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Large-scale applications of forest models

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PROCLIAS

Why do we need large-scale forest models except for academic interest?

- Assessment of forest dynamics of regions (e.g. EU)
- Comparability of projections between countries because of a similar method
- Wood demand-supply assessment for countries or regions taking into account export and import
- Assessment of the impact of policies implemented on large scales (Fit55, NRL) on wood supply, carbon sequestration and biodiversity within the region and the 'leakage effect'
- …….

What type of large-scale forest models is the best (1)?

- DGVMs – very advanced but usually complex and lack forest management and economics, hard to reproduce man-driven reality (but improving: LPJ-GUESS, ORCHIDEE-MICT)
- Age / DBH Matrix models using yield curves – can represent age dynamics and forest management effects but usually lack representation of dynamics of vegetation types and tree species, and economics, not sensitive to climate change, … (EU-CBM-HAT, EFISCEN, G4M)
- Process-based models with forest management representation – usually complex, climate sensitive, lack representation of dynamics of vegetation types and economics, hard to reproduce man-driven reality (but improving: 3PG-MIX)
- Economic forest models – advanced in forest economy but usually lack representation of age structure dynamics, details and spatial heterogeneity (GTM, GLOBIOM; some exceptions: The French Forest Sector Model; improving: GLOBIOM)

What type of large-scale forest models is the best (2)?

- Coupled models – link a few models from above, usually complex, hard to interlink dynamically, but allow answering complex research questions in a more systematic way (3PG-MIX – G4M – GLOBIOM; MAgPIE – LPJmL)
- All-In-One IAMs – dynamically linked modules, usually complex and rough representation of forestry

- Trade-offs:
    - More details and greater complexity, usually -> greater
        - use of computational resources
        - amount of input data
        - risk of data inconsistencies.

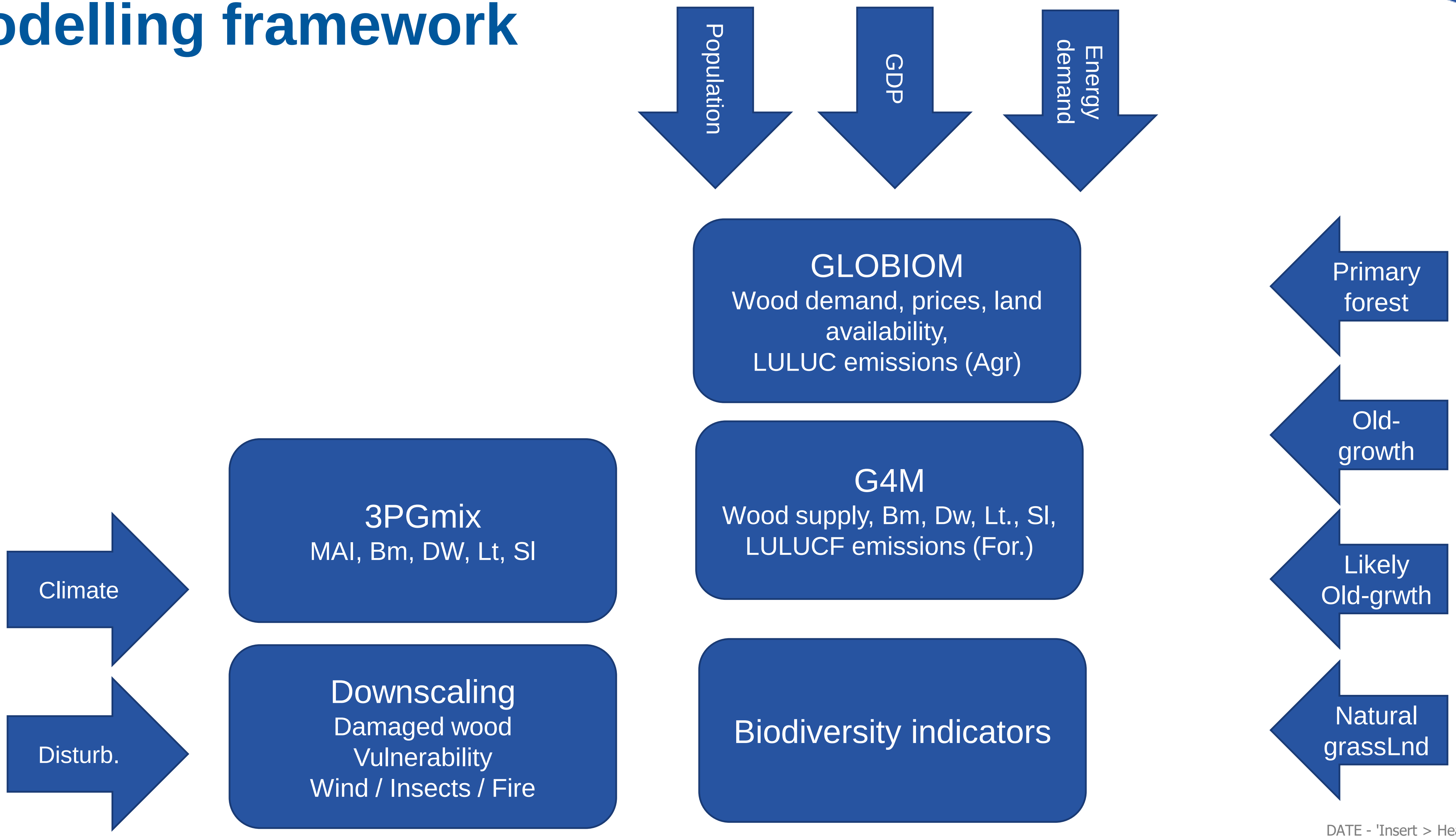
What type of large-scale forest models is the best (3)?

