6th Edition of the Forest Innovation Workshop and OptFor-EU Mid-Term Conference

OptFor-EU

Integrating Climate, Forest, and Land Surface Models to Enhance Sustainable Forest Management Practices and Carbon Sequestration

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OptFor-EU | Modelling the F-C Nexus

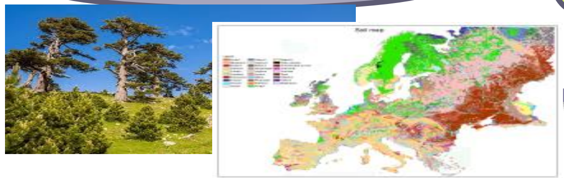
Use a **combination of forest, land surface and climate models to:**

1 **Quantify Forest-Climate Interactions & Essential Indicators**
Assess the impact of forest-climate interactions on **Essential Forest Mitigation Indicators (EFMI)** under various socioeconomic, and high-resolution climate scenarios

2 **Enhance Model Integration & Representation of Forest Management**
Improve the representation of **Forest Management Practices (FMP) within land surface and climate models** by incorporating harmonized land cover datasets, ensuring **better integration of European forests in global and regional models**

3 **Optimize Forest Management for Carbon & Ecosystem Resilience**
Identify and **assess optimal forest management strategies that enhance carbon stocks and sinks** while maintaining **Forest Ecosystem Services (FES) and resilience** under future climate conditions.

Forest, climate, soil

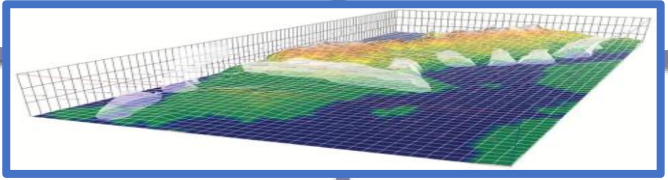


Forest Models
- **PICUS**
- **3D-CMCC-FEM**

Climate Models
- **RegCM**
- **REMO-iMOVE**

Land Surface Model
- **JULES**

Forest Management Practices



DSS (Decision Support System)

Climate Models
- **RegCM**
- **REMO-iMOVE**

| Objectives & Methods

Objectives
- **Improve the integration of European forests in regional climate models**
  - Integration of **transient (yearly-varying) land use** and **land cover changes (LULCC)** including forest cover changes
  - **Implementing forest management practice**
- **Investigate** biophysical **effects of forest cover** changes and forest management practices **on the regional climate**
- **Quantify forest-climate interactions** with a focus on climate regulating variables and selected EFMIs

Methods
- Two phases of coordinated experiments with two regional climate models
  - **RegCM (MeteoRomania)**
  - **REMO-iMOVE (Hereon)**

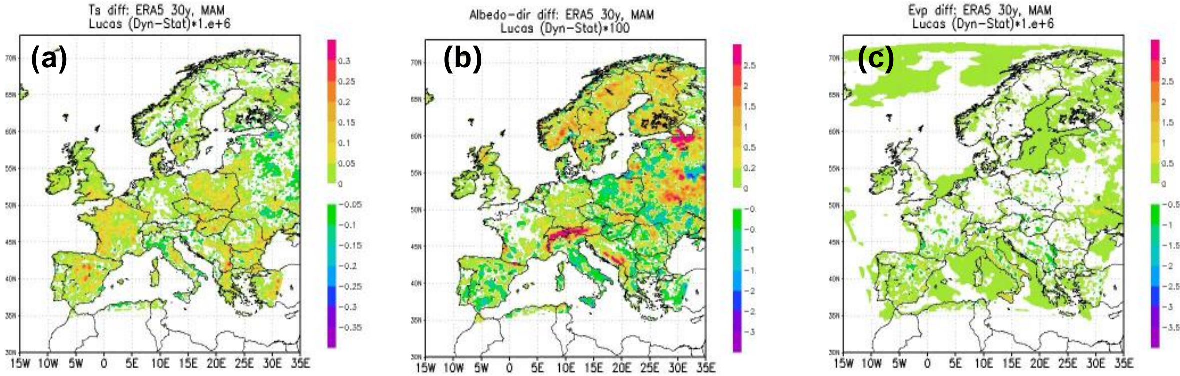
	Phase 1*	Phase 2
Domain	Europe	• CSA Romania • CSA Germany
Resolution	0.11° (~ 12.5 km)	0.0275° (~ 3 km)
Period	• ERA5-driven Evaluation 1979 – 2020 • GCM-driven Historical 1950 – 2014 • GCM-driven Scenario SSP126 2015 - 2100 incl. strong afforestation	Selected years and events
Forest cover representation	Transient forest cover changes from the LUCAS LUC dataset (Hoffmann et al. 2023)	Integration of forest management practice by reducing the forest cover according to experiments with forest models and information of stakeholders
	Reference: Static forest cover from LUCAS LUC 2015	Reference: No integration of forest management
Status	Simulations are running, partially completed	Simulation setup in preparation

