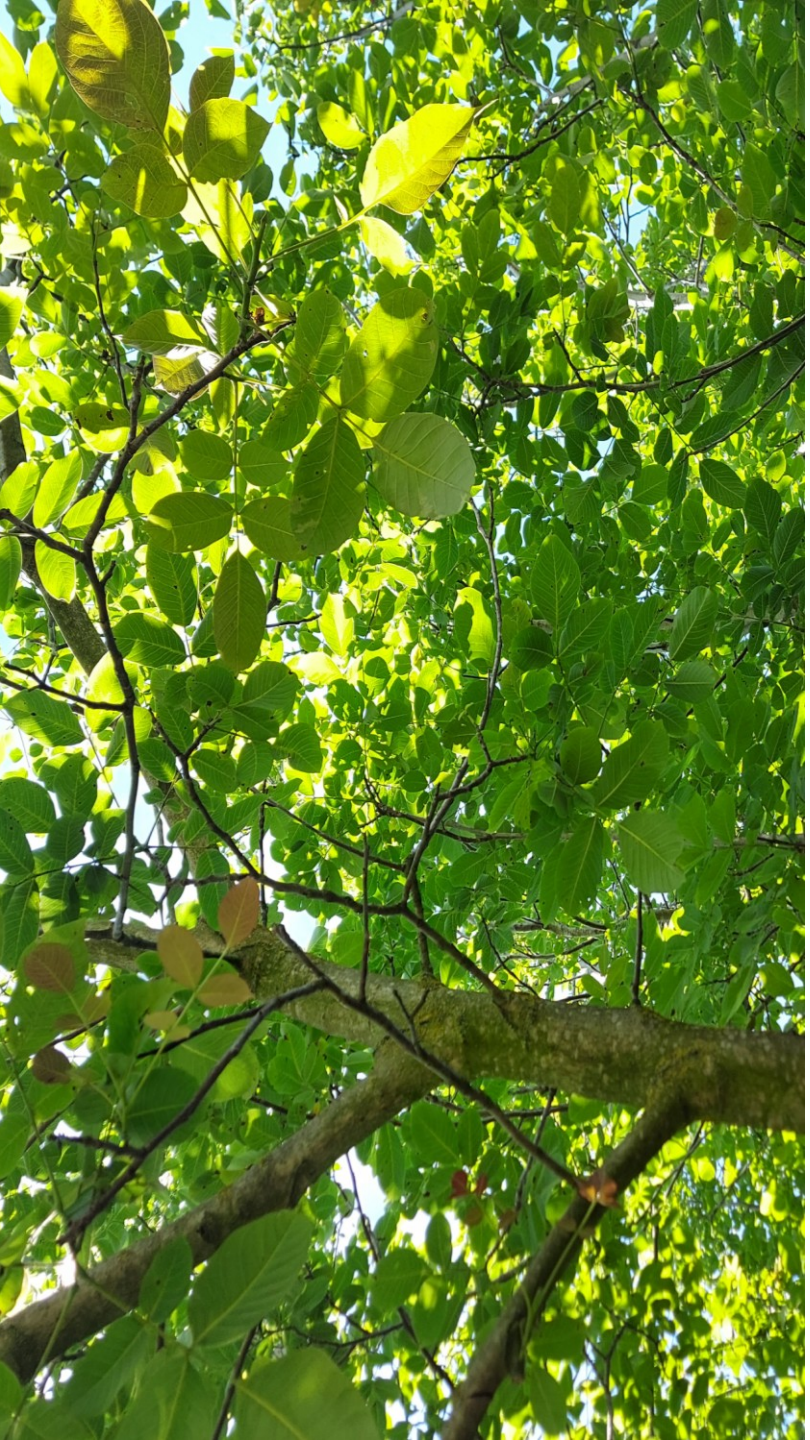


Un modello per la previsione degli impatti da cambiamento climatico e gestione forestale

(ma non solo)

Dr. Alessio Collalti

Laboratorio di Modellistica Forestale

Consiglio Nazionale delle **Ricerche**, CNR-ISAFOM

Workshop modellistica ecosistemi e biodiversità in ambito LifeWatch Italia
Pisa, Area della Ricerca CNR, 16-17 febbraio 2023

The Forest Modelling Lab.

(www.forest-modelling-lab.com/)

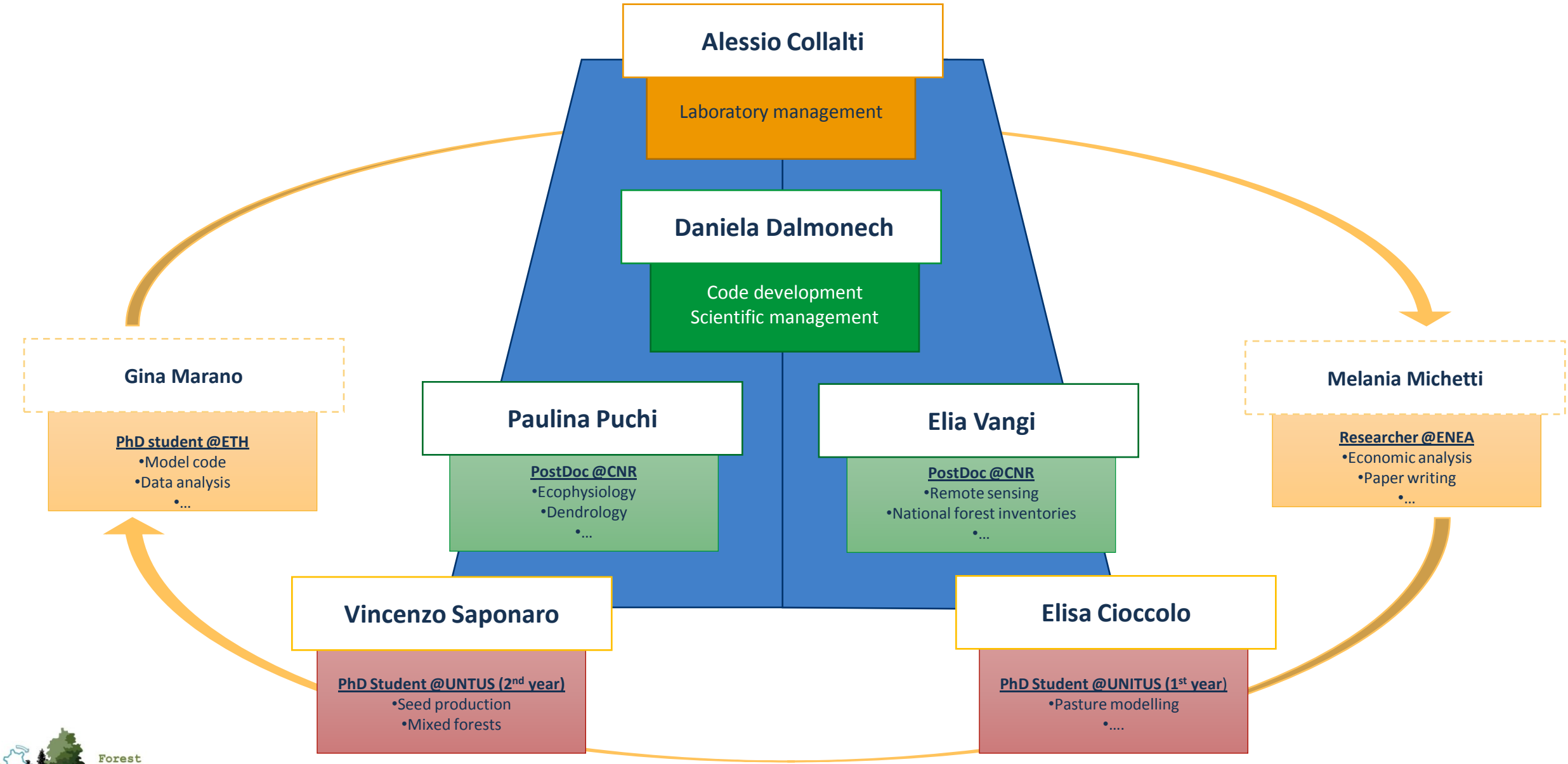
The **Forest Modelling Laboratory** is a research laboratory of the Institute for Agricultural and Forestry Systems in the Mediterranean at the National Research Council of Italy (**ISAFOM-CNR**) that specifically:

- studies and analyzes the quantitative and qualitative representation of the interactions underlying the productivity, resistance and resilience to perturbations of forest ecosystems and their responses to ecological and climate forcing;
- develops, parameterizes, validates and uses empirical and/or process-based simulation models both to deepen understanding of the processes underlying the functioning of the forest ecosystems, which to evaluate their response to the current climate as even the impacts of future climate change scenarios.
- In addition, the Forest Modelling Laboratory studies the response of forests to current and alternative/adaptive management scenarios through modeling approaches according to defined protocols.

Due to its characteristics, the Forest Modelling Laboratory is open to modeling collaborations with other CNR Institutes, others Research bodies and Universities, both Italian and foreign.

Despite laboratory members are sparse all around the world the Laboratory has formally its base at the Institute for Agriculture and Forestry Systems in the Mediterranean (ISAFOM-CNR) location in Perugia (PG), Italy.

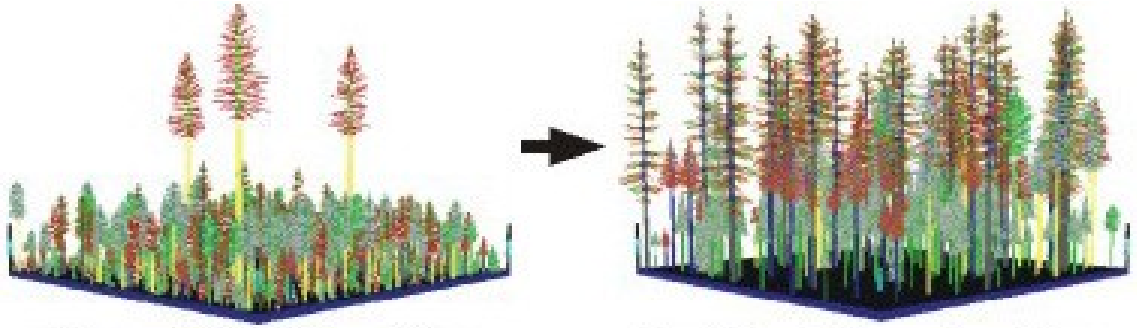
Team



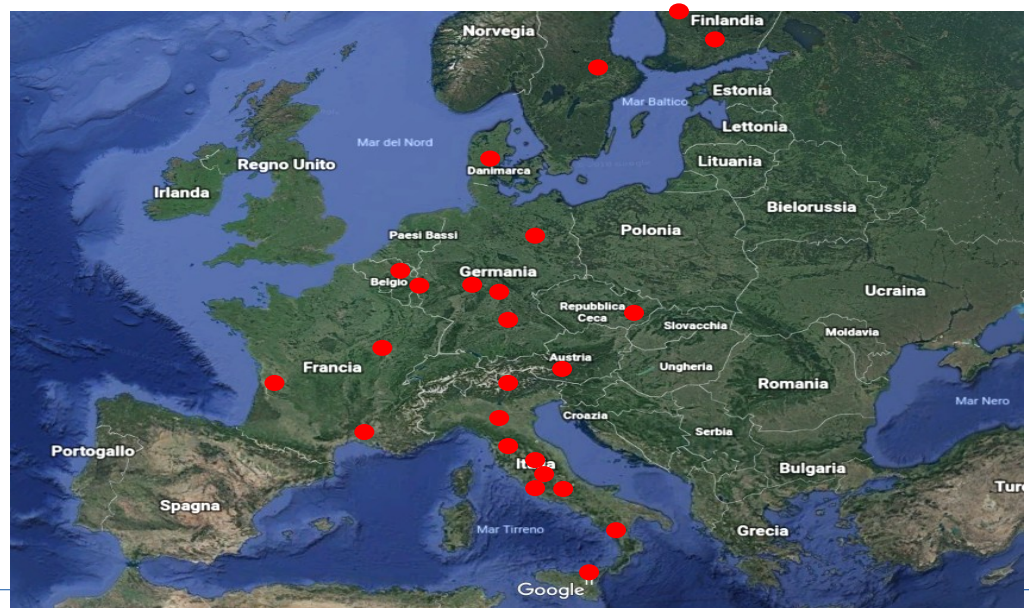
Forest modelling Lab.

What about the 3D–CMCC–FEM

(Three Dimensional – Coupled Model Carbon Cycle – Forest Ecosystem Model)



- Simulate **stand growth and development** under current and future environmental conditions (pasture modelling under construction) including **C**, **H_20** and **Energy fluxes** (and **C-stocks**)
- **Bio-geochemical, Bio-physical, Process-Based Model**
- Couple the **Process-Based** models' **robustness** of the layer and cohort models
- Variable **temporal** scale(daily to annual)
- Variable **spatial** scale (1ha to *x* Km^2)
- **Forest Management** (thinning, harvest, replanting) and other "**disturbances**"
- **C**-language but with lots of **R-wrappers**!

