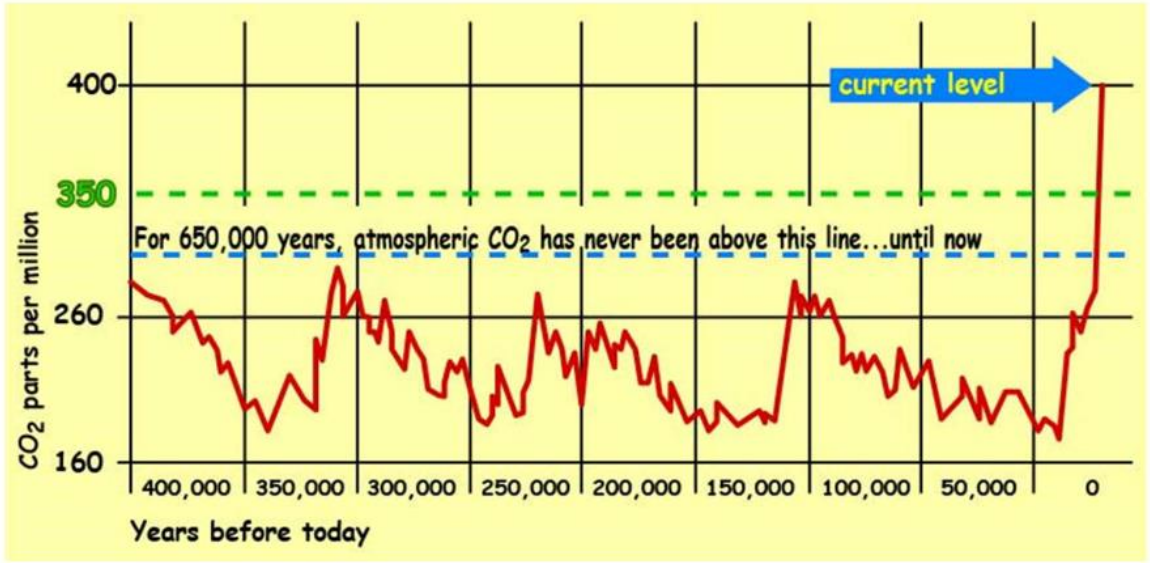
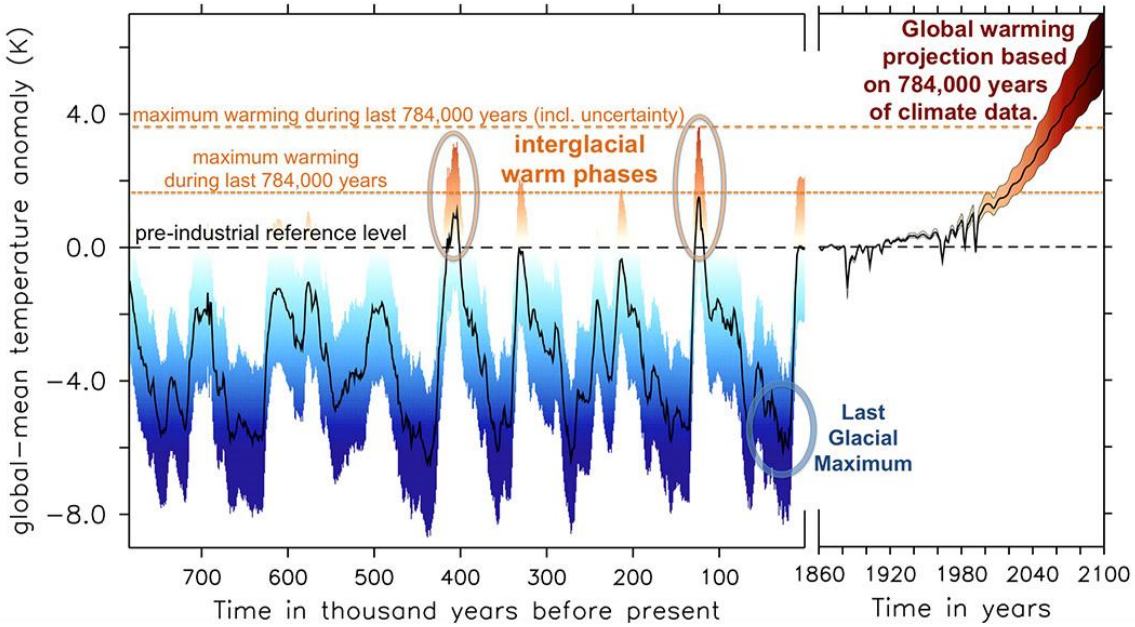
Climate change and modelling

