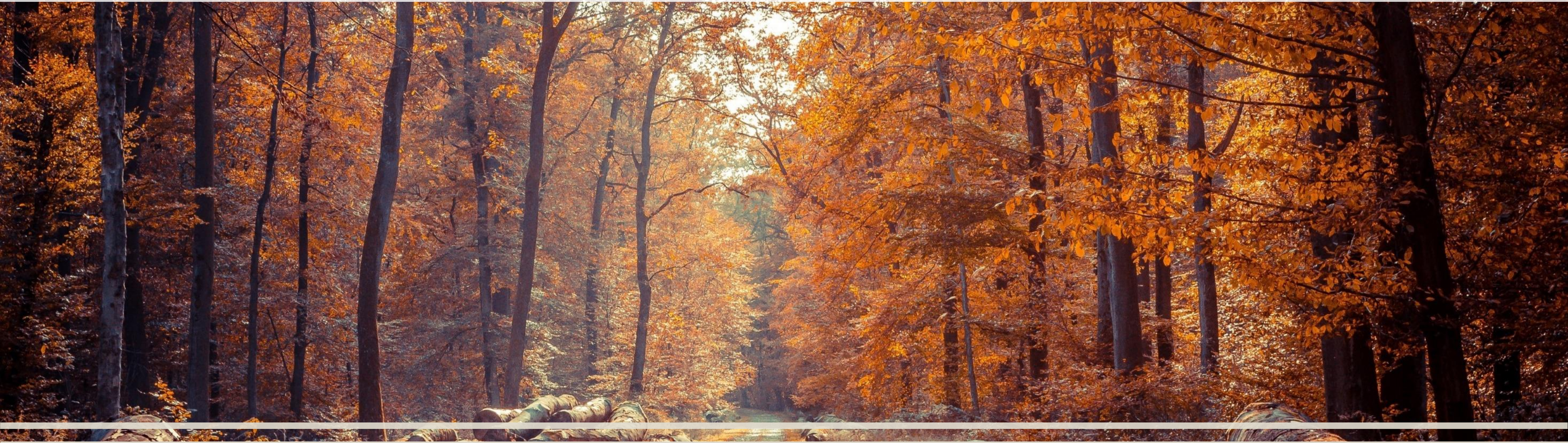
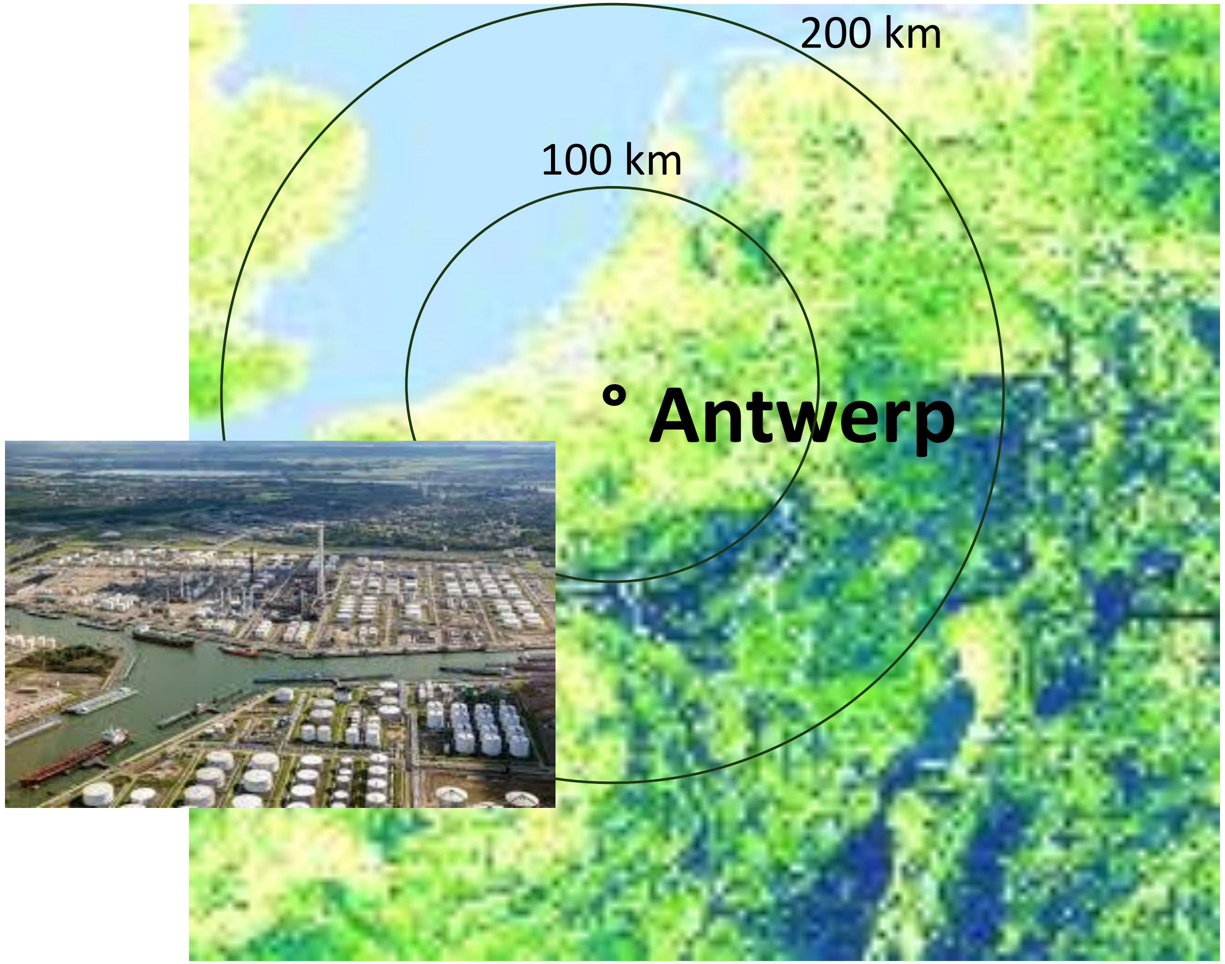