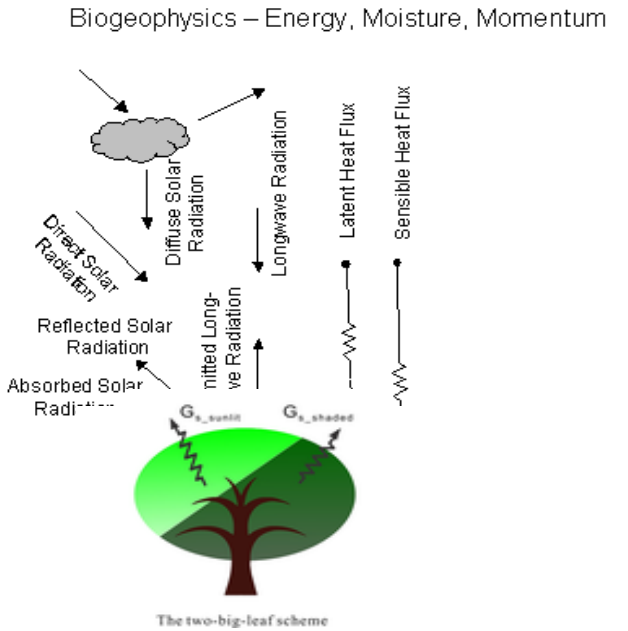


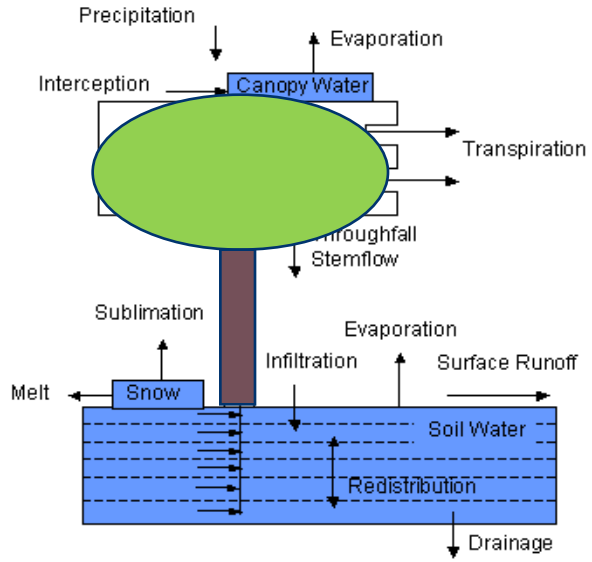
15 years of model applications across Europe

Forest modelling Lab.

3D-CMCC-FEM Biophysical processes:

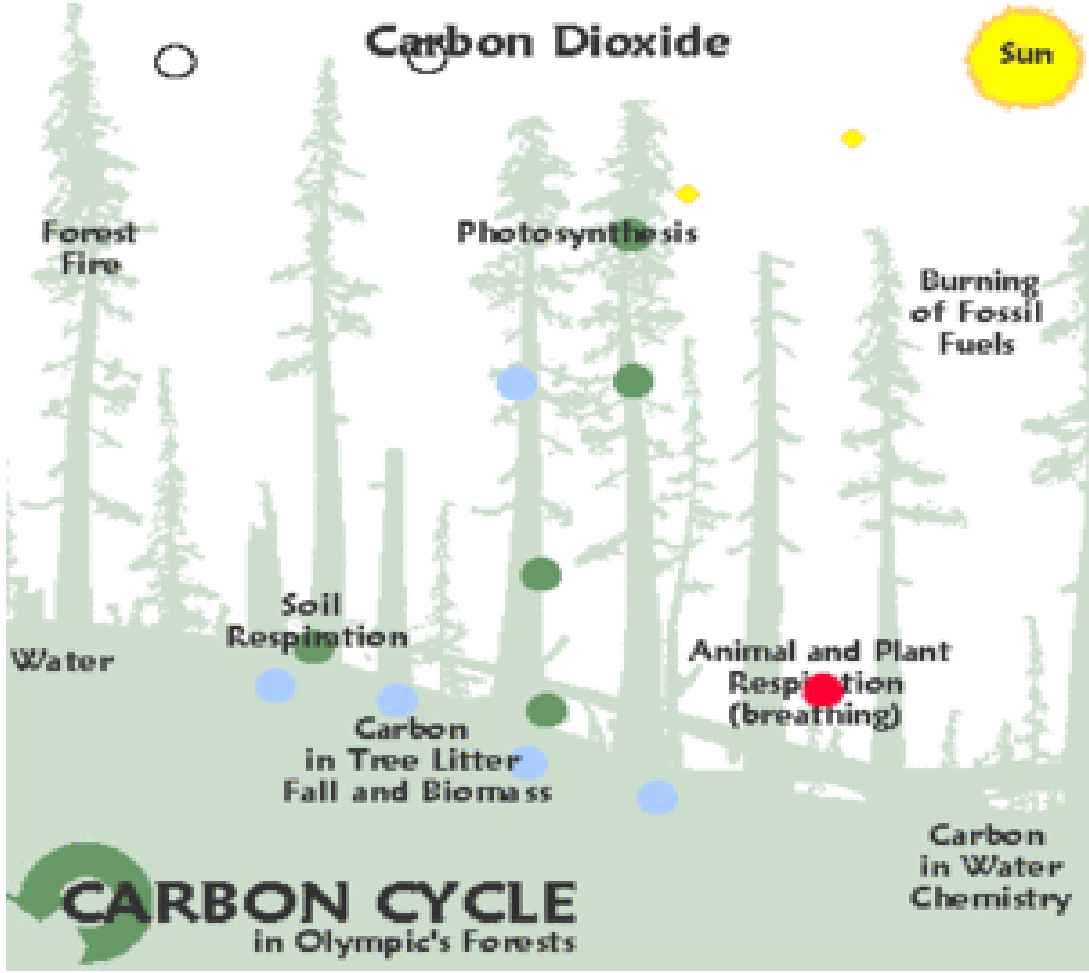
- SURFACE ALBEDOS
- RADIATIVE TRANSFER
- SENSIBLE HEAT (under development) AND LATENT HEAT FLUXES
- SOIL AND SNOW TEMPERATURE
- CANOPY TRANSPIRATION
- CANOPY INTERCEPTION
- SOIL EVAPORATION
- SNOW
- SURFACE RUNOFF AND INFILTRATION
- SOIL WATER CONTENT



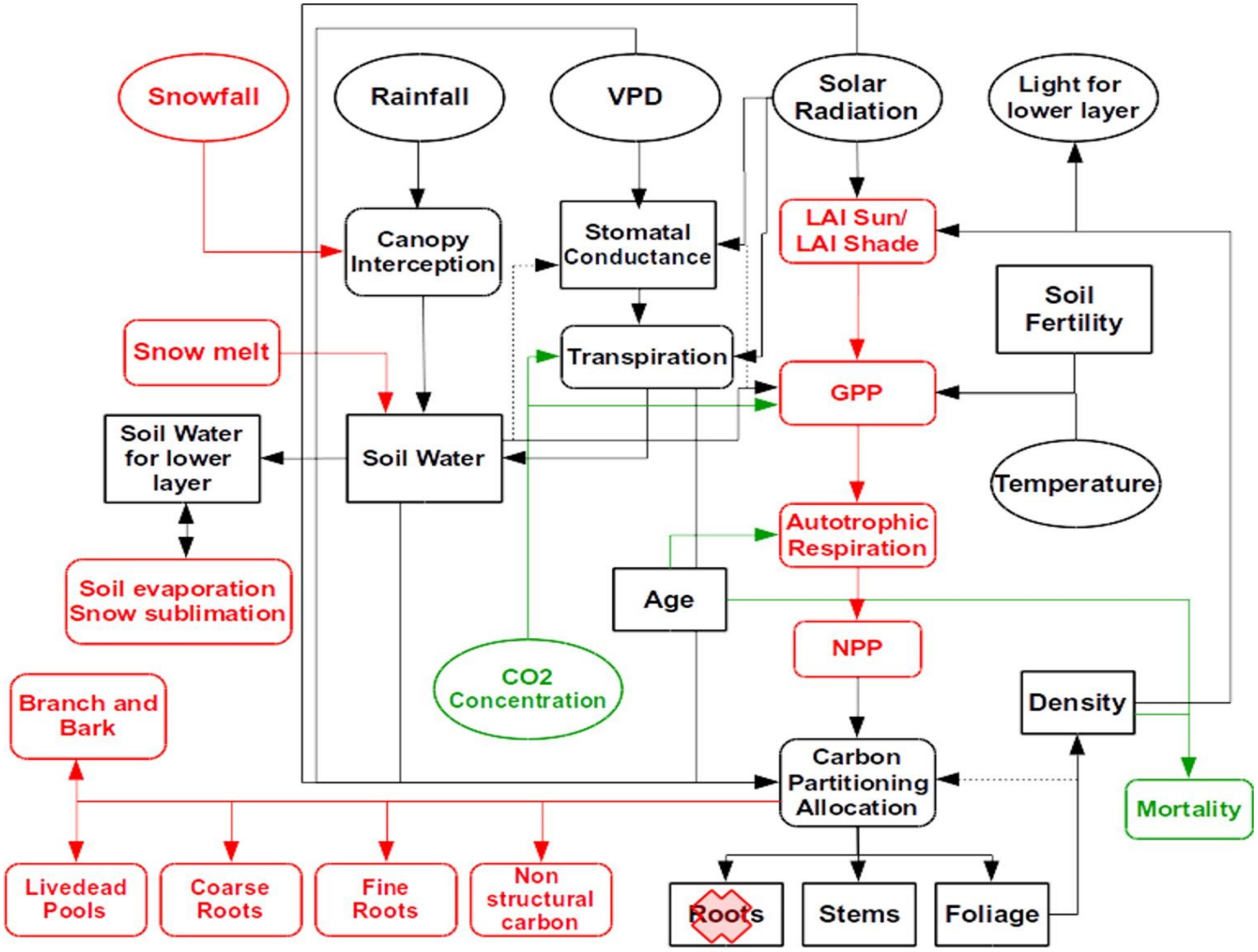


3D-CMCC-FEM Biogeochemical processes:

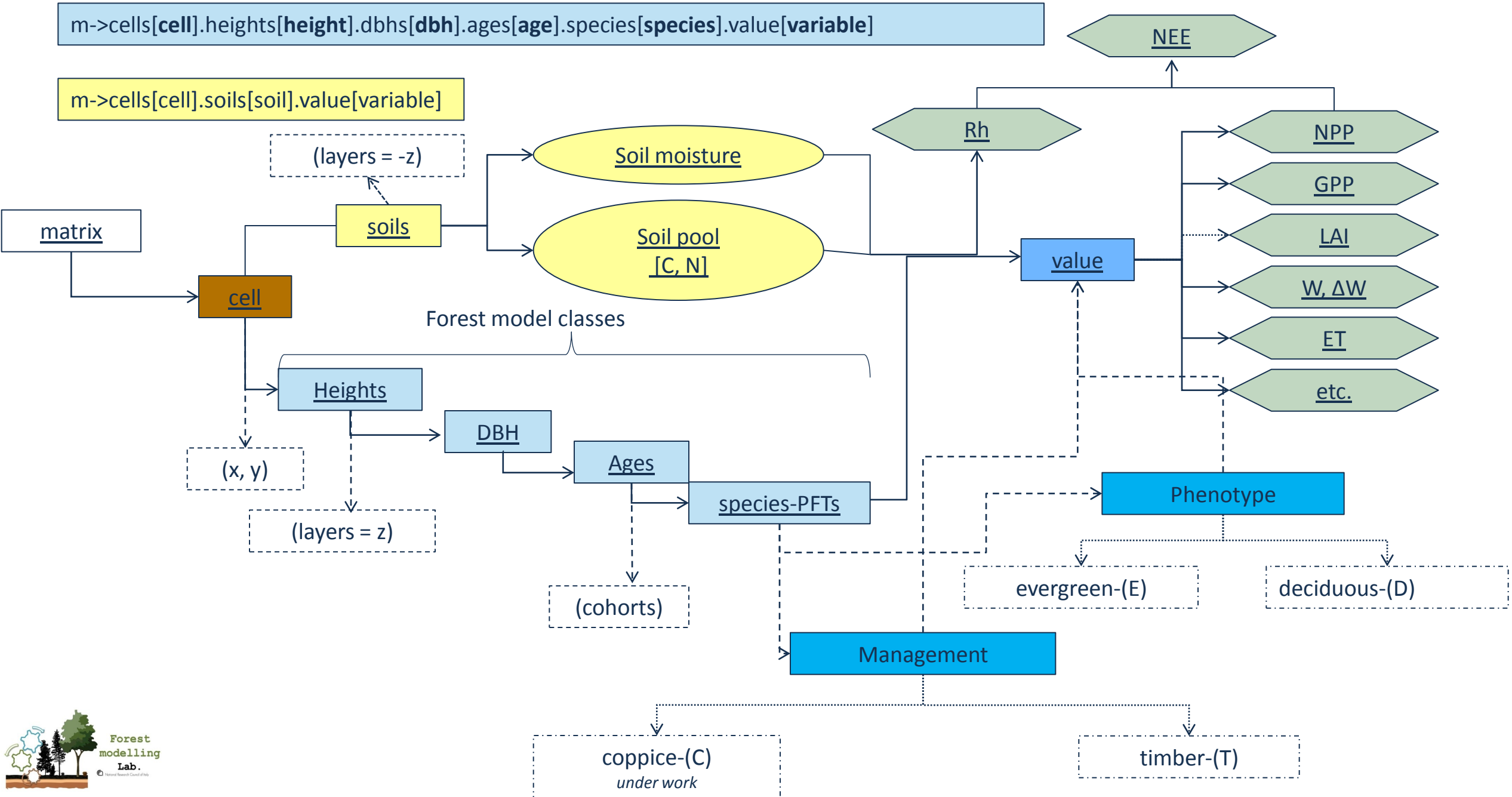
- CANOPY PHOTOSYNTHESIS
- AUTOTROPHIC RESPIRATION
- HETEROTROPHIC RESPIRATION (coming soon)
- CARBON ALLOCATION
- NSC-Dynamic
- WOOD PRODUCTION
- PHENOLOGY
- Changes in Forest STRUCTURE
- LITTERFALL production
- ...