- The best model (type) is
  - the one allowing to answer the research question
    - taking into account the available data, computational resources and reasonable time.

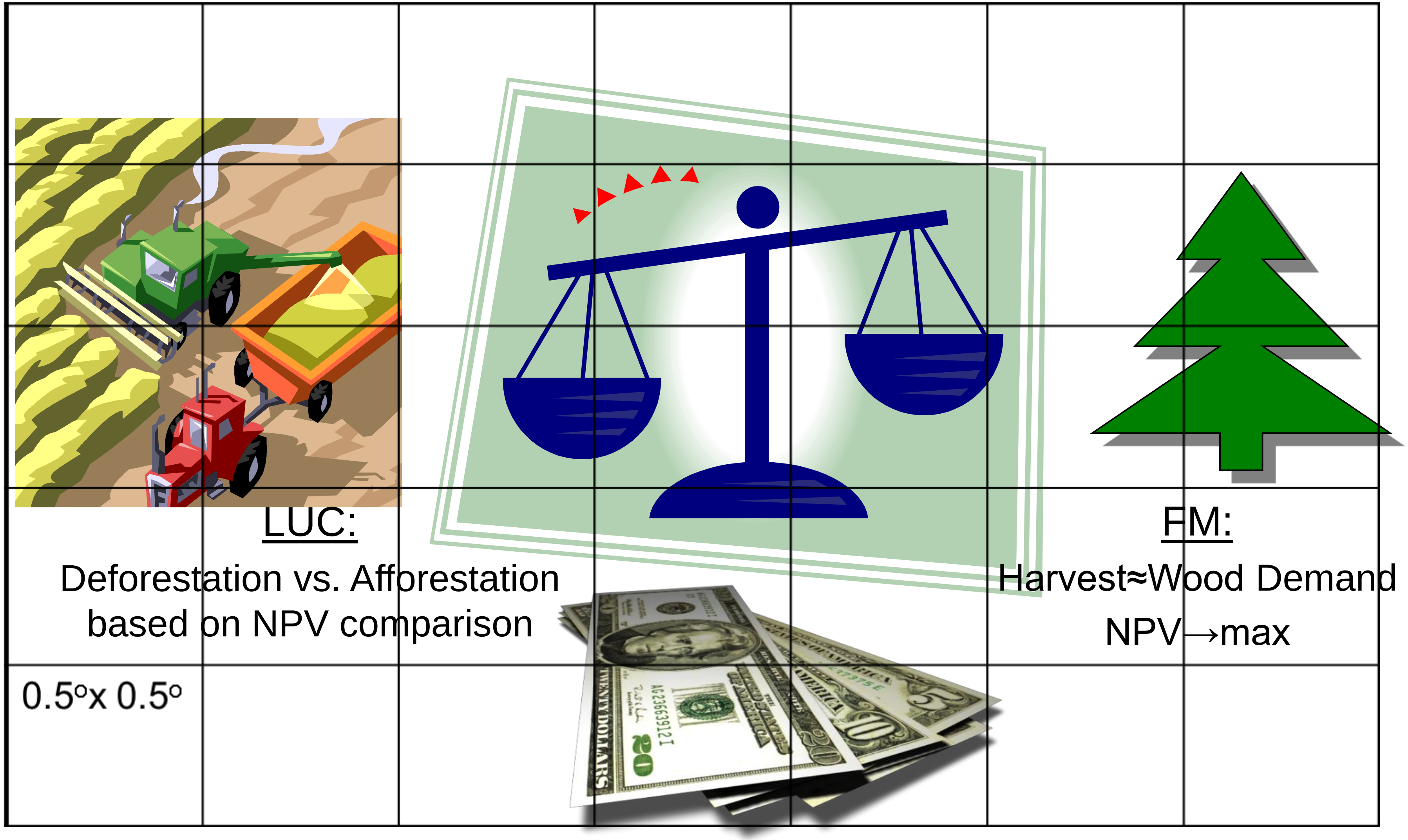
Large-scale forest models (e.g. G4M)