Mechanistic growth simulation versus empirical growth tables in spatio-temporal decision support for forest management

Ilié Storms, Bruno Verbist, Jos Van Orshoven, **Bart Muys**

The Biorefinery challenge

BioWood: *"Creating a new lignin-first value chain in Flanders"*



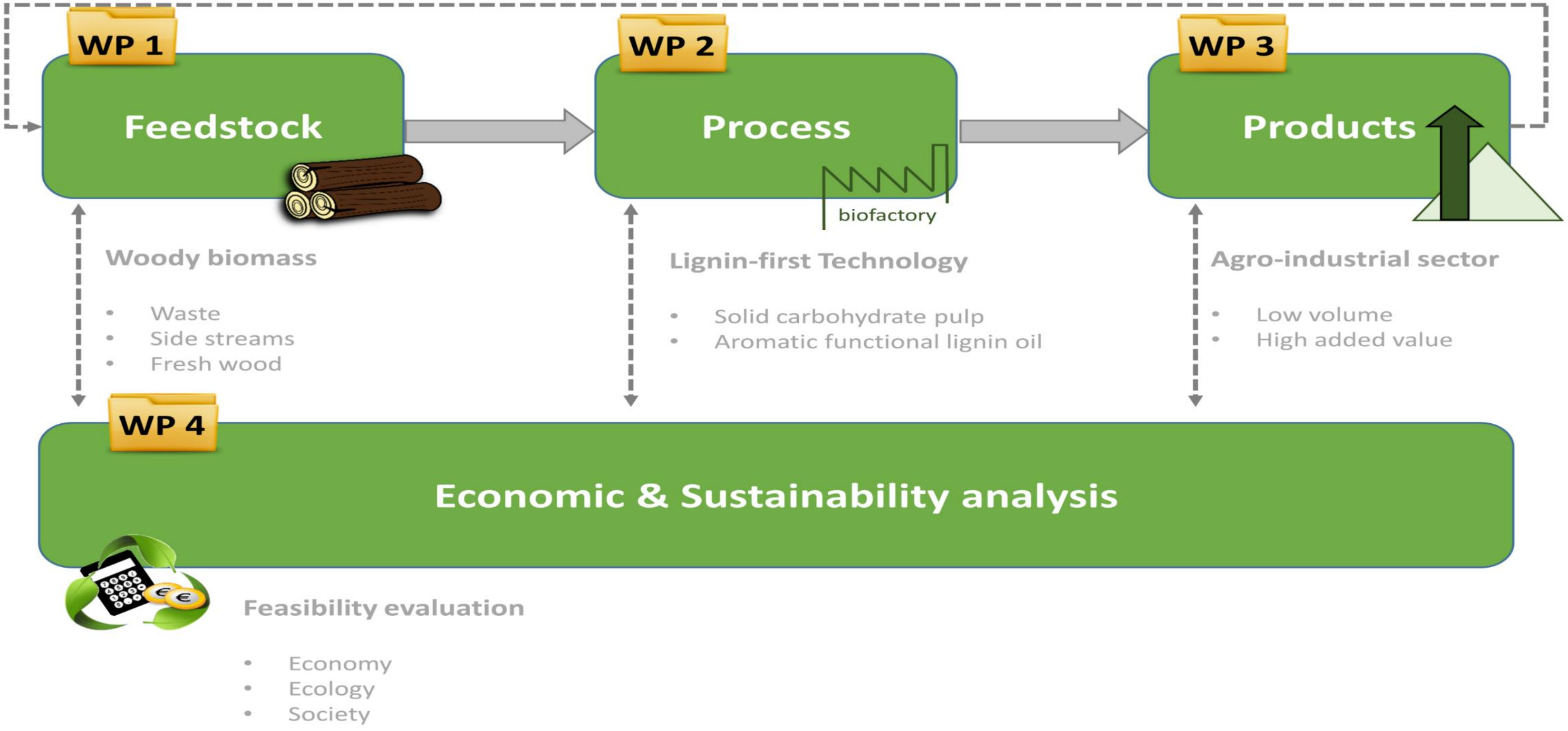
Source: EFI forest productivity map of Europe