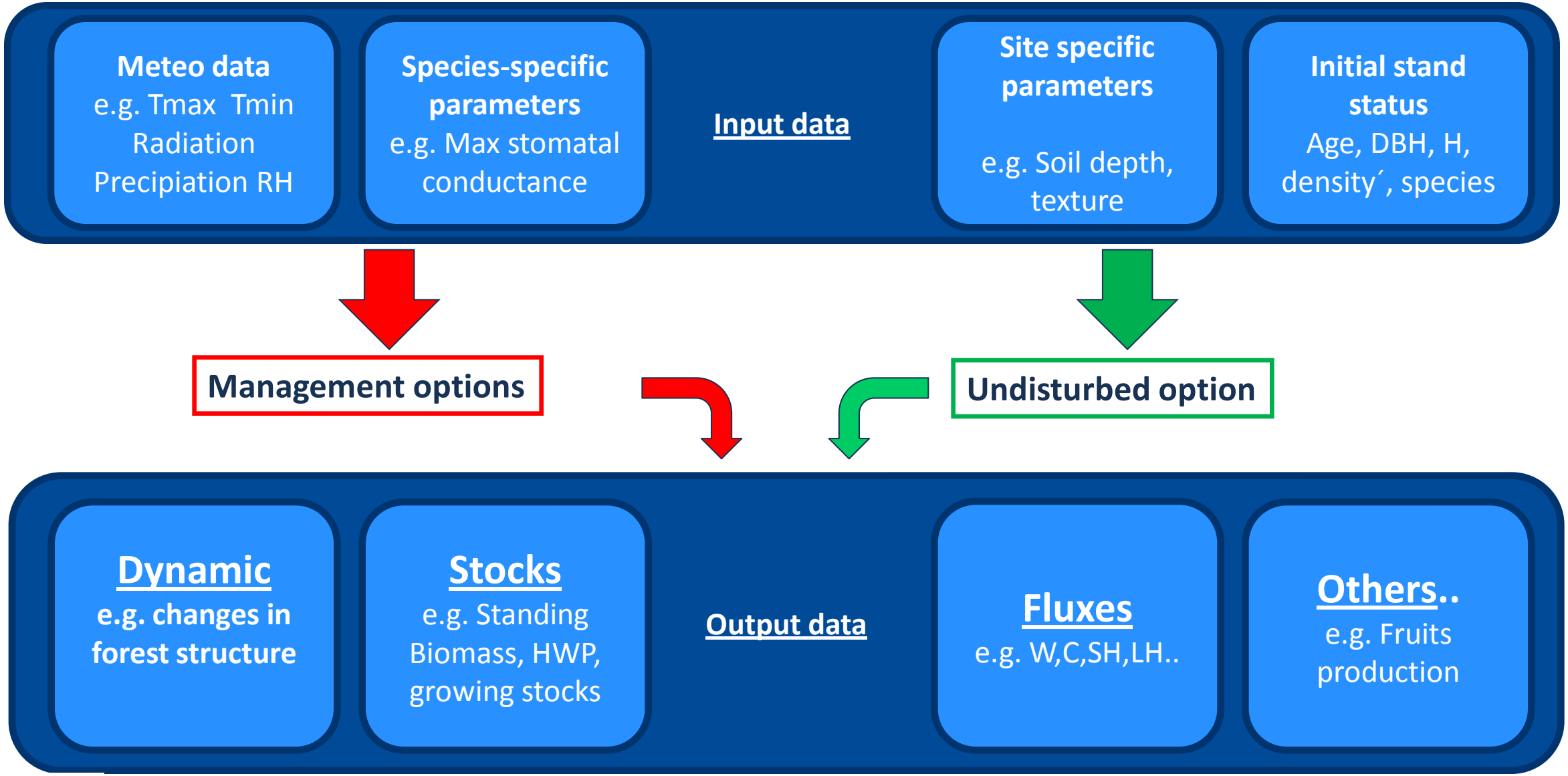
3D-CMCC-FEM Model Flowchart:



3D-CMCC-FEM Model C-language core logic-structure



Input/output model data and simulation options

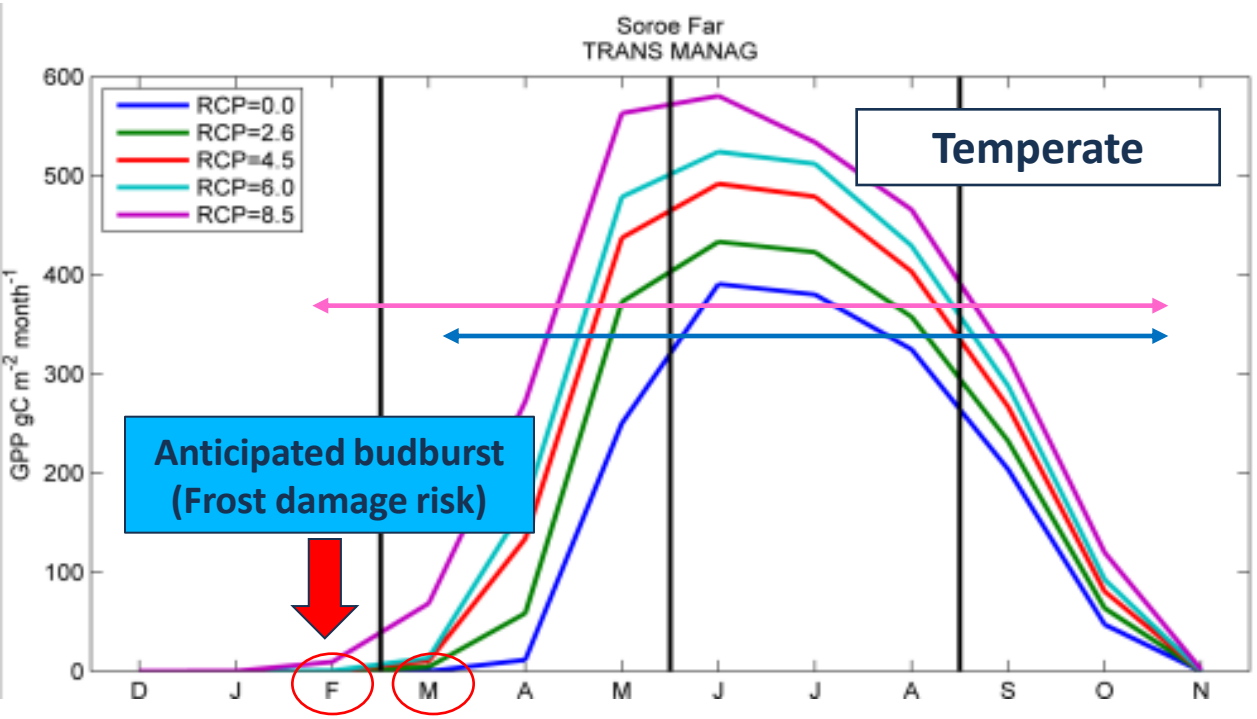


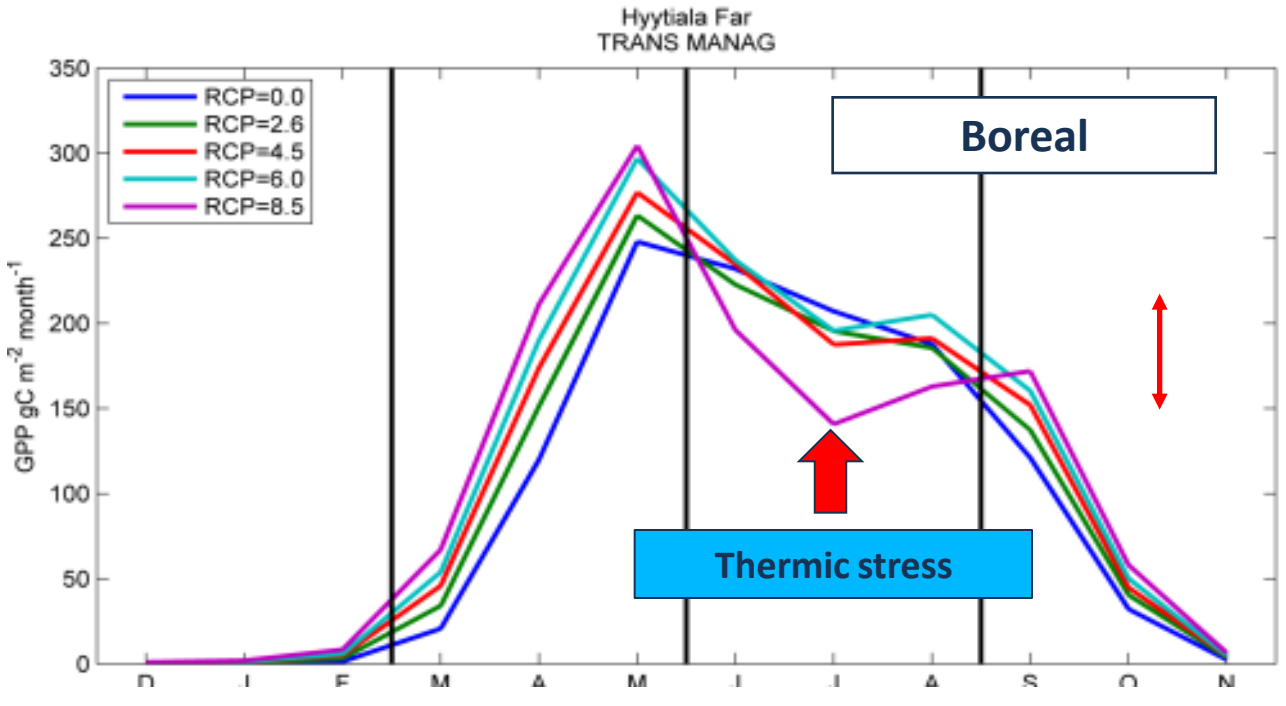
What about climate change, forest management and forests?

Forest modelling Lab.

Make predictions on impacts from climate change

Changes in **phenology** and **GPP** under different **climate forcing scenarios** from 1950 to 2100





Sorö site (Denmark)
Fagus sylvatica L.

(Collalti et al., 2018; JAMES)

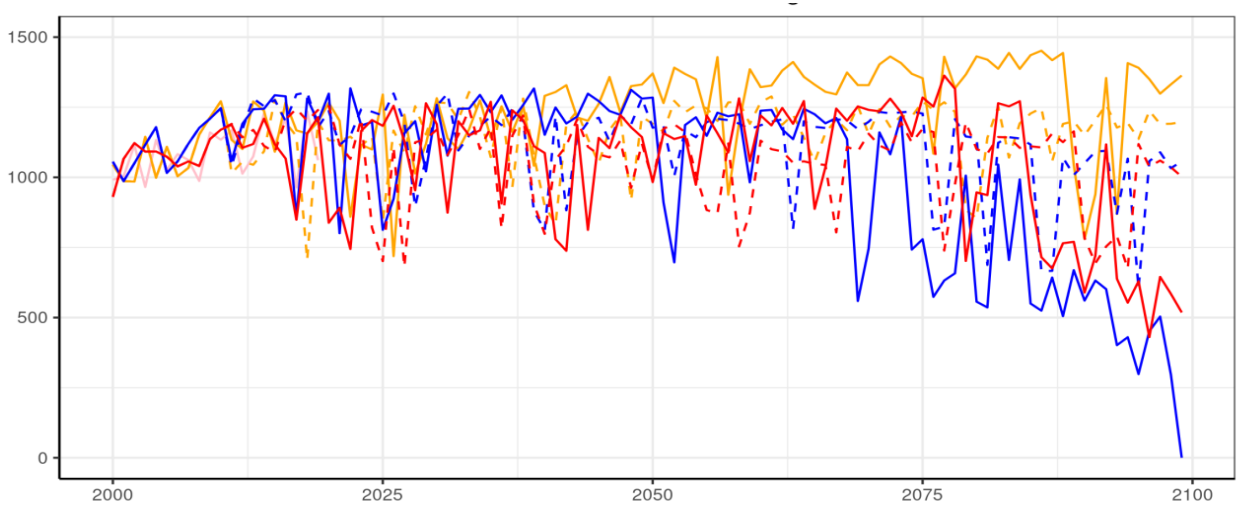
Hyytiälä site (Finland)
Pinus sylvestris L.