*follows the experiment protocol of the flagship pilot study LUCAS of WCRP CORDEX

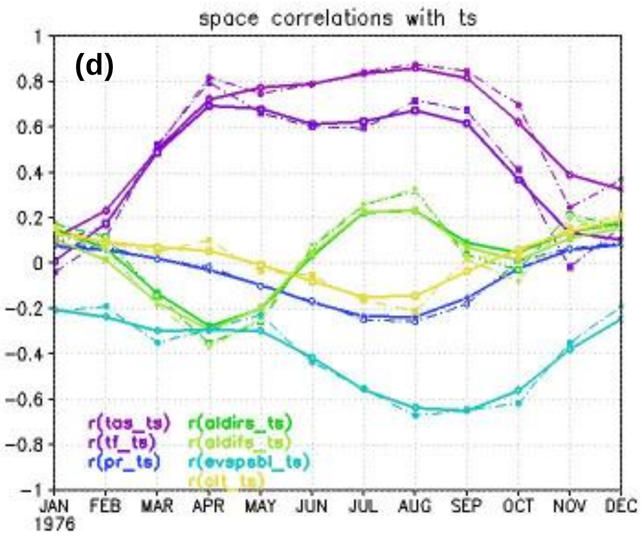
Climate Models
- **RegCM**
- **REMO-iMOVE**

| Preliminary Results

Effects of transient forest cover changes on surface variables with RegCM



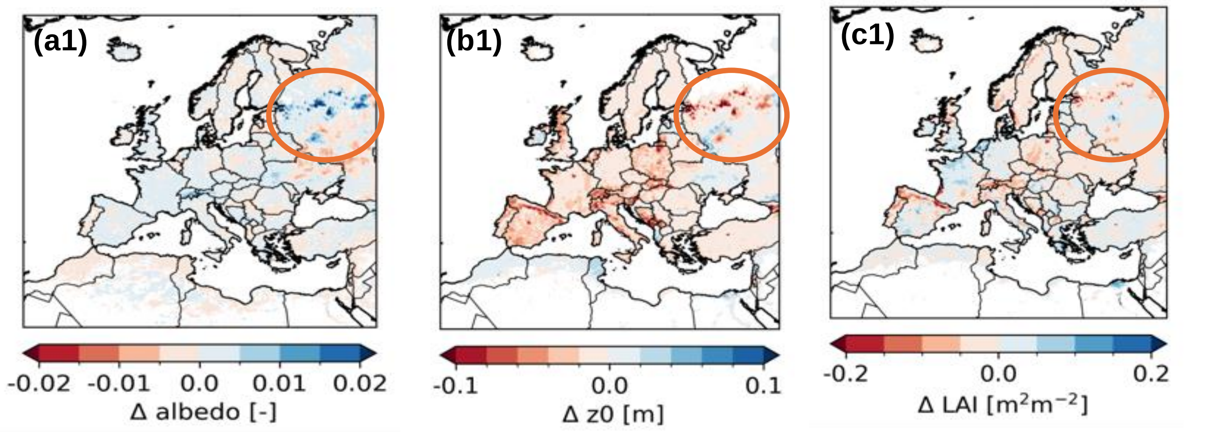
(a) Temperature seasonal differences (δ**TS**, D-S) are maximal in MAM, related to the balance between time-decreasing (b) albedo differences (δALB, D-S) and (c) increasing evaporation differences (δEVP, D-S).



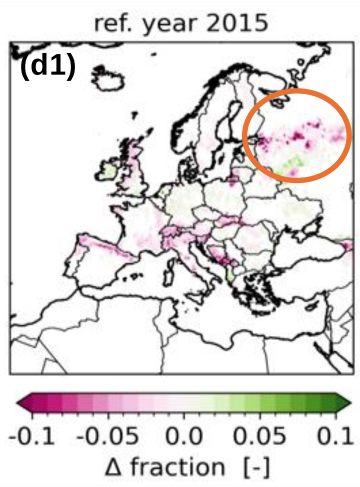
(d) Space correlations of TS change (δTS) with changes in:
- albedo (green)
- evapotranspiration (blue) precipitation(dark blue)
- cloud cover (yellow)
- air-foliage temperature (plum)

Space correlations of δTS (D-S) with **δALB and δEVP are both negative in spring**, while in mid-summer the **evapo-transpiration contribution appears to be a stronger driver of the TS** response to land cover changes.