- **Pros**
  - Feasibility of parameterization for different countries
  - Similar approach for different countries - comparability
  - (Use of publicly available data)
  - Heavily data-driven, empirical -> the results are tight to the data and can be used for official reporting if proper data are used
- **Cons**
  - Lack country- or site-specific details -> not as good as dedicated country models
  - Rough spatial and thematic resolution (0.5 deg. / strata; stands; limited amount of tree species; problems with representation of mixed stands and selective logging etc.)
  - **Heavily data-driven, empirical -> projections for changing environment is a challenge, e.g., projections under climate change**

Climate Change Impact Assessment – modelling framework



G4M: general approach



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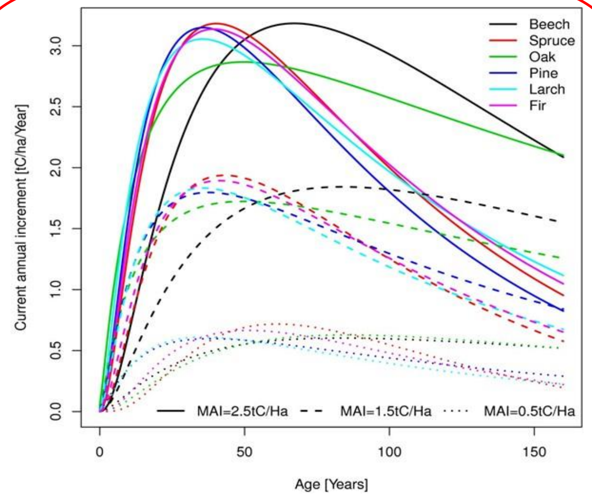
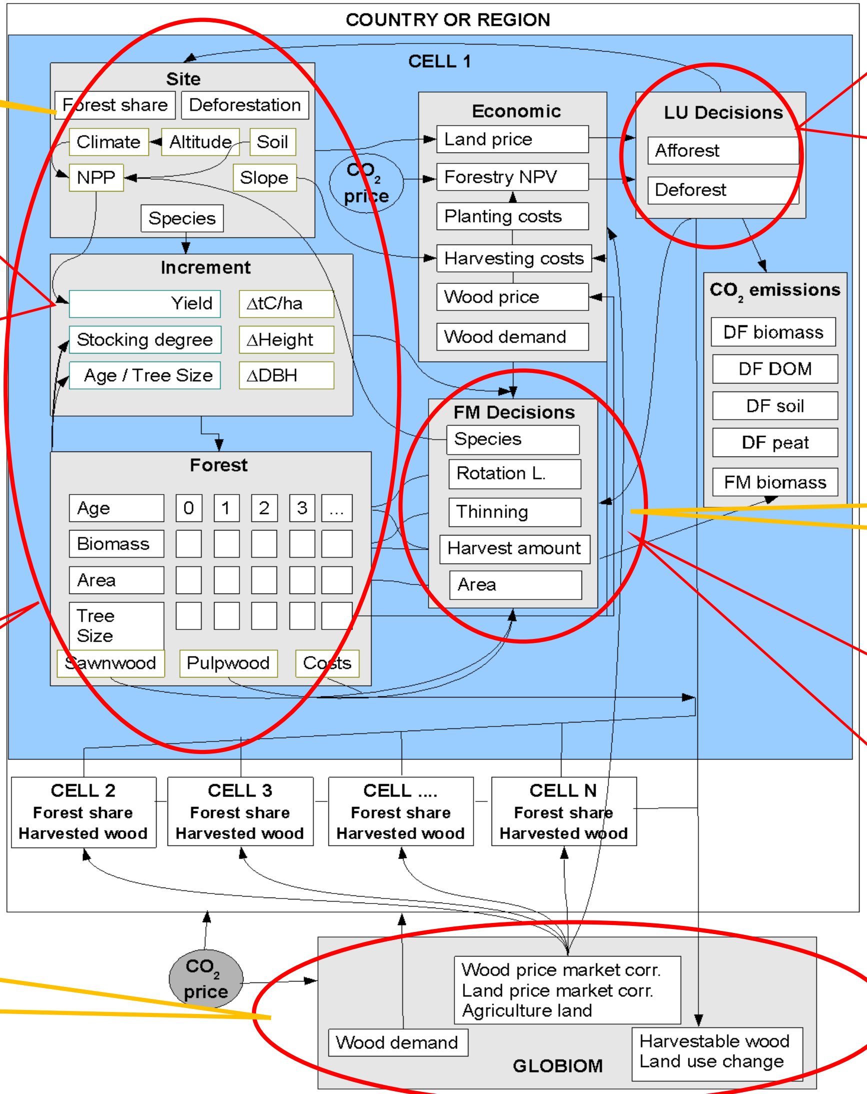
G4M overview