Harbour of Antwerp: petrochemical hub n°1 in Europe

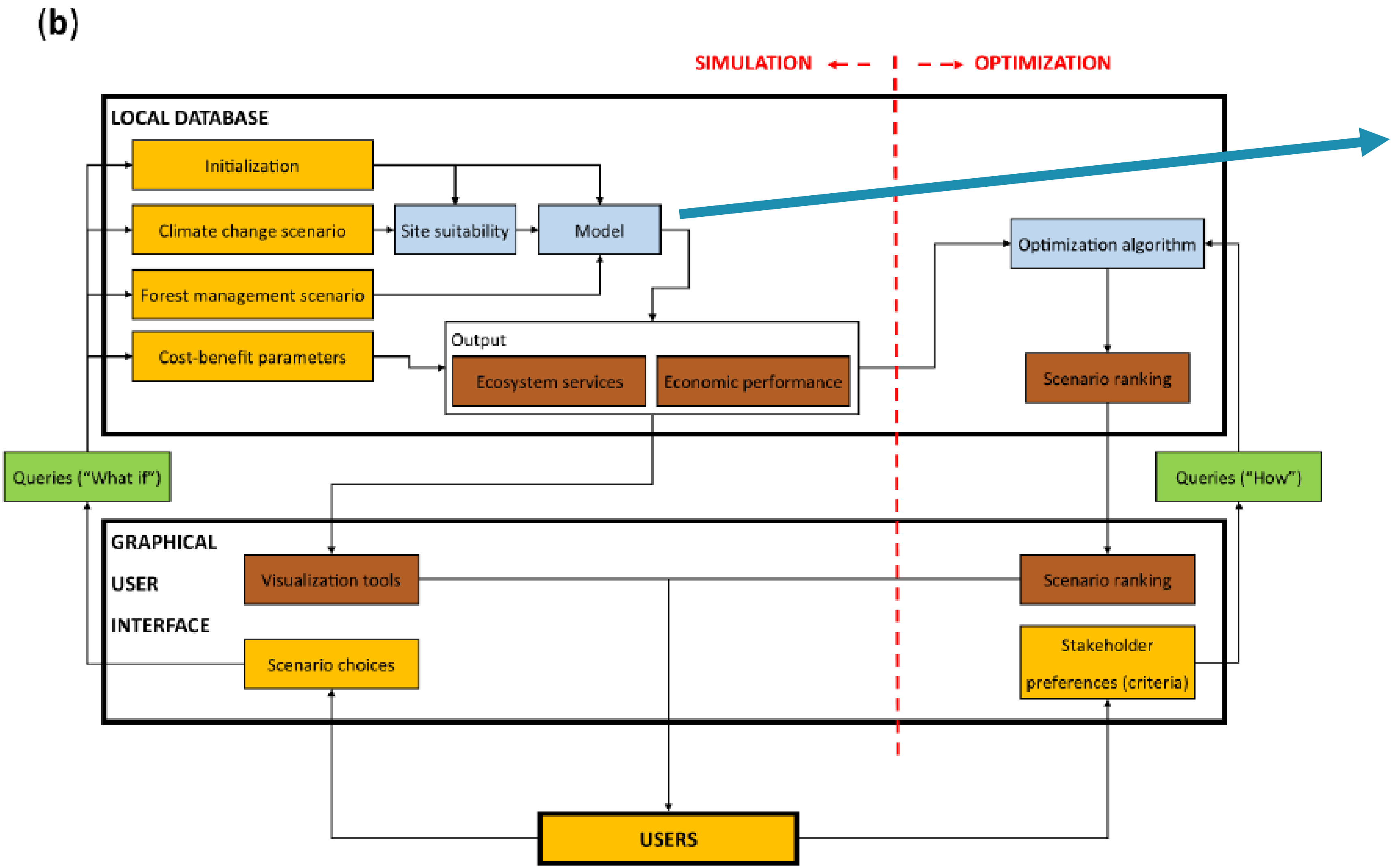
- 45 Mt/yr petrol import (= not sustainably replaceable with European wood)
- 6% or 2.7 Mt/yr for the petrochemical industry (sustainable provision with locally sourced wood possible?)

The BioWood project

BioWood: *"Creating a new lignin-first value chain in Flanders"*



Sim4Tree Decision Support System



Empirical yield tables

(Jansen & Oosterbaan 2018, Opbrengstabellen voor Nederland)

Dalemans et al. 2015 *Forests*

Empirical versus mechanistic forest growth models

Empirical models:

- seek to describe statistical relationships of growth with predictors, but have limited understanding of the forest's structure and function.
- Consequence: prediction in other (future) forests uses the same parameters (**parameter constancy**)

Mechanistic models:

- seek to predict growth by describing the key mechanisms determining structure and function of the forest.
- Consequence: their mechanistic understanding implies that they keep some degree of relevance in other (future) forests (**mechanism constancy**)

(after Korzukhan et al. 1996, *Can J For Res*)

For this reason, mechanistic forest models have been considered superior, especially in a context of climate change. But often they have **untransparant empirical hocus-pocus**.

Process-based versus empirical models

(after Adams et al. 2013 Front. Plant Sci.)

	Process-based	**Empirical**
Relationship type	Causal	Correlative
Relative comprehensiveness	More comprehensive	Less comprehensive
Incorporation of mechanism	Explicit	Implicit
Primary source of error	Unknown parameters and processes	Extrapolation
Model accuracy	Lower	Higher
Data requirements	Higher	Lower
Spatial scale for calibration	Smaller	Smaller to larger
Spatial scaling of prediction	Smaller to Larger	Best at scale of calibration

Regional forest growth modelling under climate change

Aim: high accuracy forest growth predictions as an input for decision support to the future forest-based bioeconomy

Objective: Improve the flexibility and accuracy of empirical yield tables to describe actual forest growth using mechanistic modelling techniques

Research questions:

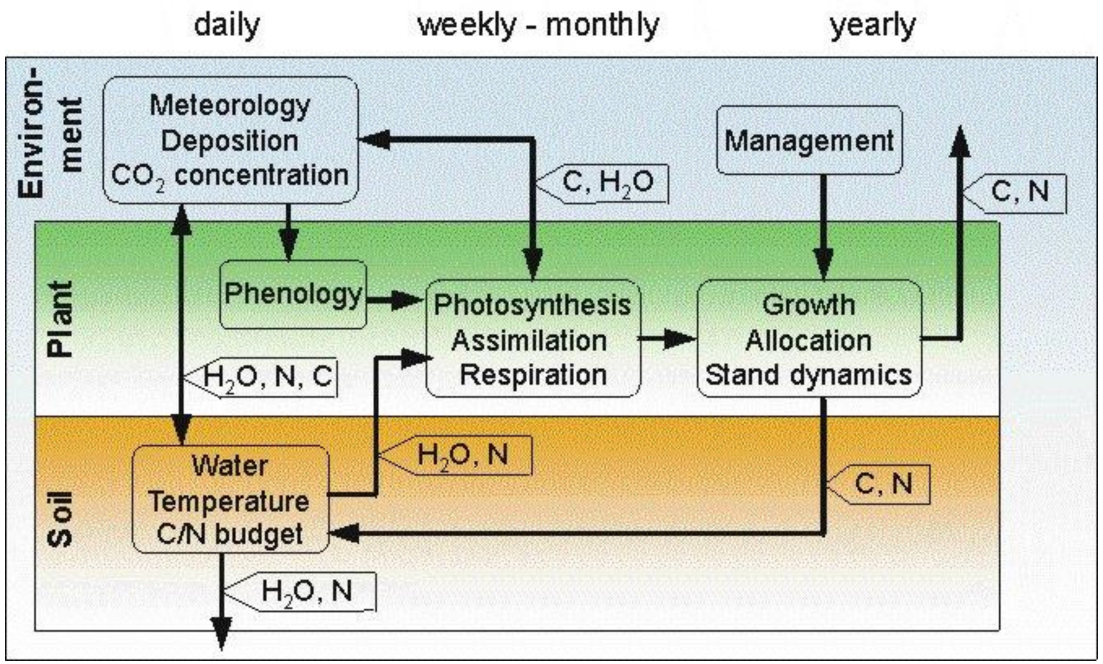
1. Are scaling factors necessary to predict future forest growth using empirical yield tables?
2. Can mechanistic forest growth model provide these scaling factors?
3. To what extent will water and nitrogen influence future forest growth?

Output:

1. Mechanistic forest growth model for Flanders
2. Site and species specific scaling factors for yield tables for Representative Concentration Pathways RCP2.6, RCP4.5, RCP6.0 and RCP8.5

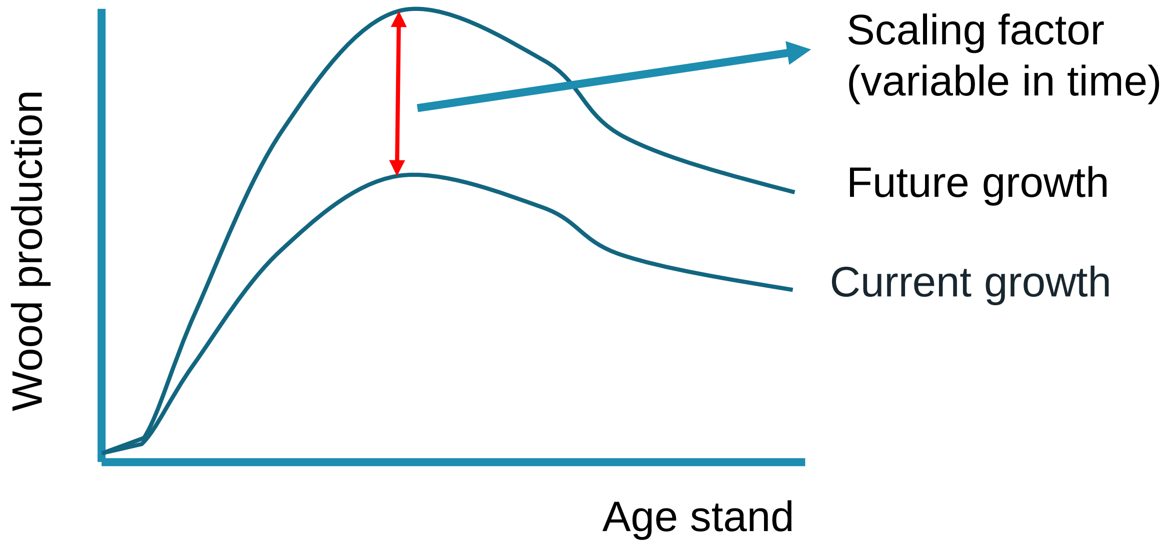
Mechanistic model: 4C

- Origin: Potsdam Institute for Climate Impact Research (PIK)
- Start development: 1997
- Tested in Germany, Belgium, Siberia, European scale
- Species:
    - *Beech*
    - *Norway spruce*
    - *Scots pine*
    - *Oak*
    - *Birch*
    - *Aspen*
    - *Douglas-fir*
    - *Black locust*
    - *Pine sp (sylvestris, halepensis, contorta)*