CLIMATE CHANGE impacts on FLUXES and GROWTH MODULATED BY RESERVE

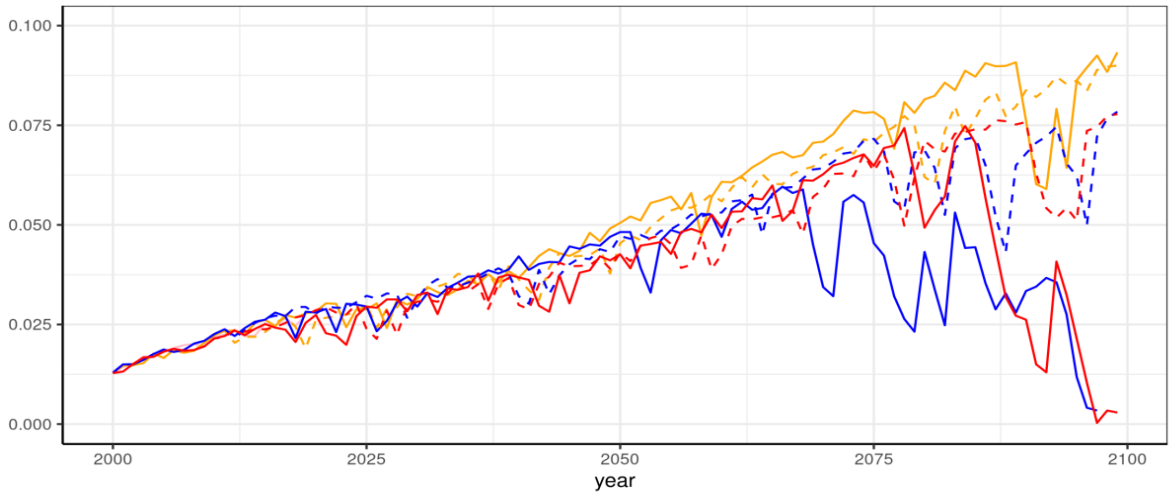
Quercus Frainetto San Paolo Albanese (PZ)
Preliminary results

- CNRM_CLM_RCP4.5
- CNRM_CLM_RCP8.5
- EC_EARTH_SMHI_RCP4.5
- EC_EARTH_SMHI_RCP8.5
- MPI_CLM_RCP4.5
- MPI_CLM_RCP8.5

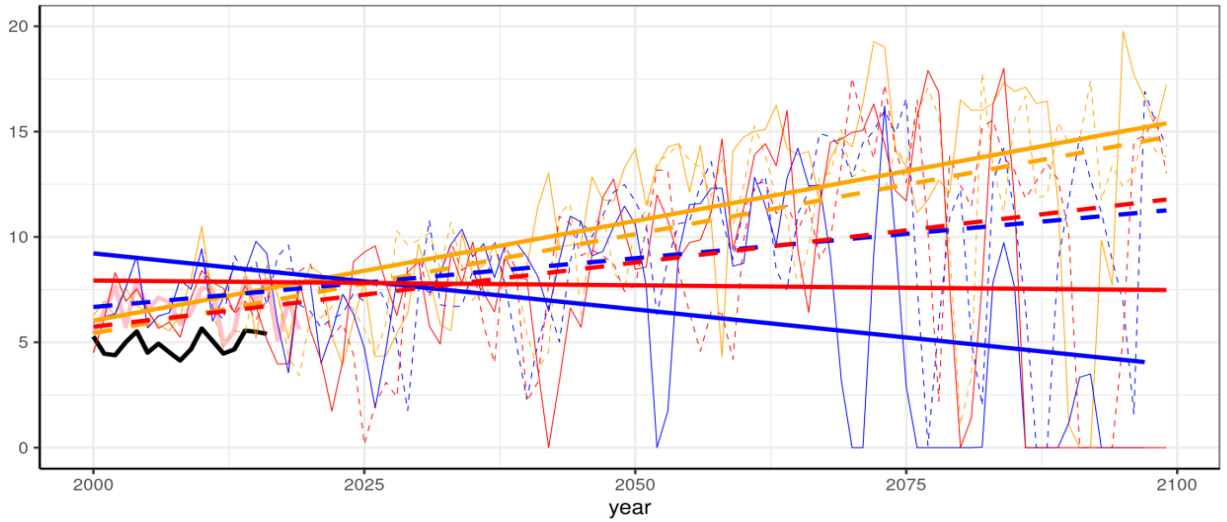
GPP GROWING SEASON gC m^{-2} $year^{-1}$



TREE MINIMUM RESERVE tC



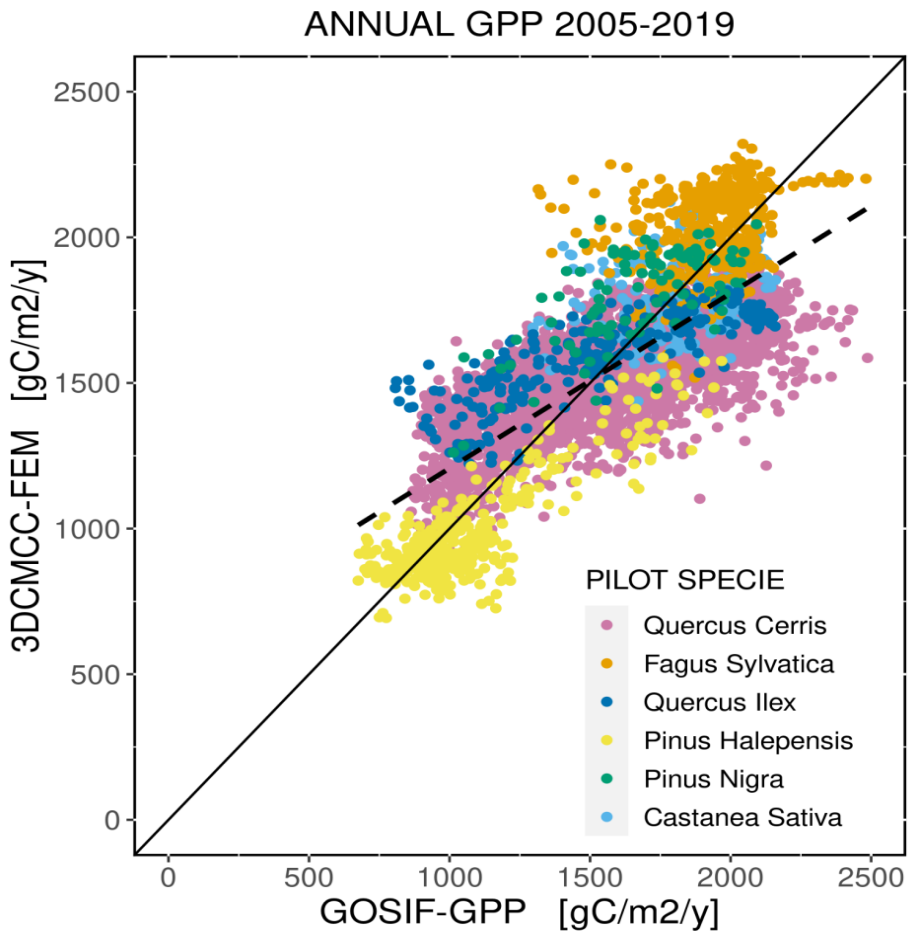
BAI cm^2 $year^{-1}$

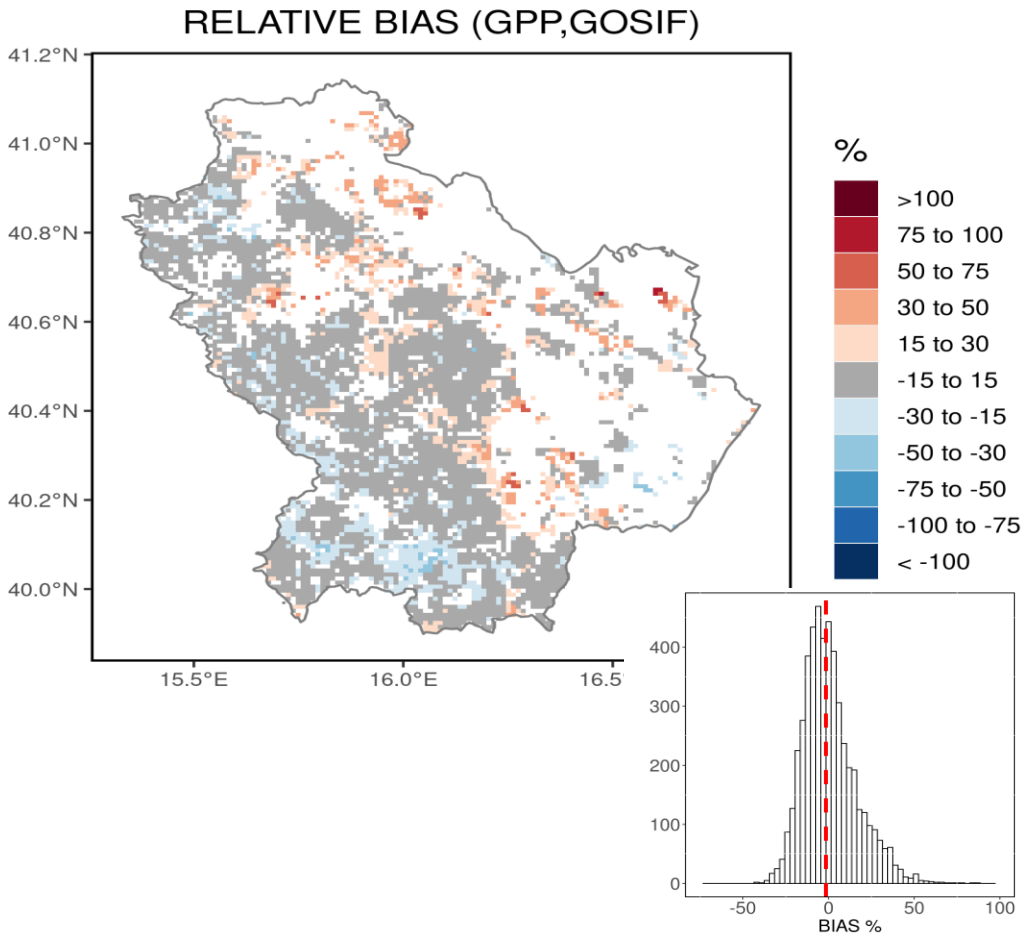


Forest modelling Lab.

(Dalmonech et al., in prep.)

LARGE SCALE applications of GPP on Basilicata Region



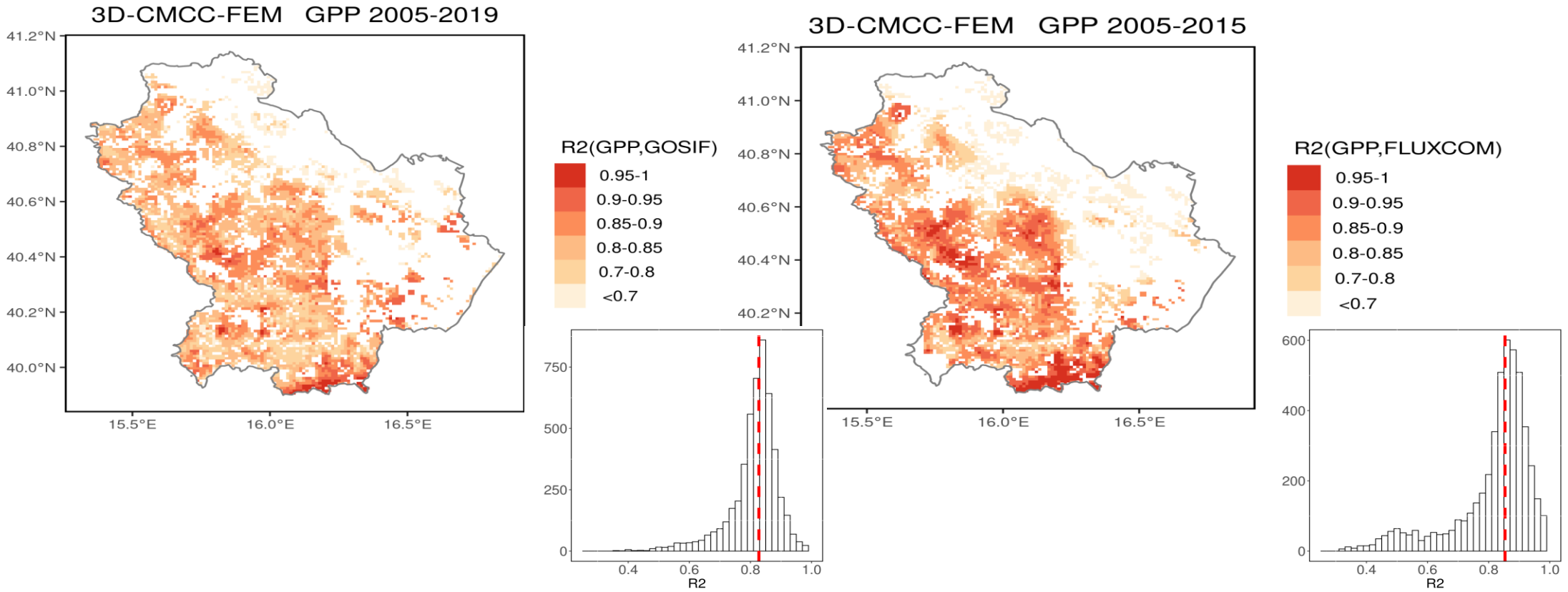


(Dalmonech et al., in prep.)