Effects of transient forest cover changes on surface variables with REMO-iMOVE



Δ = mean(sim. with transient LULCC 1980 - 2020) - mean(sim. with static LULC 2015)



(a1) Δalbedo, **(b1)** Δroughness, **(c1)** ΔLAI and **(d1)** Δforest_fraction

Forest cover changes as difference of using the **transient LUCAS LUC dataset compared to static forest cover from 2015.**

Effects in **surface variables** influence land - atmosphere interactions (e.g., evapotranspiration, turbulent heat fluxes). Consequently, these effects influence **atmospheric variables** (e.g., 2 m temperature)

Forest Models
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Land Surface Model
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| Objectives & Methods

OptFor-EU

Forest Models

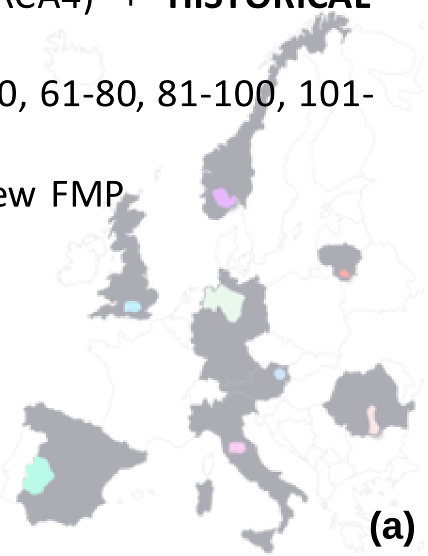
Objective

- Evaluate of forest-climate interactions **on EFMI under various socioeconomic, and climate scenarios (RCP 2.6, 4.5 and 8.5)**
- **Expand on existing FMP,** such as Business as Usual (BAU) and No Management (NOMAN), by **integrating new management practices into model simulations**

Methods

- 2 Forest Model: **PICUS (BOKU) and 3D-FEM-CMCC (CNR)**
- **8 Case Study Area (CSAs**) across Europe **(a)**
- **3 RCPs scenario**: RCPs 2.6, 4.5 and 8.5
- **3 RCMs** (RACMO22E, HIRHAM5, and RCA4) + **HISTORICAL** (CERRA)
- **8 age classes selected:** (0-20, 21-40, 41-60, 61-80, 81-100, 101-120, 121-140 and >141)
- **Management practices:** NOM, BAU and new FMP

CSA		
Code	***Nation***	***Region***
CSA1	Norway	*Vestfold and Telemark region*
CSA2	Lithuania	*Čepkeliai – Dzūkija National Park*
CSA3	United Kingdom	*Wytham Woods*
CSA4	Germany	*Lower Saxony*
CSA5	Austria	*Biosphere Reserve "Wiener Wald"*
CSA6	Romania	*Arges Vedea Watershed*
CSA7	Spain	*Extremadura Pine Forest*
CSA8	Italy	*Florentine Mountians*



(a)

Land Surface Model

Objective

- **Improved representation of forest and forest management in a land-surface model**, and implications for Earth System Modelling (ESM)

Methods

- **Model**: **JULES (JULES is the land surface component of the UK Earth System Model)**
- **Use 3D-CMCC-FEM to calibrate European forests in JULES** by establishing a parameter mapping where possible and fitting JULES parameters to 3D-CMCC-FEM output where not.
- **Compare different methods for implementing forest management practices and their impact on carbon and water fluxes,** given the importance of these fluxes for ESM feedbacks.

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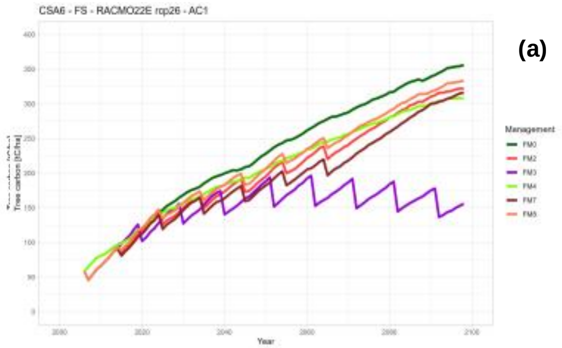
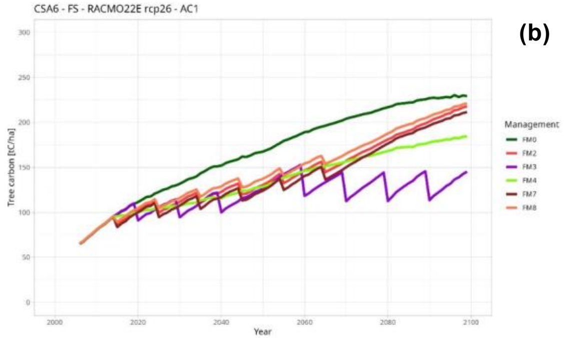
| Preliminary Results