- Climate change brings novel combinations of environmental conditions that plants have not encountered yet





- Climate-sensitive models needed

https://www.soest.hawaii.edu/soestwp/announce/news/new-study-concludes-warm-climate-is-more-sensitive-to-changes-in-co2/

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Climate change and modelling

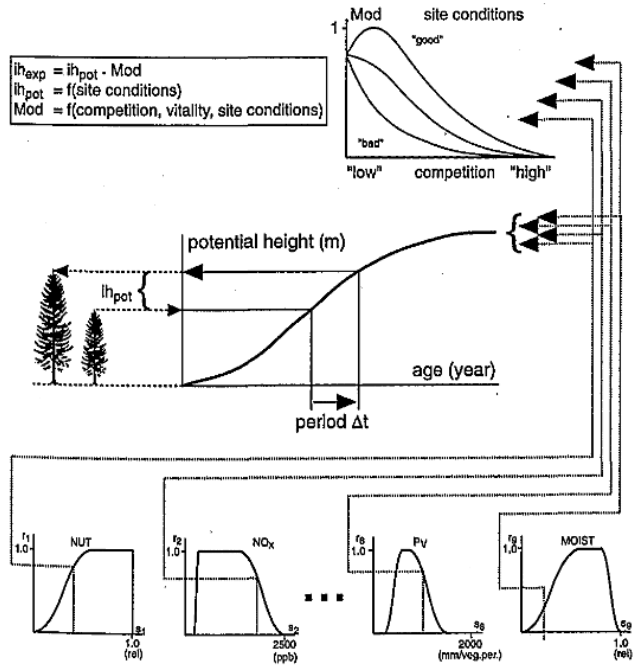
Climate-sensitive models

Empirical

e.g. SILVA 2.2 (Pretzsch 1992, 1997, 2002)

SIBYLA (Fabrika 2005)

Ecological amplitudes according to Kahn (1994)

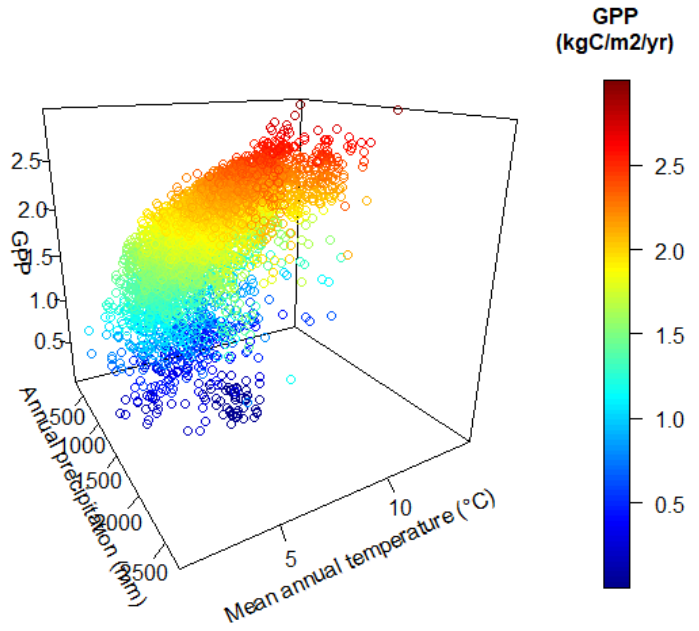


(Pretzsch 2002)