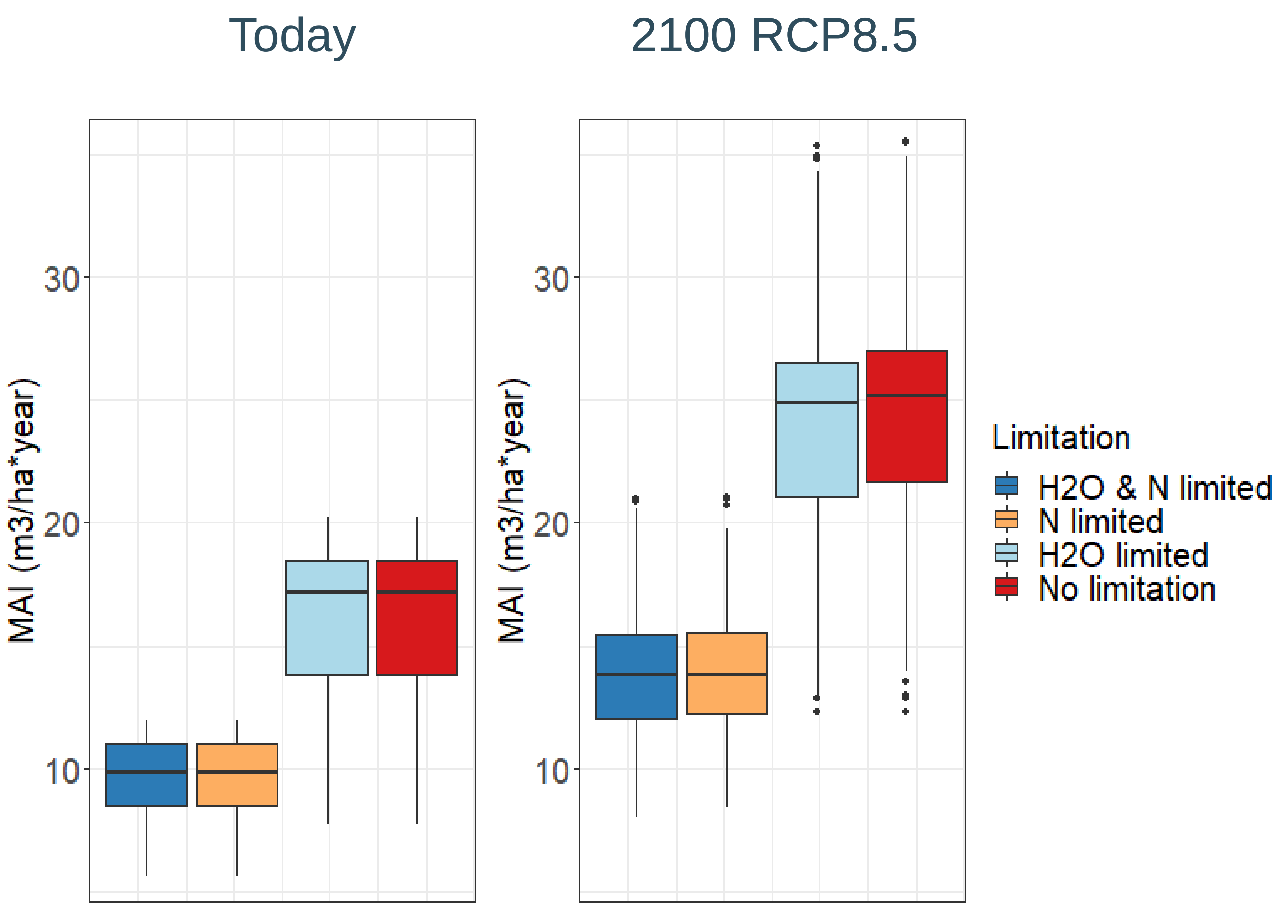


Scaling factors

Scaling factor: $$f(x,t) = \frac{Future\ growth}{Current\ growth}$$

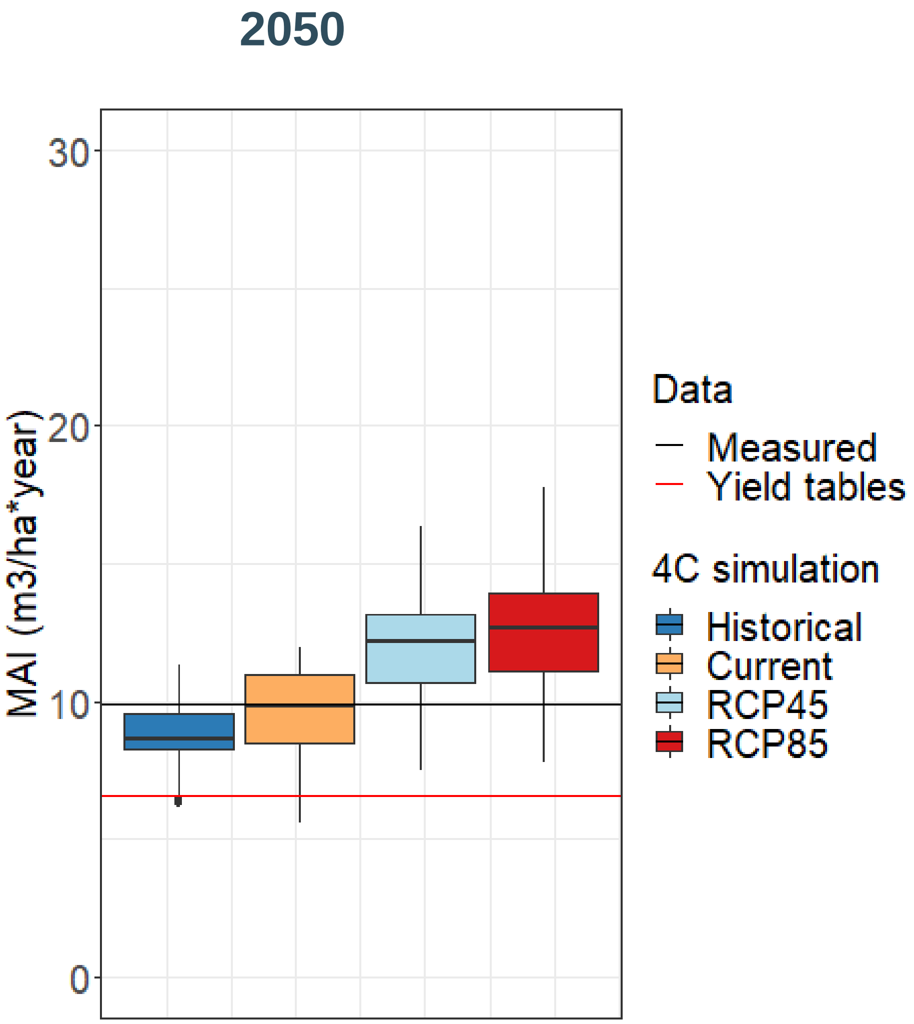


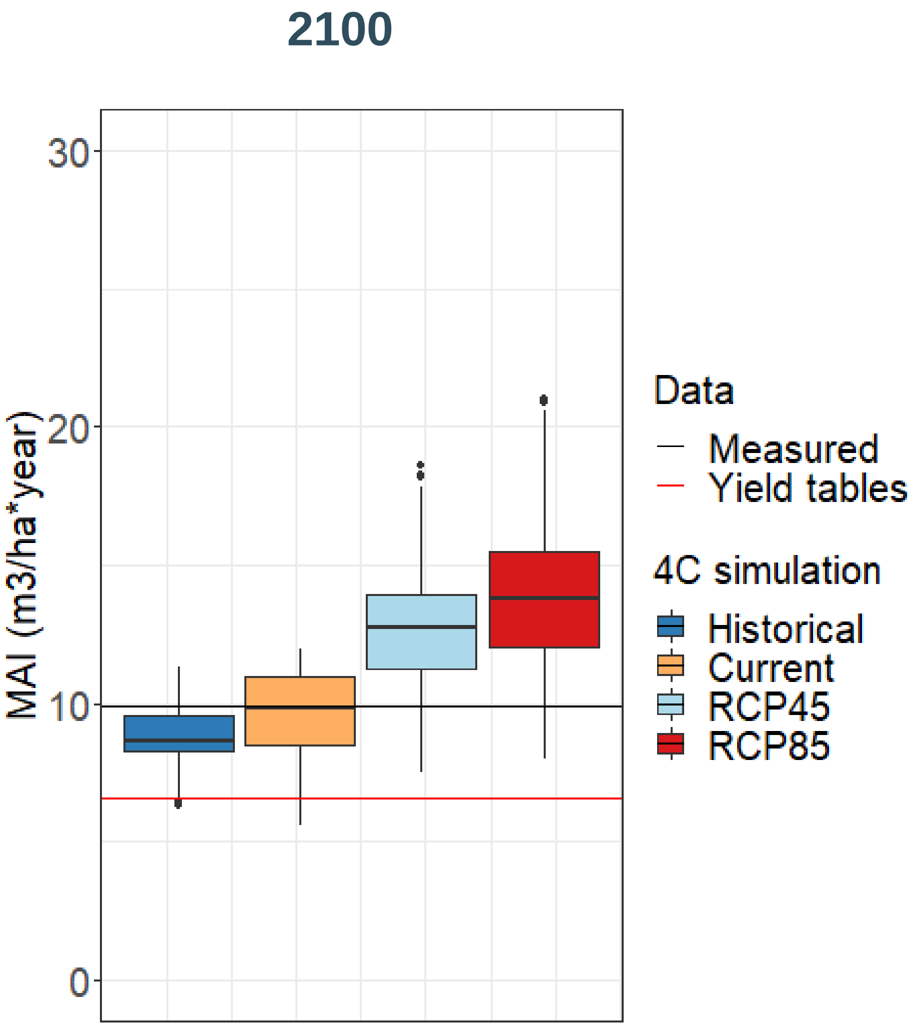
Sensitivity of the model



- Beech on sandy clay soil
- Considering CC, N and water limitation
- N limitation leads to rather realistic yields
- H20 limitation has very limited effect