LARGE SCALE applications of GPP on Basilicata Region

Maps of R^2 between modeled and 'observed' mean seasonal cycle

GOSIF 2005-2019

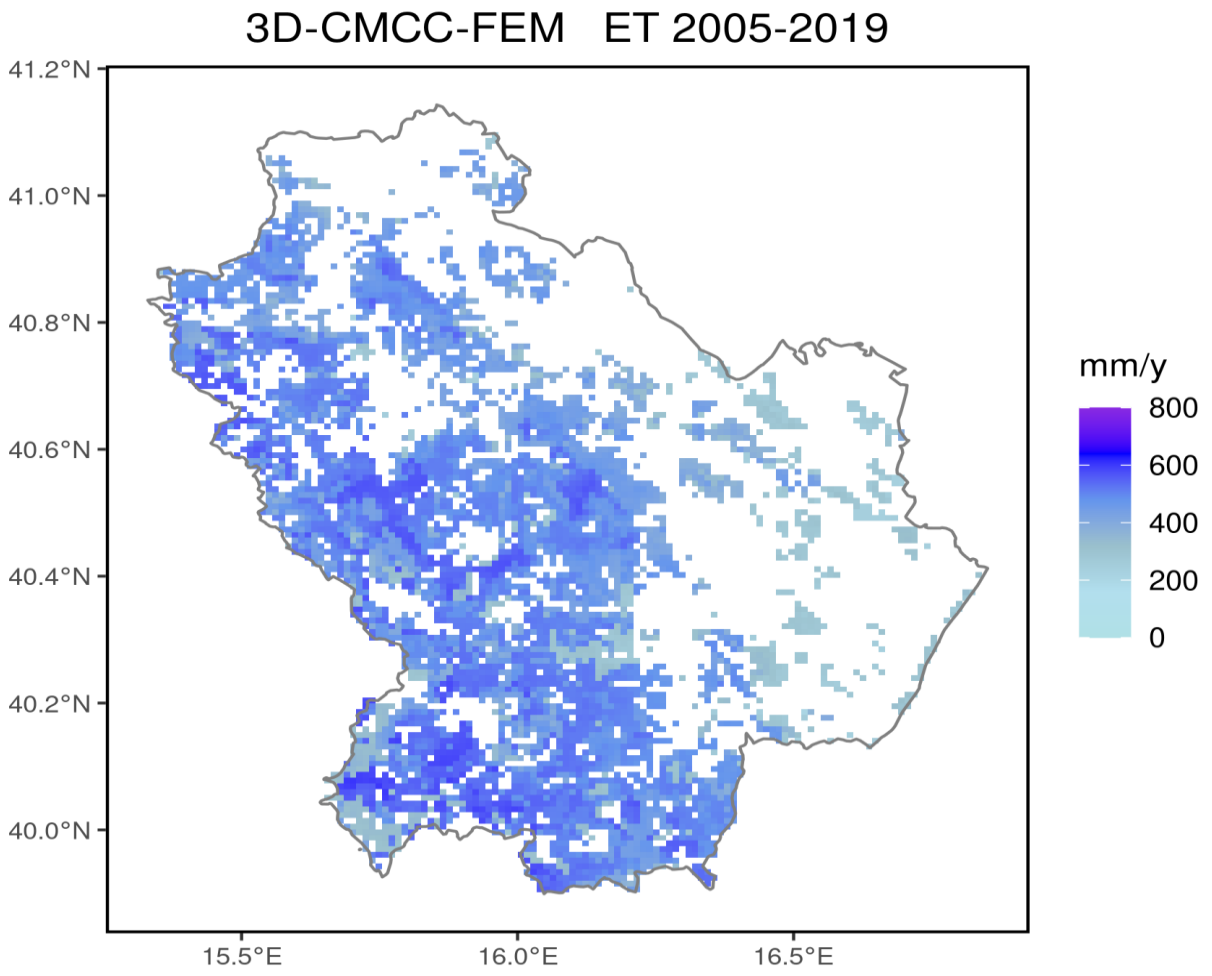


FLUXCOM 2005-2015

Forest modelling Lab.

(Dalmonech et al., in prep.)

LARGE SCALE applications of ET on Basilicata Region

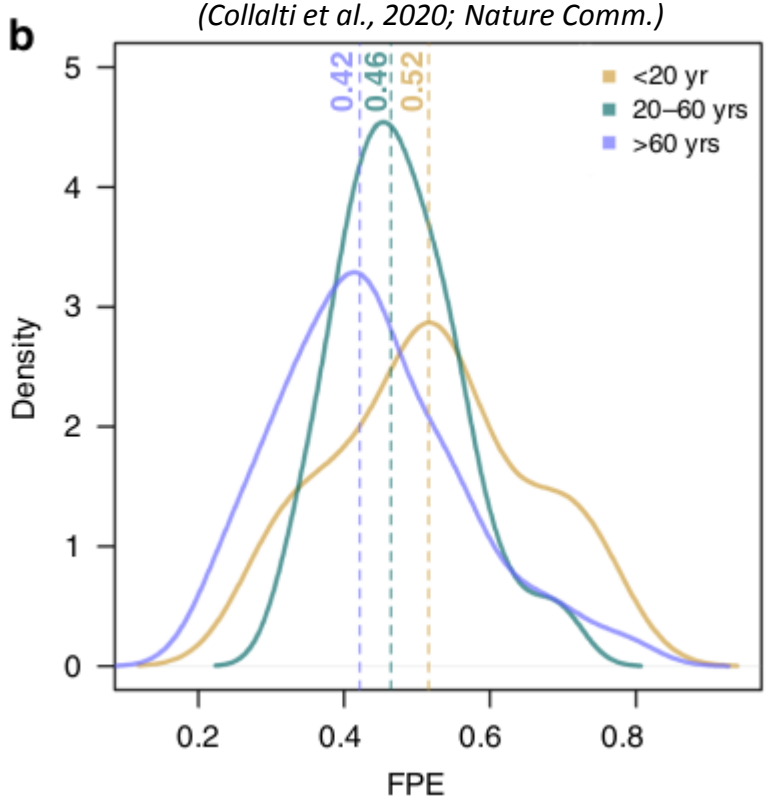


Forest modelling Lab.

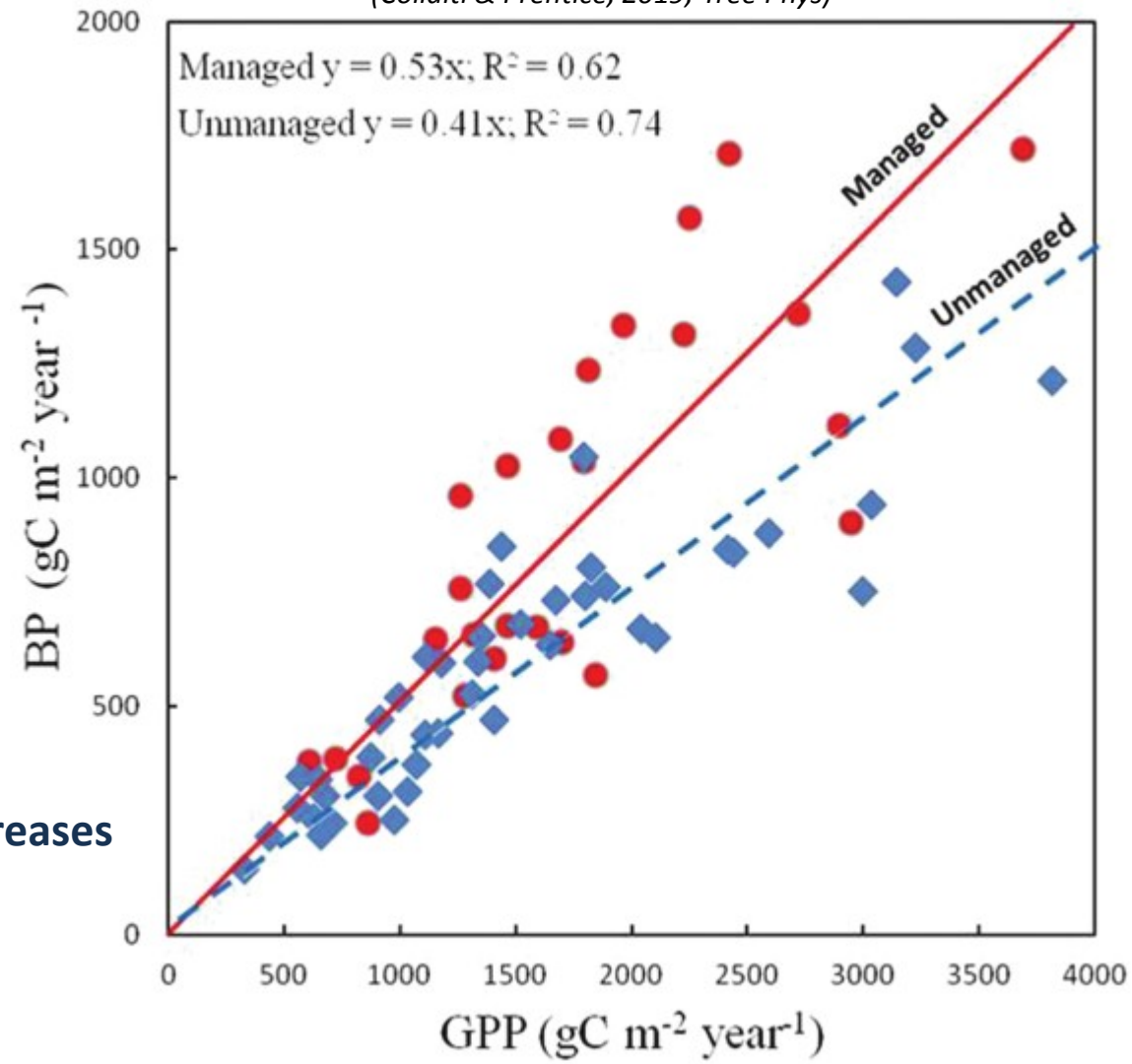
(Dalmonech et al., in prep.)

Forest management and observations

(Collalti et al., 2020; Nature Comm.)



(Collalti & Prentice, 2019; Tree Phys)

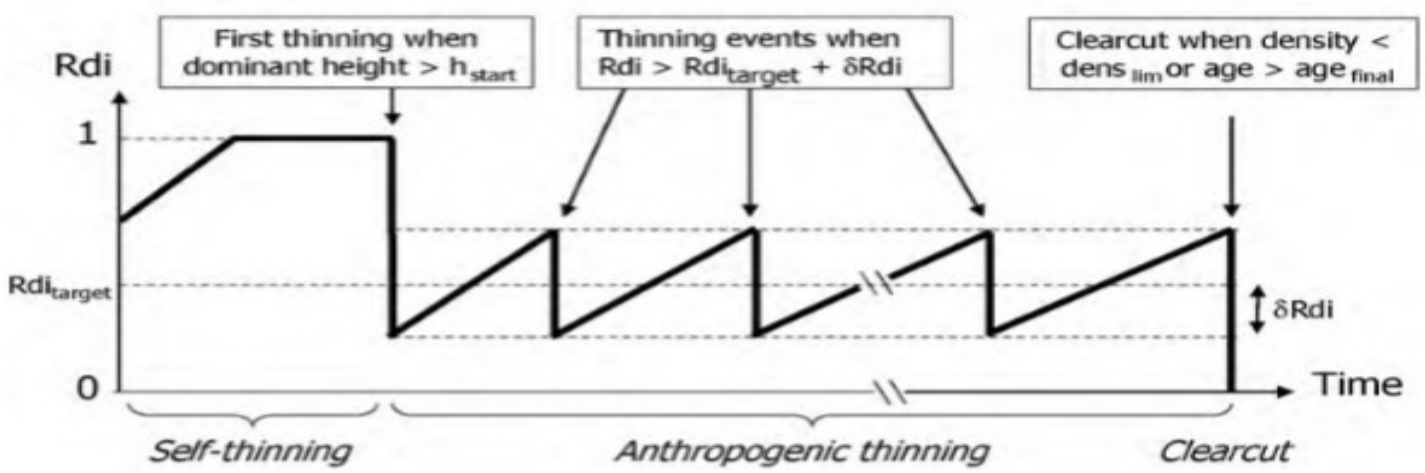


At increasing forest **age** biomass production efficiency **decreases**

Forest modelling Lab.

Make predictions on forest management

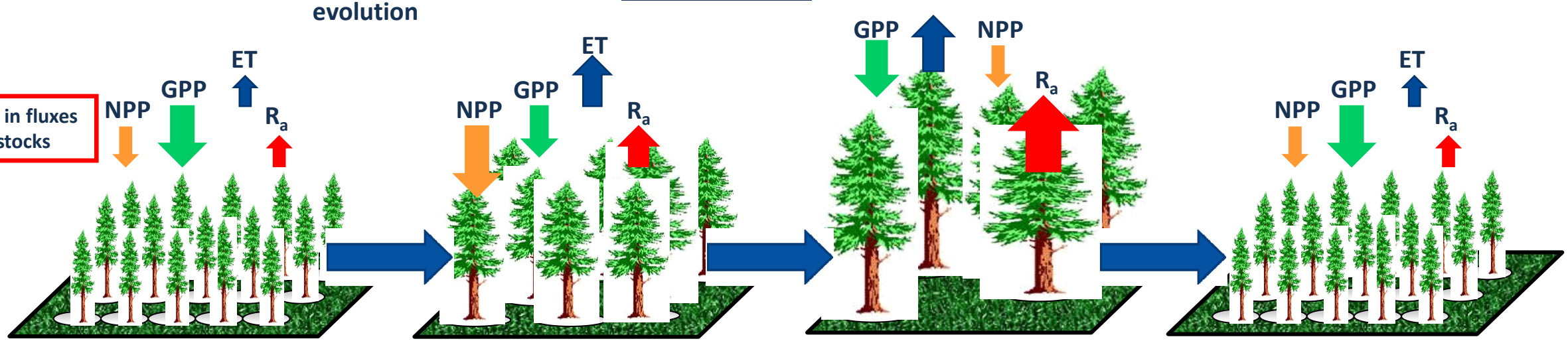
What happens if we manage forests?



(Bellassen et al. 2010)

Natural evolution — **Managing forests** →

Changes in fluxes and stocks



Initial state (real case) | Thinning | Thinning | Clearcut and replanting

Forest modelling Lab.

Initial state → **Final state**

Research question

Is managing forests (vs. non managing) the best option for Net Primary Productivity and Carbon Stocks under climate change?

Are any other options to manage forest in the future?

Forest modelling Lab.