Process-based

climate characteristics are drivers

all climate-sensitive

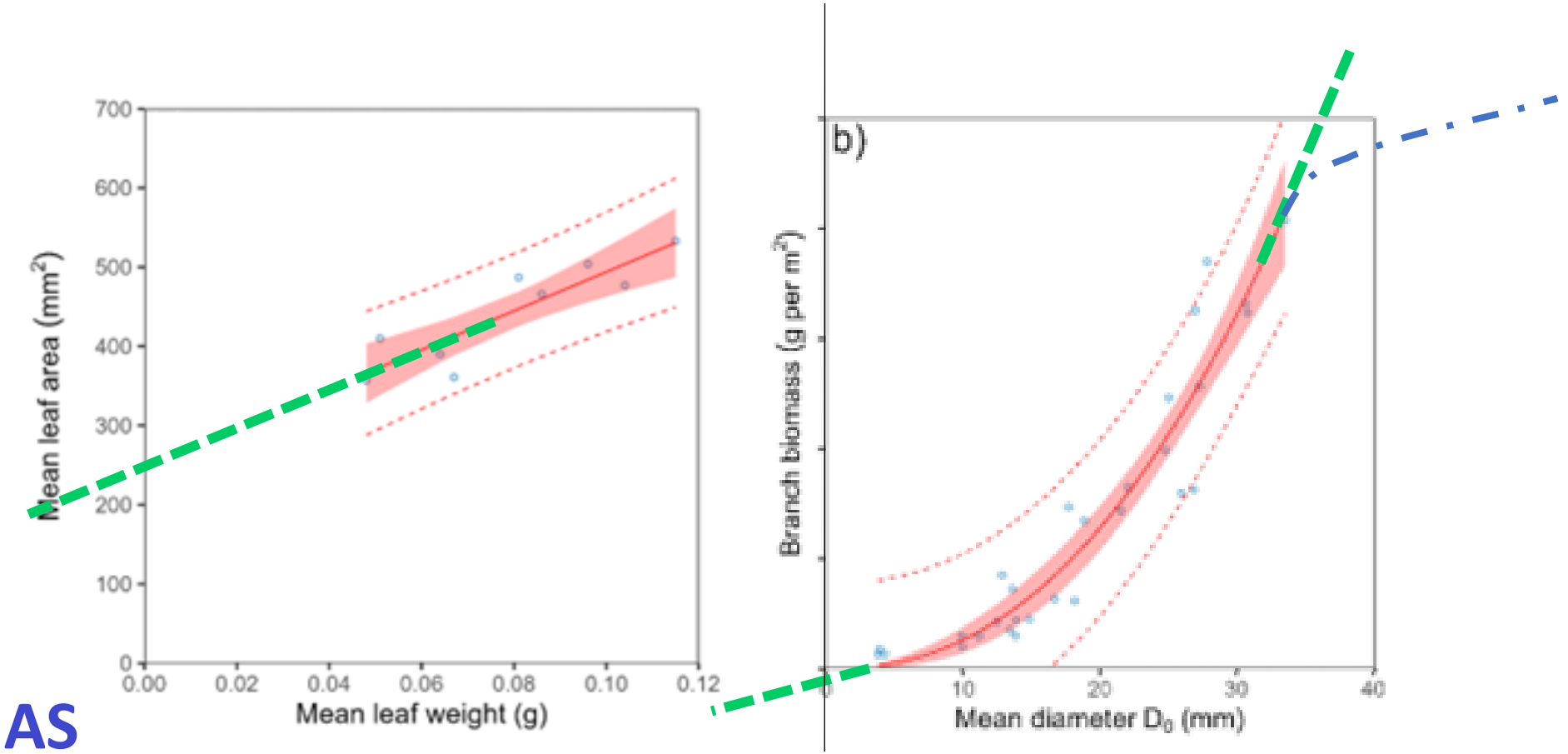


(Merganicova et al. 2024)