Results Beech in level II plot 11





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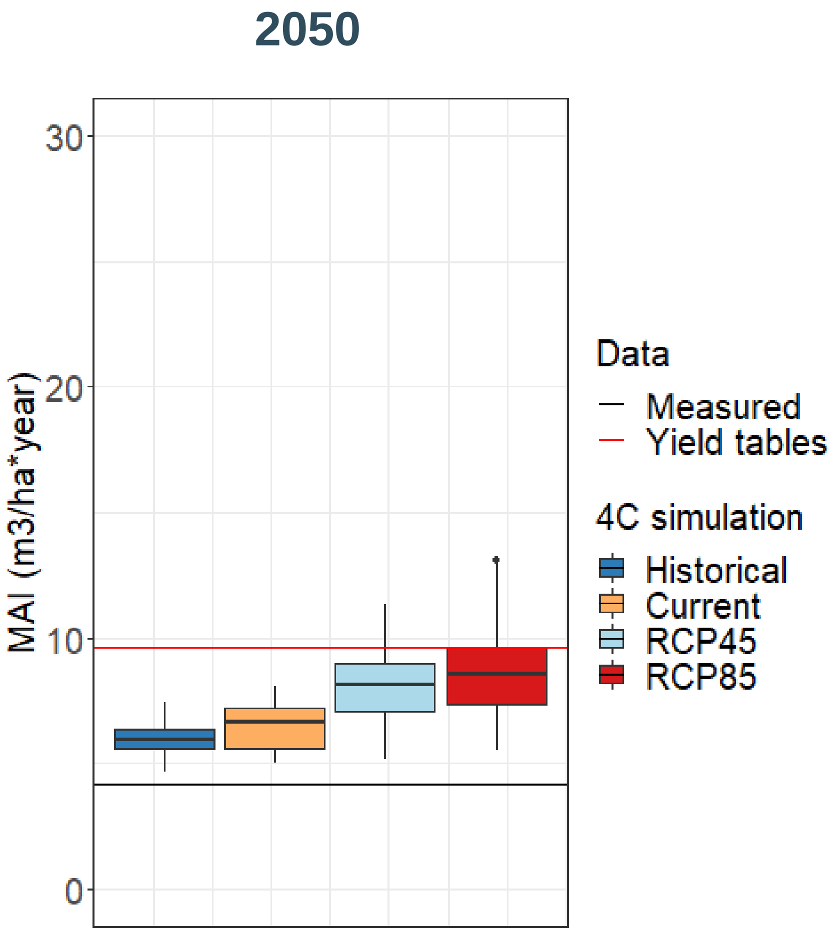
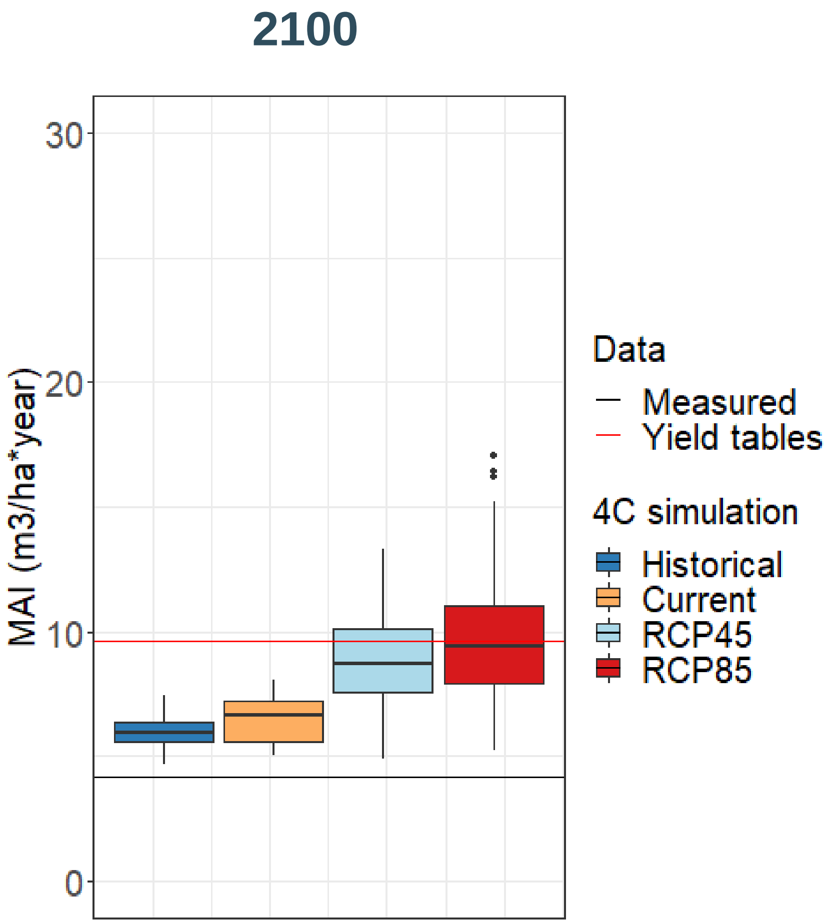
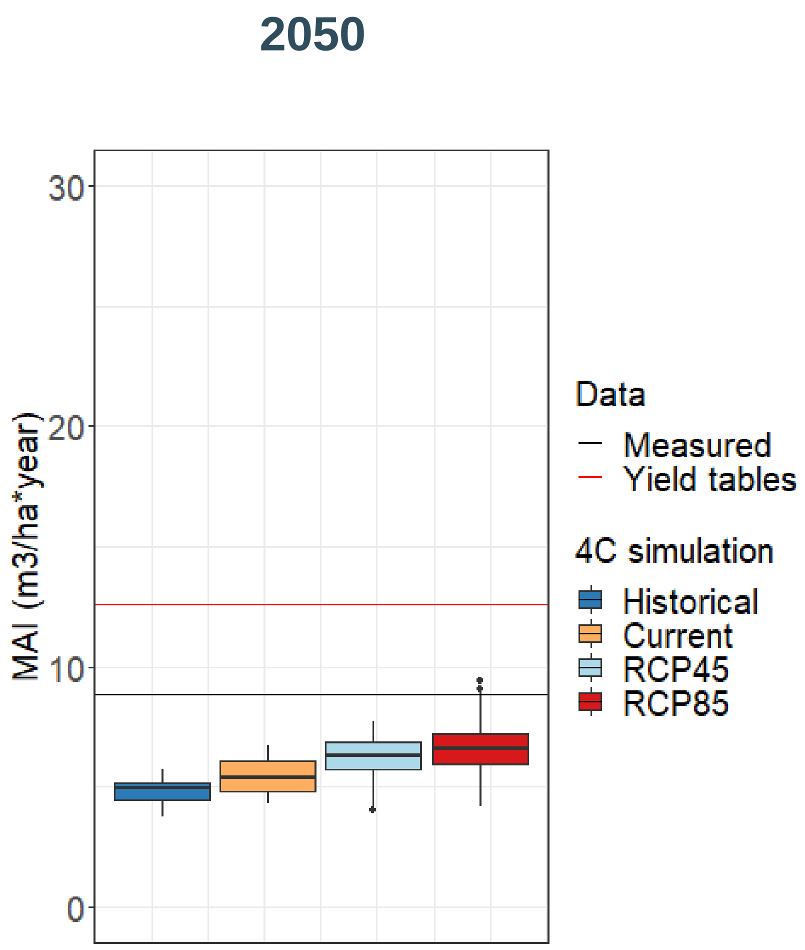
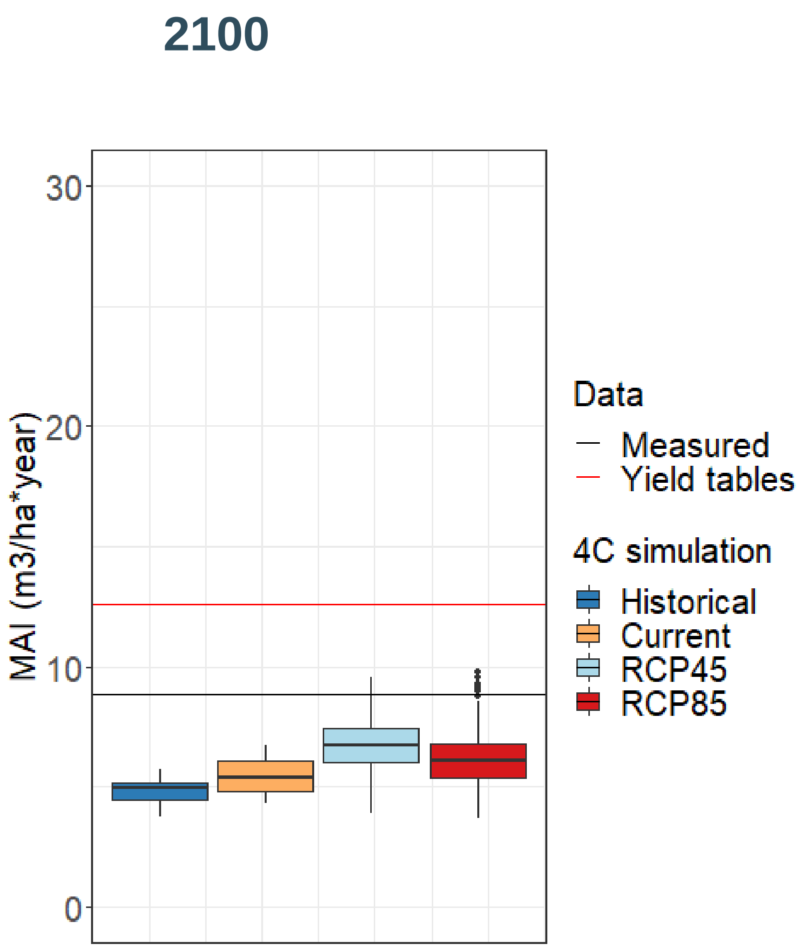
Results pine in level II plot 15