Test sites and simulation compset

Site info

Hyytiälä (Finland):
- *Pinus sylvestris* L.
- DBH:~**10 cm**
- Age: **28 yrs**
- Tree Height: **10 m**
- Density: **1800 trees/ha**

Sorø (Denmark):
- *Fagus sylvatica* L.
- DBH:~**25 cm**
- Age: **80 yrs**
- Tree Height: **25 m**
- Density: **400 trees/ha**

Bilý Kříž (Finland):
- *Picea abies L.*
- DBH:~**7.1 cm**
- Age: **16 yrs**
- Tree Height: **5.6 m**
- Density: **2408 trees/ha**

Climate scenarios

5 Earth System Models (1950 – 2099)
4 Scenarios (RCP 2.6, 4.5, 6.0, 8.5)

Management scenarios

***Pinus sylvestris* L.:**
- Thinning intensity = 20%
- Thinning interval = 15yrs
- Rotation age = 140yrs
- + No management

(Lasch et al. 2005)

***Fagus sylvatica* L.:**
- Thinning intensity = 30%
- Thinning interval = 15yrs
- Rotation age = 140yrs
- + No management

(Cescatti & Piutti, 1998)

***Picea abies* L.:**
- Thinning intensity = 30%
- Thinning interval = 15yrs
- Rotation age = 120yrs
- + No management

(Fürstenau et al. 2007)

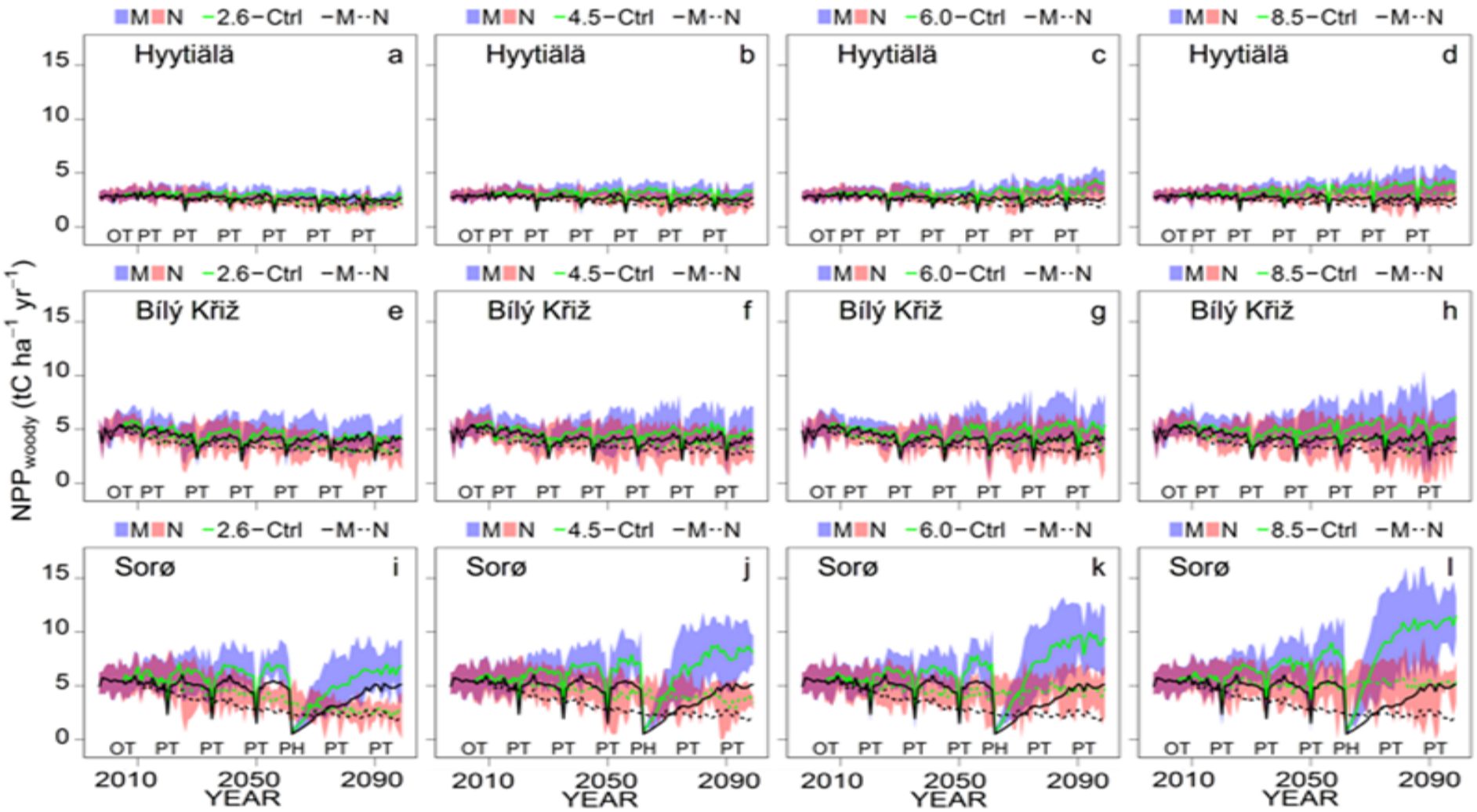
Forest modelling Lab.

→ 3 Sites x 5 ESMs x 4 RCPs x 2 Management scenarios = 120 simulations

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

Testing Management Vs. No Management Under Climate Change

Net Primary Productivity (NPP)



Management is the best choice for NPP

(Collalti et al., 2018; JAMES)

No Managed

Managed

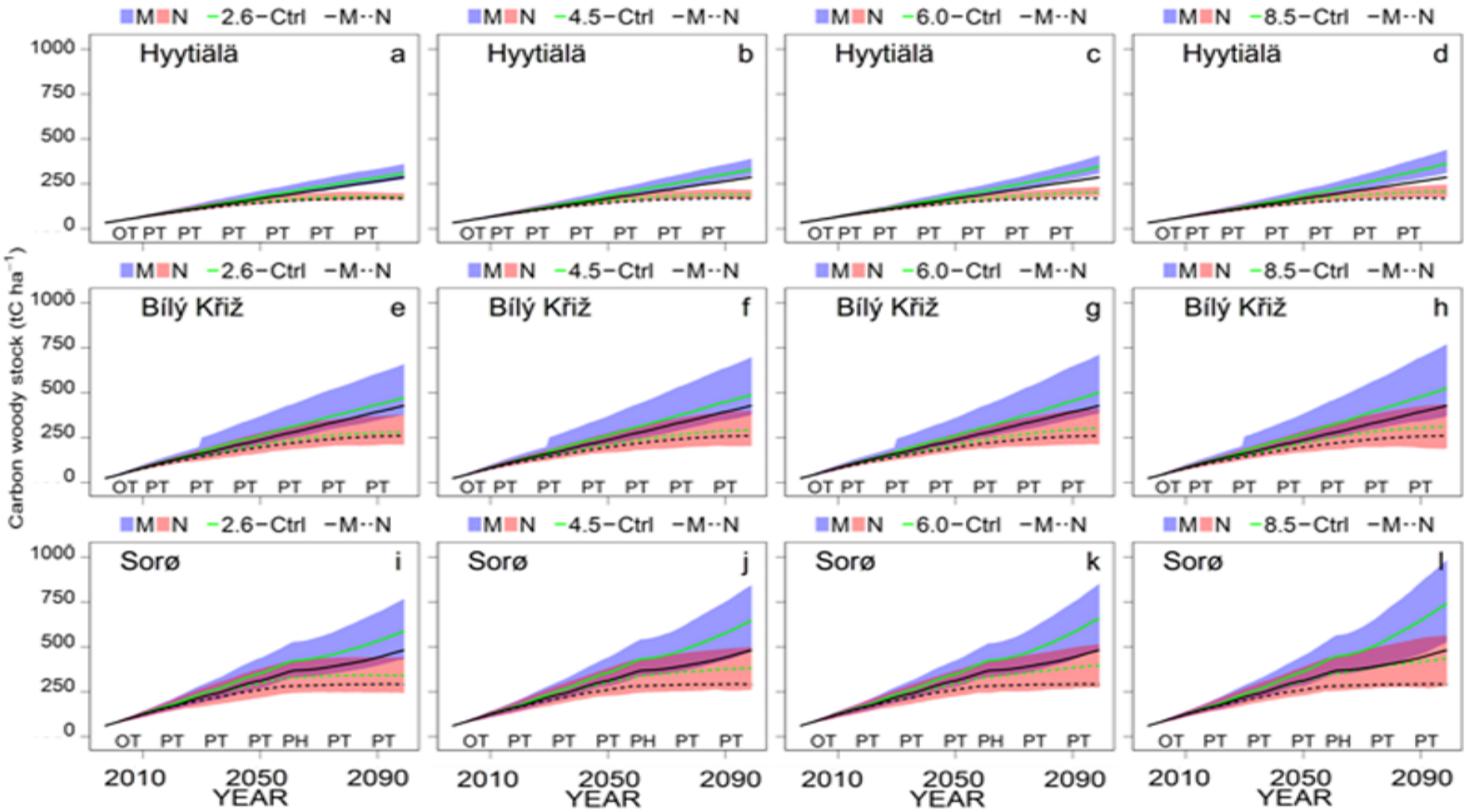
OT = observed thinning, PT = prescribed thinning, PH = prescribed harvesting

Forest modelling Lab.

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

Testing Management Vs. No Management Under Climate Change

Carbon Woody Stocks



Management is the best choice for Carbon Woody Stock

(Collalti et al., 2018; JAMES)

No Managed

Managed

OT = observed thinning, PT = prescribed thinning, PH = prescribed harvesting

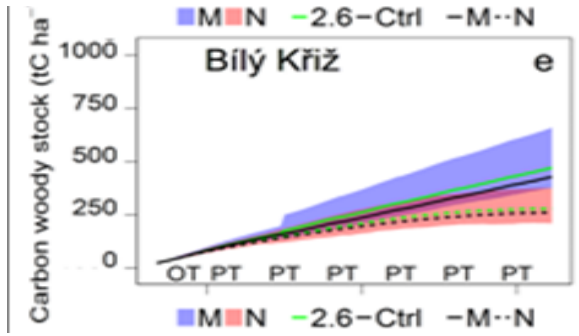
Forest modelling Lab.

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

What about future forest management and climate change ?

Business as usual or No management

Future climate



Research question: can we increase through **alternative management options** NPP and Carbon Stock?

Forest modelling Lab.

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

Test sites and simulation compset

Site info

Hyytiälä (Finland):
- *Pinus sylvestris* L.
- D
- A
- T
- D

All age classes

Sorø (Denmark):
- *Fagus sylvatica* L.
- D
- A
- T
- D

All age classes

Bilý Kříž (Finland):
- *Picea abies L.*
- D
- A
- T
- D

All age classes

Climate scenarios

5 Earth System Models (1950 – 2099)
4 Scenarios (RCP 2.6, 4.5, 6.0, 8.5)

Management scenarios

***Pinus sylvestris* L.:**
- Thinning intensity = 20% → 10 - 30%
- Thinning interval = 15yrs → 5 - 25yrs
- Rotation age = 140yrs → 120 - 160yrs
- + No management

(Lasch et al. 2005)

***Fagus sylvatica* L.:**
- Thinning intensity = 30% → 20 - 40%
- Thinning interval = 15yrs → 5 - 25yrs
- Rotation age = 140yrs → 120 -160yrs
- + No management

(Cescatti & Piutti, 1998)

***Picea abies* L.:**
- Thinning intensity = 30% → 20 - 40%
- Thinning interval = 15yrs → 5 - 25yrs
- Rotation age = 120yrs → 100 - 140yrs
- + No management

(Fürstenau et al. 2007)

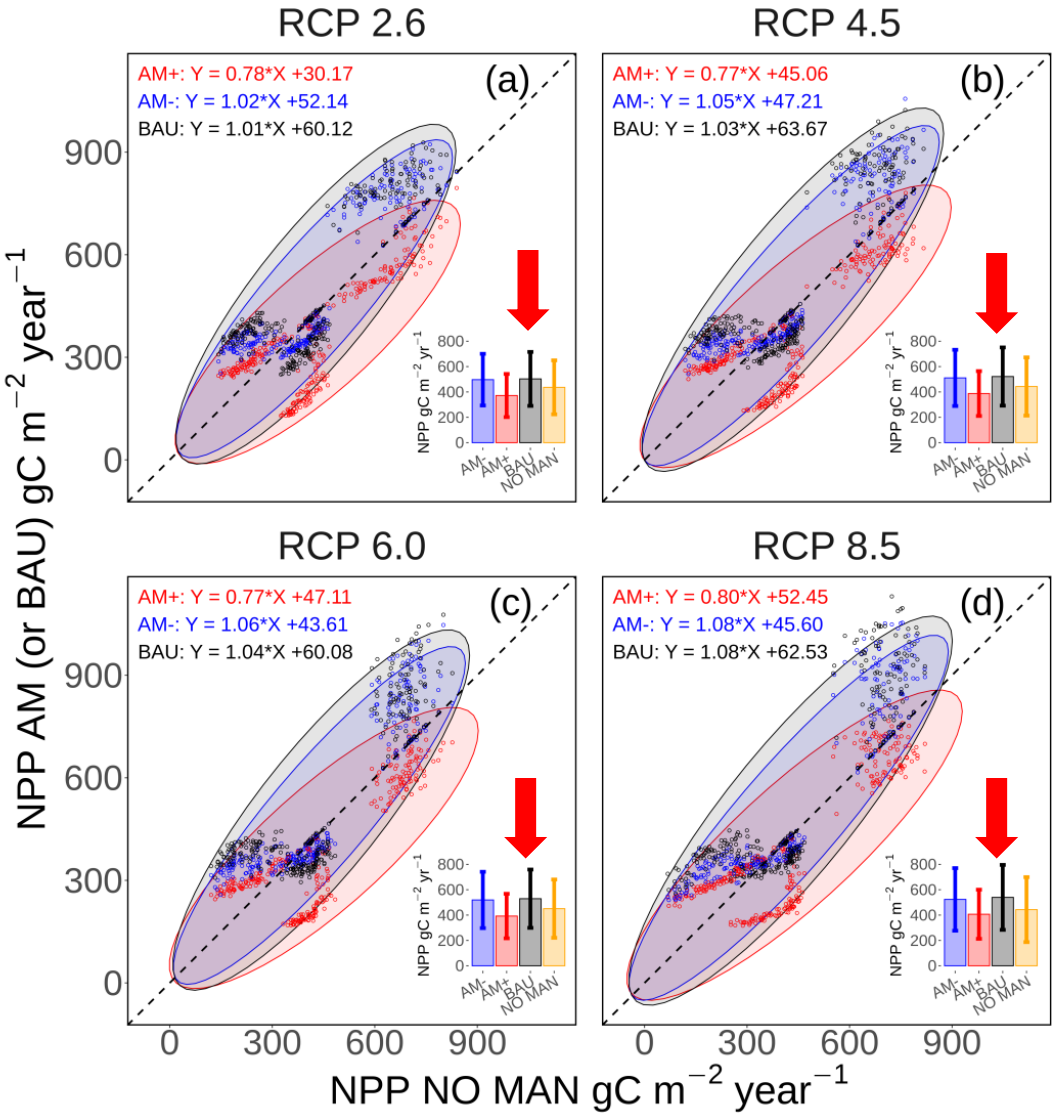
Forest modelling Lab.