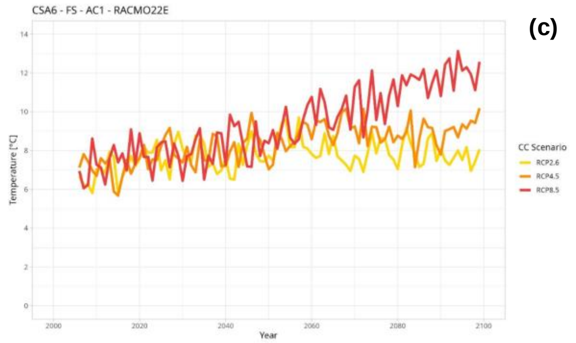
Forest Models



(a)



(b)



(c)

Comparing forest carbon stocks (tC ha^{-1}) for one simulation unit (CSA6, EFT 6, Class Age 1, RACMO22E and RCP 2.6) simulated forest management options and **using forest model PICUS (a) and 3D-CMCC-FEM (b).**

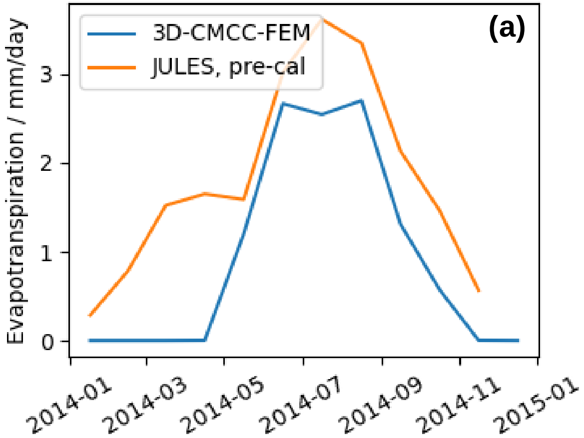
- Tree carbon stocks across various FMPs, such as shelterwood management (**FM2**), continuous cover (**FM3**), and low-intensity harvesting (**FM4**), **reveal trade-offs between carbon storage, forest structure, and wood production**

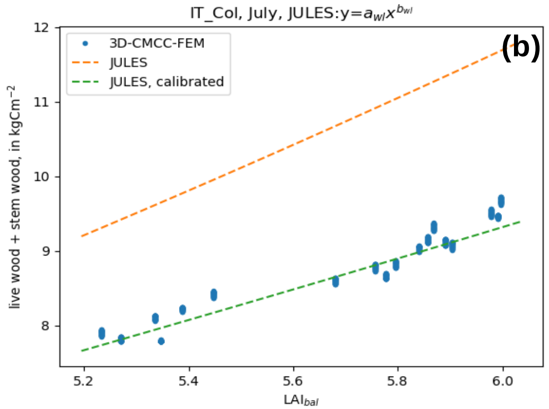
- **FM0** (NOMA) **leads to the highest carbon stocks,** other **FMPs balance carbon sequestration** with timber yield, **ensuring sustainable forest management under changing climate conditions.**

(c) Climate input datasets (RACMO22E HADGEM2ES) using annual average temperature (°C) for CSA6 and EFT6.

- Both forest models, **PICUS and 3D-CMCC-FEM, exhibit sensitivity to climate variables,** which results in varying simulated forest conditions depending on multiple factors

Land Surface Model





(a) Model evapotranspiration for an example deciduous broadleaf site in Italy (FLUXNET site IT-Col). **(b) Example using 3D-CMCC-FEM output to calibrate two JULES input** parameters that relate balanced Leaf Area Index (LAI) to the sum of live wood and stem wood.

- **Compared JULES and 3D-CMCC-FEM output for a broadleaf deciduous site and needle leaf site in Europe**, including carbon and water fluxes.

- **Found compensating biases in JULES** (example, water stress and leaf area index)

- Established a **mapping from 3D-CMCC-FEM parameters to JULES** parameters for 25 JULES plant tile input parameters, 3 JULES water stress input parameters and 9 JULES soil input parameters

- Investigated the **potential to calibrate the 4 plant tile input parameters that determine the relationship between the tree height, peak summer LAI and stem carbon on each plant tile to 3D-CMCC-FEM**

Thank you

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