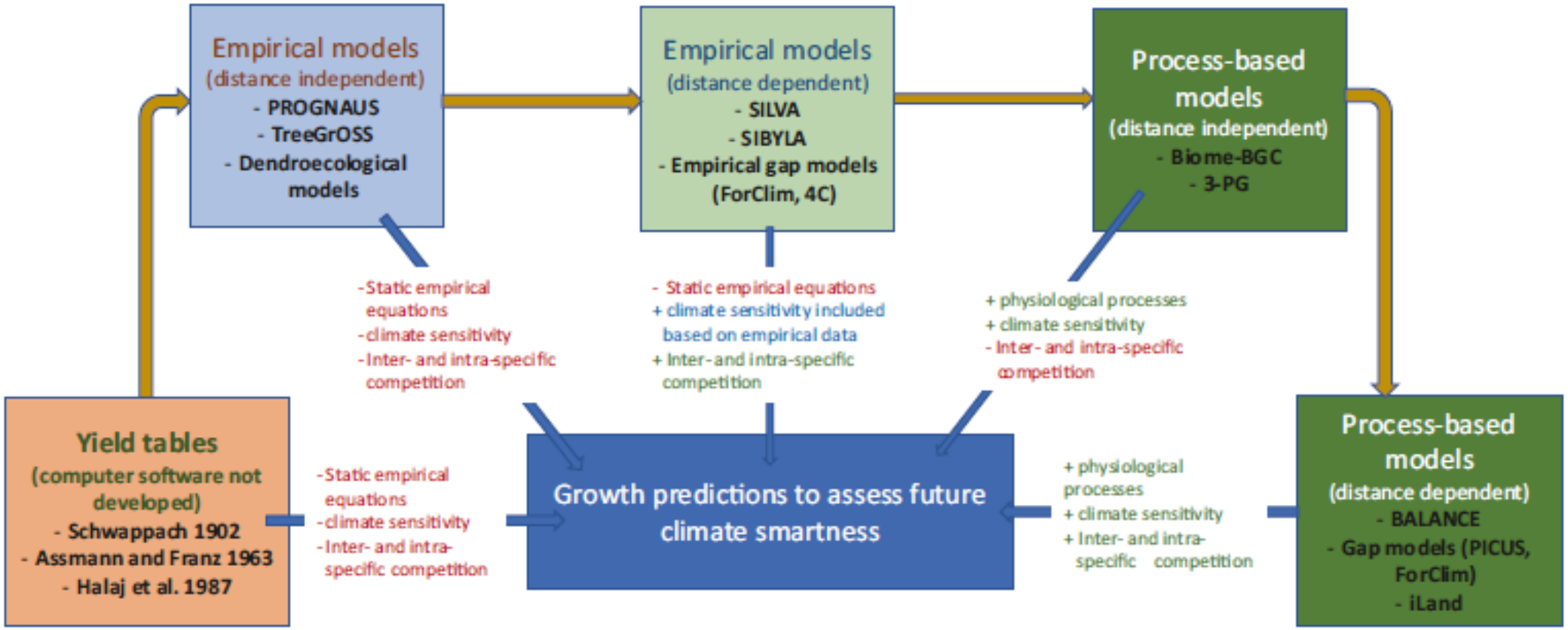
Climate change and modelling

Empirical models

Extrapolation problem – models are valid only within the range of observations that were used to derive models



Climate change and modelling



(Bošeľa et al. 2022)

Next programme

Process-based models

Stand scale –Andrey 

 Cohort model – Thirza

Individual tree based model - Katarina 

 Large scale applications – Mykola

SSP scenarios - Andrey 

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ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

Thank you for your attention.

Have fun