→ 3 Sites x 11 Age classes x 5 ESMs x 4 RCPs x 27 Management scenarios = 16200 simulations

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

Testing Management Vs. No Management Under Climate Change

Net Primary Productivity (NPP)



AM+ = Increased management intensity

AM- = Decreased management intensity

BAU = Business as Usual

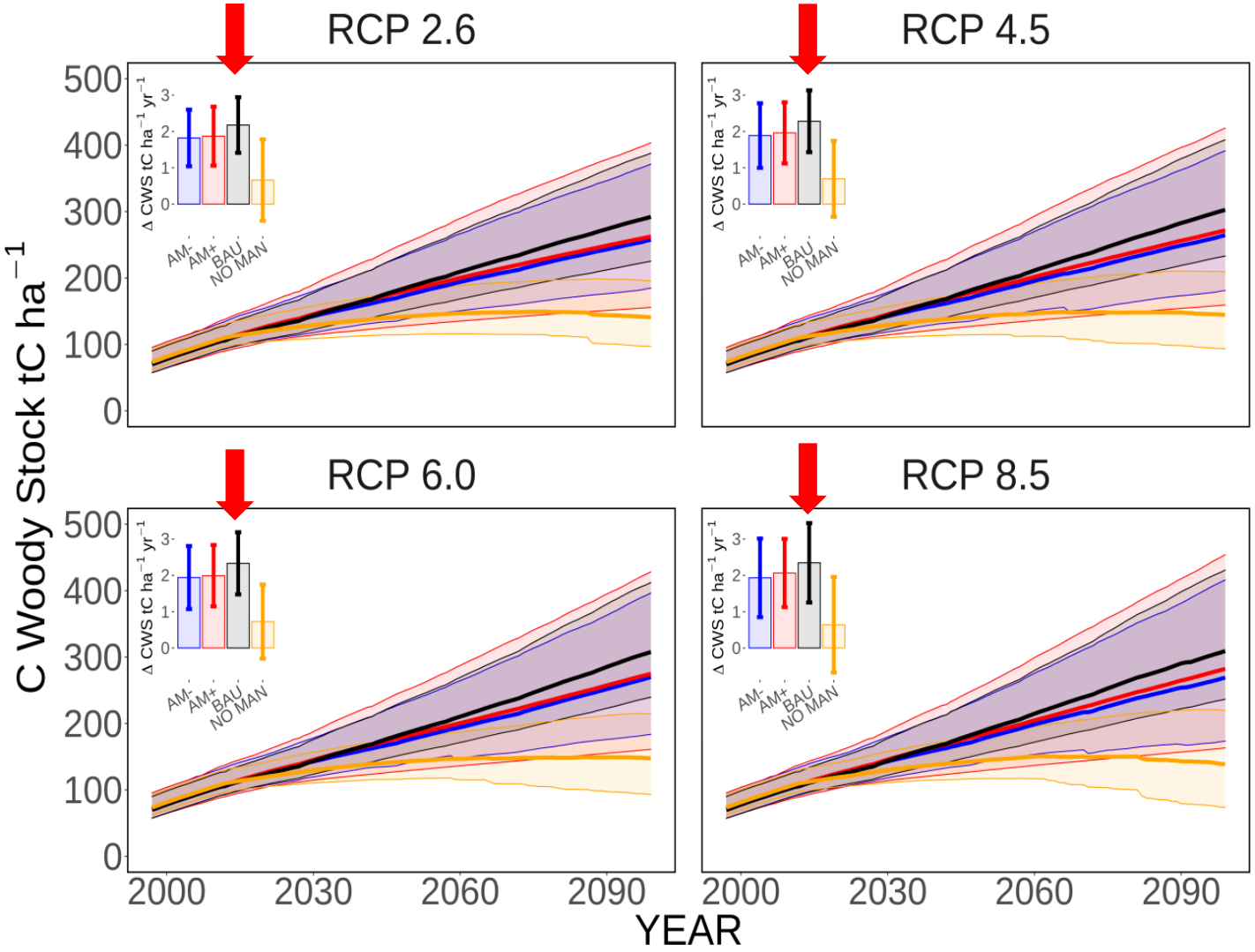
NO MAN = No management

Business as Usual is the best choice for NPP (and no apparent differences across RCPs)

(Dalmonech et al. 2022, AFM)

Testing Management Vs. No Management Under Climate Change

Carbon Woody Stocks



AM+ = Increased management intensity

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Business as Usual is the best choice for Carbon Stocks (and no apparent differences across RCPs)

(Dalmonech et al. 2022, AFM)

Forest modelling Lab.

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

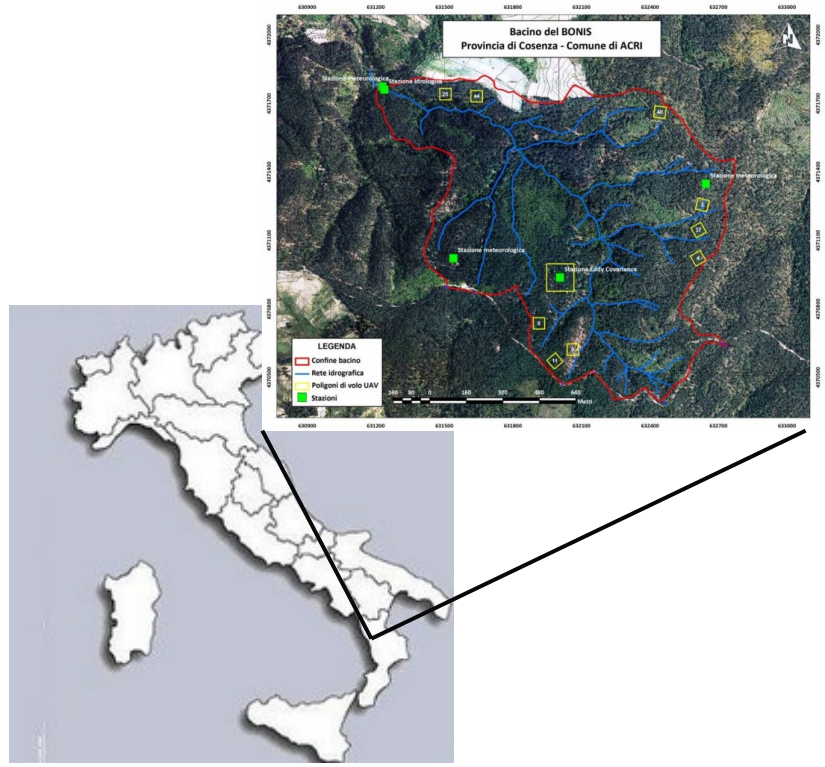
The Bonis case: Is forest management really, always and everywhere the best choice?

Bonis (Italy):
- *Pinus nigra* var. *Laricio*
- DBH: 1 cm
- Age: 4yrs
- Tree Height:
- Density: ca. 3000 tree/ha

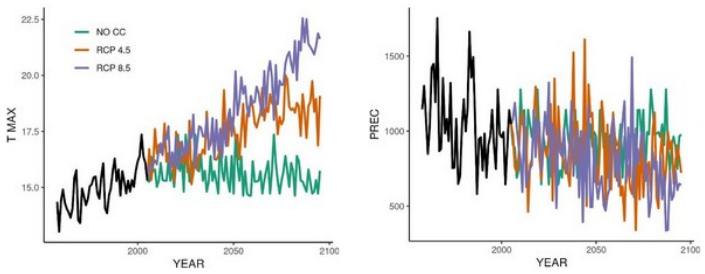
-1 Regional (8km res.) climate model (COSMO-CLM: 1968-2095)
-2 RCPs (4.5, 8.5)

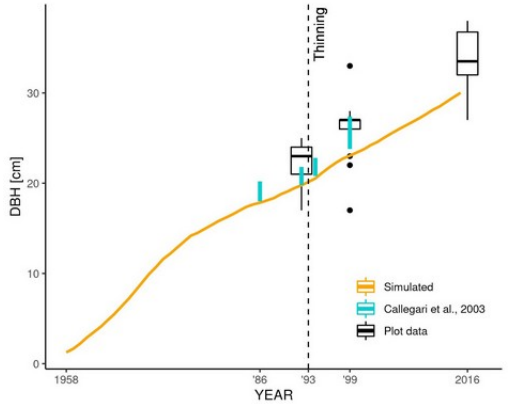
	Type	Detail	Objective	*t*	thBA	thinterval	harvesting	rep density	Notes
				year	%	year	%	n saplings	
Option 1	No management	No interventions	Model evaluation	NA	NA	NA	NA	NA	This option is used for the evaluation and only included the documented thinning in 1993 (25% basal area).
Option 2	Natural regeneration	Clearcut + natural regeneration	Post disturbance (wildfire)	80	NA	NA	YES	5013	Complete harvesting after 80 years from plantation (2038). After that, natural regeneration is established (age = 4; dbh = 1; h = 1.3).
Option 3	Patch clearcut	Clearcut + artificial regeneration (replanting)	Production / Commercial forest	80	NA	NA	YES	2425	Complete harvesting after 80 years from plantation (2038). After that, replant the same number of trees as in 1958 (age = 4; dbh = 1; h = 1.3; 2425 trees/ha).
Option 4	Shelterwood	Thinnings	Production / Commercial forest	NA	20	10	NA	NA	2 thinnings (2017/27), 1 heavy thinning in 2038 with regeneration (age = 4; dbh = 1; h = 1.3), harvest in 2048.
		Establishment cut		80	80	NA	NA	5013	
		Removal cut		90	100	NA	YES	NA	
Option 5	Shelterwood BAU	Thinnings	Production / Commercial forest	NA	28.5	10	NA	NA	3 thinnings (2017/27/37), 1 heavy thinning in 2048 with regeneration (age = 4; dbh = 1; h = 1.3), harvest in 2058.
		Establishment cut		90	80	NA	NA	5013	
		Removal cut		100	100	NA	YES	NA	
Option 6	Light thinning	Multiple thinning interventions	Biodiversity / Renaturalization	NA	28	15	NA	NA	4 thinnings (2017/32/47/62).
Option 7	Heavy thinning	Multiple thinning interventions	Biodiversity / Renaturalization	NA	35.5	15	NA	NA	4 thinnings (2017/32/47/62).

→ 1 Site x 1 Regional model x 2 RCPs x 7 Management scenarios = 14 simulations

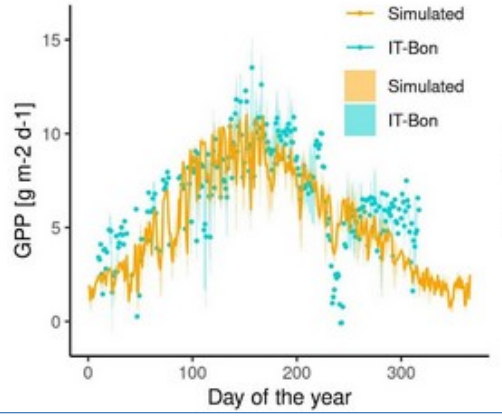


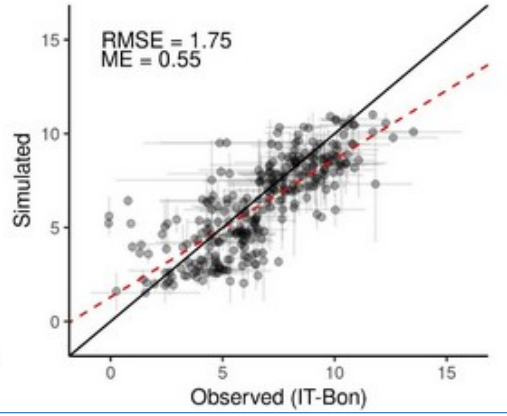
(Testolin et al. 2023, STOTEN)





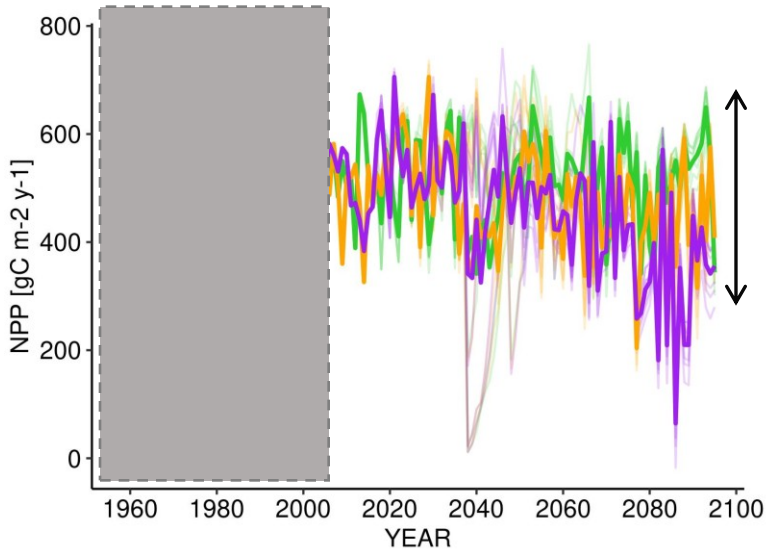
Validation



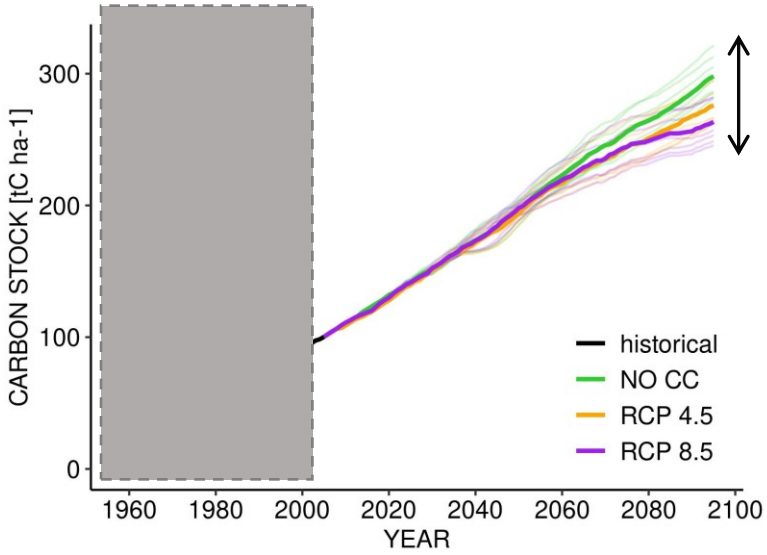


Forest modelling Lab.