Results oak in level II plot 21





Obtained scaling factors

PlotID	Species	Soil	Historical	Current	2041 - 2070	2071 - 2100
11	Beech	Sandy Clay	0.916	1	1.213	1.279
					1.276	1.402
15	Pine	Sand	0.924	1	1.207	1.302
					1.277	1.432

RCP 4.5
RCP 8.5

Upscaling exercise

Correct region-wide increments from yield table with scaling factors

	PERIOD	MODEL	AREA	ANNUAL YIELD	DIFFERENCE	% DIFF
Beech	Current	Yield table	8168	64 772.24		
	2050	YT		49 579.76		
		YT*RCP45		63 412.51	13 832.75	27.90
		YT*RCP85		69 510.82	19 931.06	40.20
	2100	YT		57 502.72		
		YT*RCP45		73 545.98	16 043.26	
		YT*RCP85		80 618.81	23 116.09	
Pine	Current	YT	39604	262 970.56		
	2050	YT		250 297.28		
		YT*RCP45		325 887.06	75 589.78	30.20
		YT*RCP85		358 425.70	108 128.42	43.20
	2100	YT		409 901.40		
		YT*RCP45		533 691.62	123 790.22	30.20
		YT*RCP85		586 978.80	177 077.40	43.20

Take home messages

- Wood-based bioeconomy investments should be based on realistic wood resource availability predictions
- Predictions for given management scenarios should be climate change sensitive and accurate
- A cross-fertilization approach between mechanistic models and yield tables seems a promising alley
- Mechanistic modelling using 4C allows determining future deviations from yield tables
- Obtained scaling factors allow revising resource availability of the future
- But further work is needed to improve mechanistic models (drought, other disturbances,…)