The Bonis case: results



Spread across different management options and RCPs



No significant differences between different management options but there are between RCPs

(Testolin et al. 2023, STOTEN)

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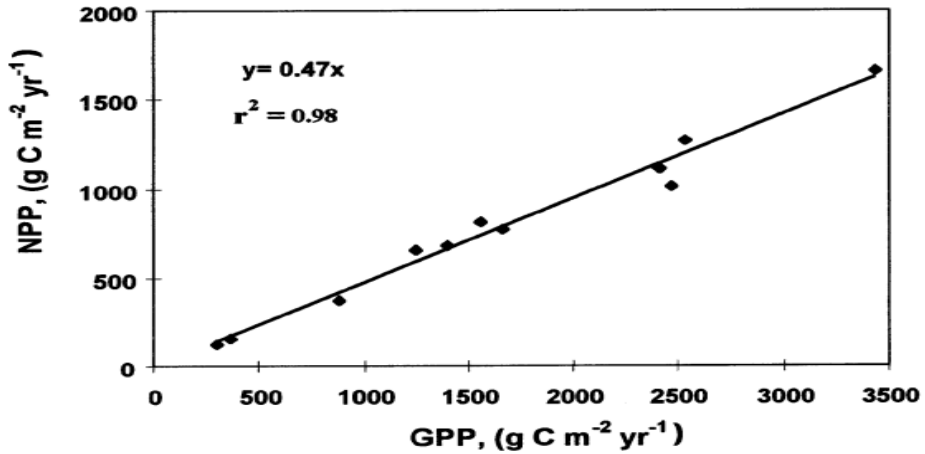
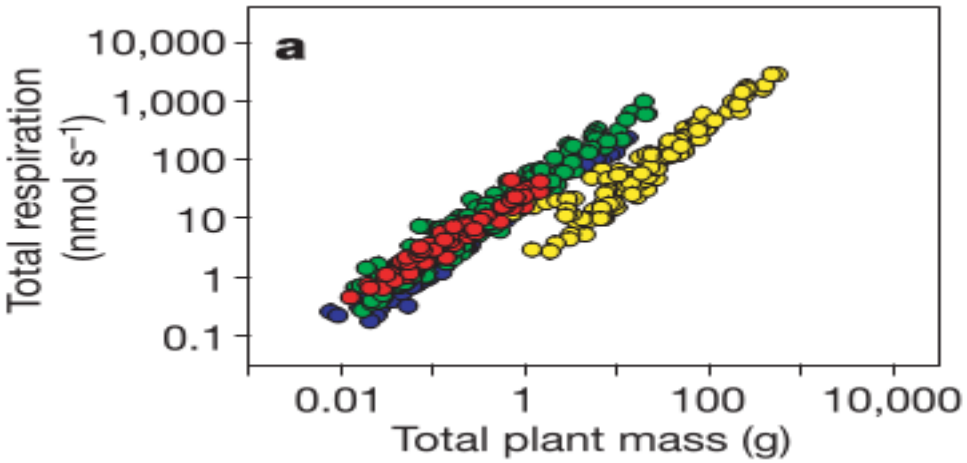
Process-Based Model (PBMs) – Testing long-lasting ecological theories

Question: Plant respiration is controlled by photosynthesis or biomass?



(*Waring et al. 1998, Tree Physiology*)



(*Reich et al. 2006, Nature*)

H_1: "Respiration is controlled by **photosynthesis**"

H_2: "Respiration is controlled by (total) **biomass**"

Results: none of these two hypotheses are actually correct!

(but how we found out that?)

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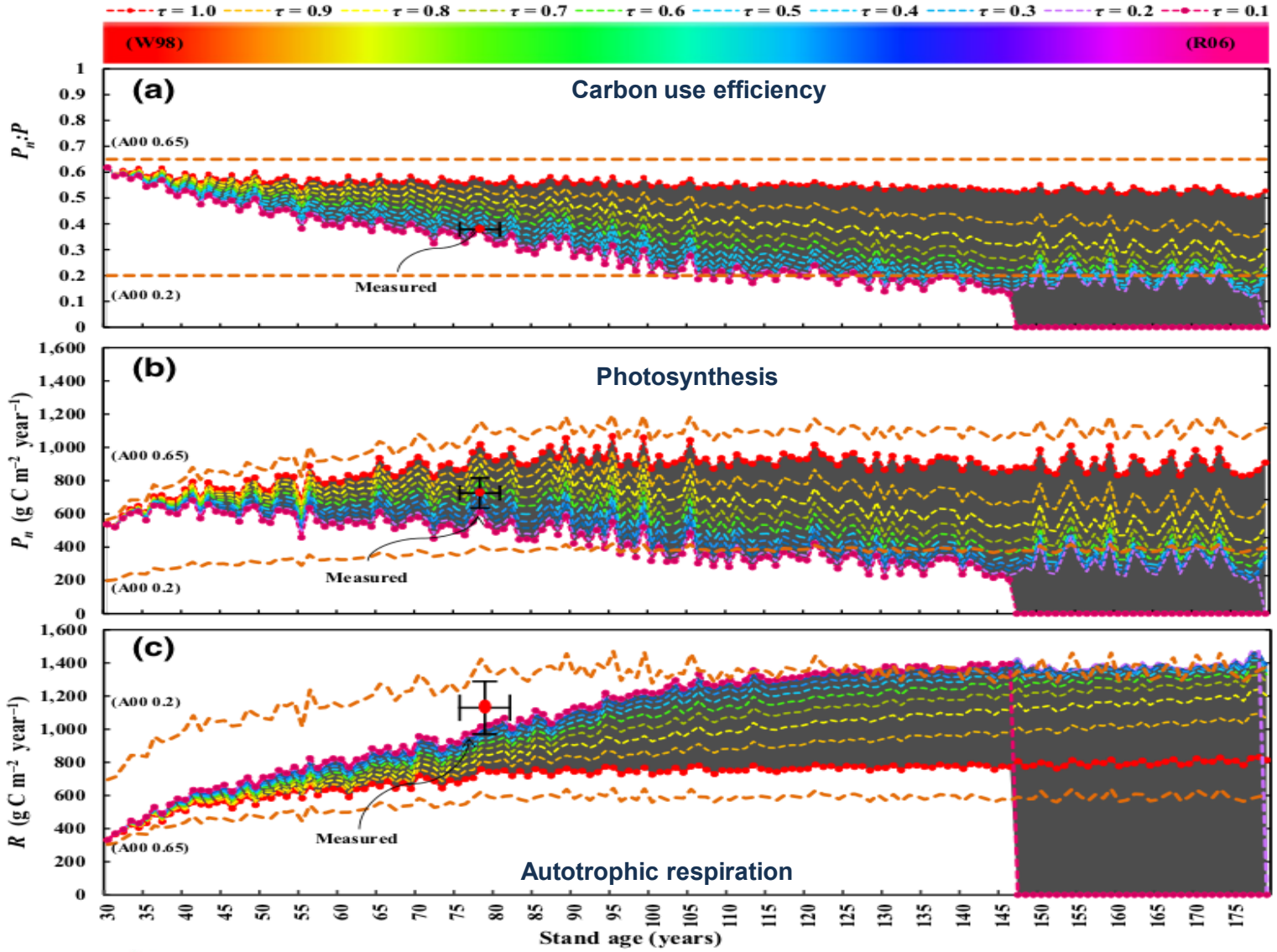
Process-Based Model (PBMs) – Testing long-lasting ecological theories



If respiration would be controlled only by photosynthesis in winter, when photosynthesis is stopped, all live cells would die. However, there have been found many live cells older than year

H_1: Respir **thesis** REJECTED

If respiration would be controlled only by biomass at increasing forest age respiration would became too high, consuming too much carbon, and trees would completely die when mature

H_2: Respir **mass** REJECTED

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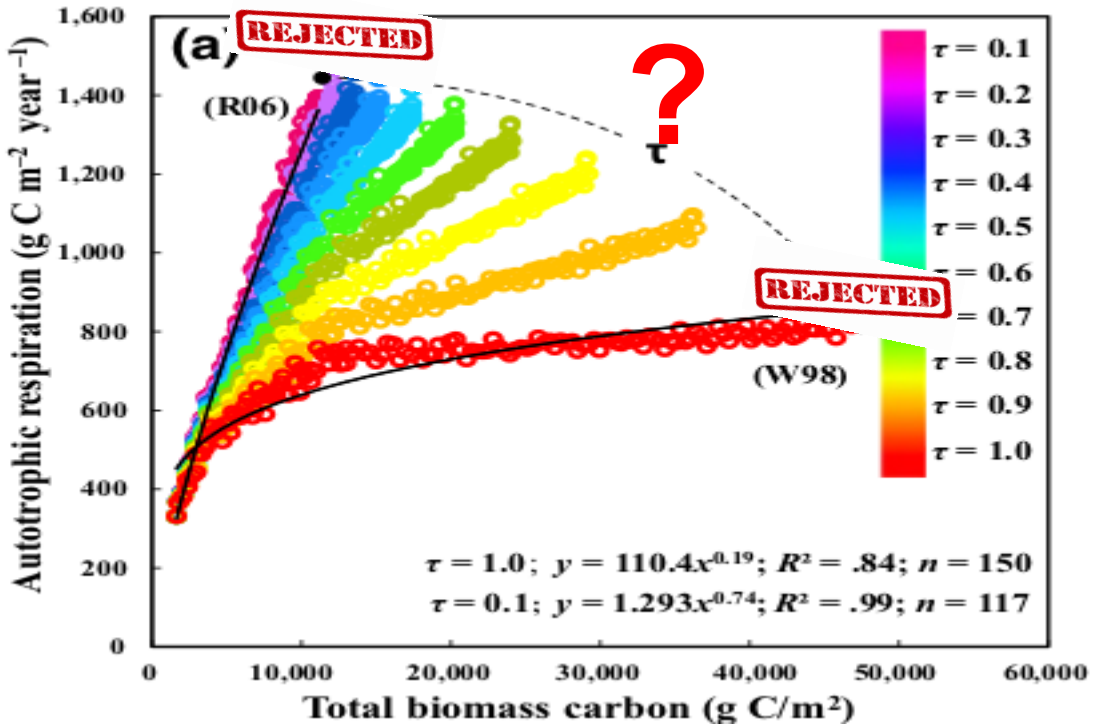
(Collalti et al., 2020; GCB)

Process-Based Model (PBMs) – Testing long-lasting ecological theories

Conclusion: Respiration is controlled by **both photosynthesis** and **biomass** at a variable extent, which we do not currently know, but somewhere in between the two hypotheses (both excluded)



(Collalti et al., 2020; GCB)

Some info

- The **3D-CMCC-FEM** is basically a research tool which is freely available ***only*** for non-commercial use.
- The **3D-CMCC-FEM** code is released under the GNU General Public Licence v3.0 (GPL).
- To avoid multiple model versions (code fragmentation) we ask users to use our **GitHub** versioning at **https://github.com/Forest-Modelling-Lab/3D-CMCC-FEM**
- **C**-language but with lots of **R**-wrappers!

- **3yrs Fixed Term position available** soon in the H2020 OptForEU project

Forest-Modelling-Lab / **3D-CMCC-FEM** Public

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software	fixed problems in fagus sylvatica parameterization	2 years ago
.gitignore	prove	6 years ago
LICENSE	Create LICENSE	3 years ago
README.md	Update README.md	2 weeks ago

README.md

3D-CMCC-FEM

Three Dimensional - Coupled Model Carbon Cycle - Forest Ecosystem Model

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3D-CMCC-FEM code

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Grazie per l’attenzione!

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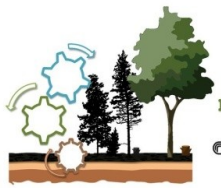
https://www.forest-modelling-lab.com/

https://github.com/Forest-Modelling-Lab



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