Input of increment shifts from 3PGmix



Forest simulator

0.5x0.5 deg. grid



<u>LUC decisions principals:</u>

Deforest if:
NPVagri + DeforWood x Price > NPVfor

Afforest if:
NPVfor>NPVagri

Input of damaged wood amount

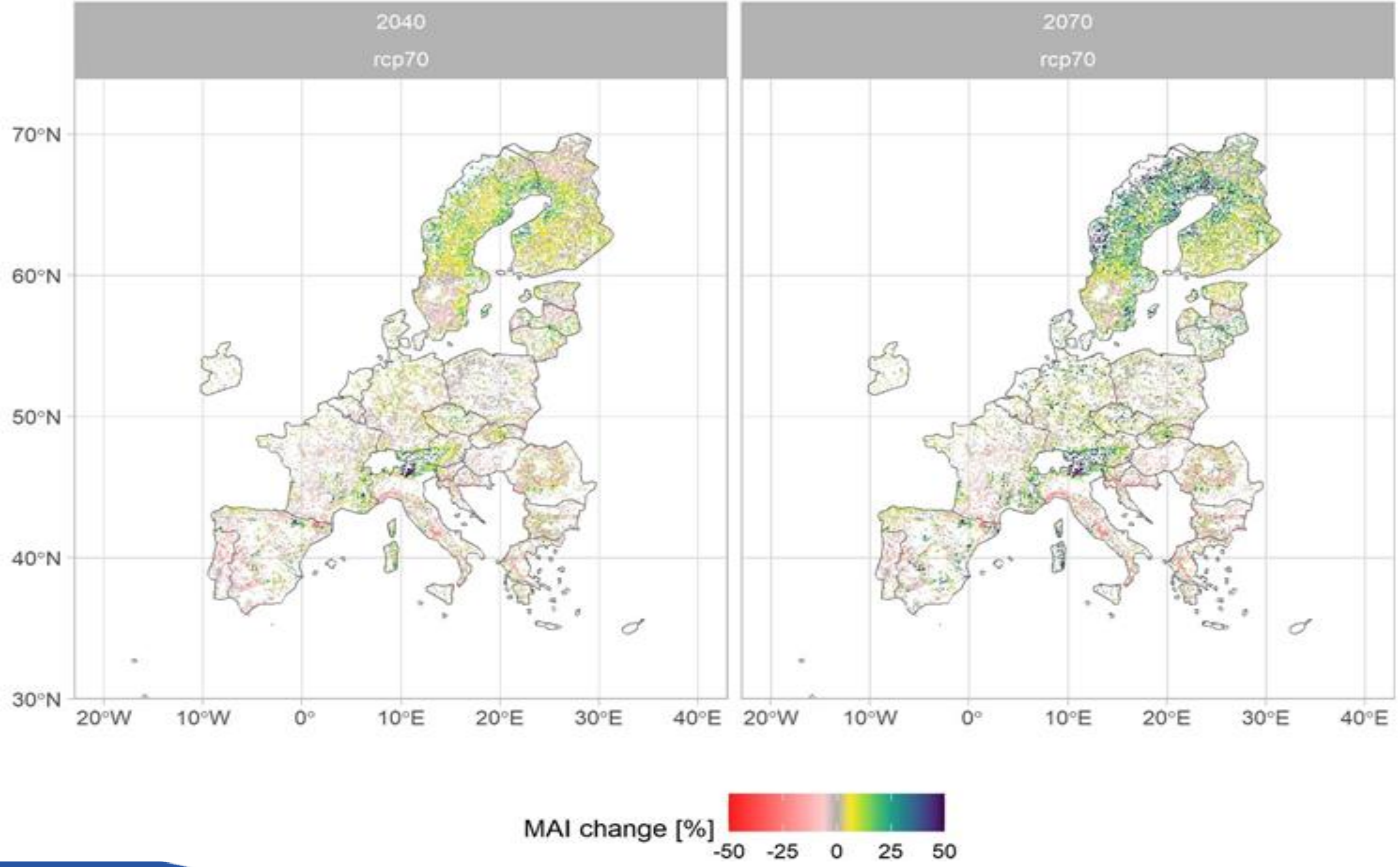
<u>FM decisions principals:</u>

Country harvest ≈ Wood demand
RL_maxMAI ≤ RL ≥ RLmaxBM
NPVnew ≥ tol. x NPVold
Init.harv.intensity to Verkerk et al (2015)

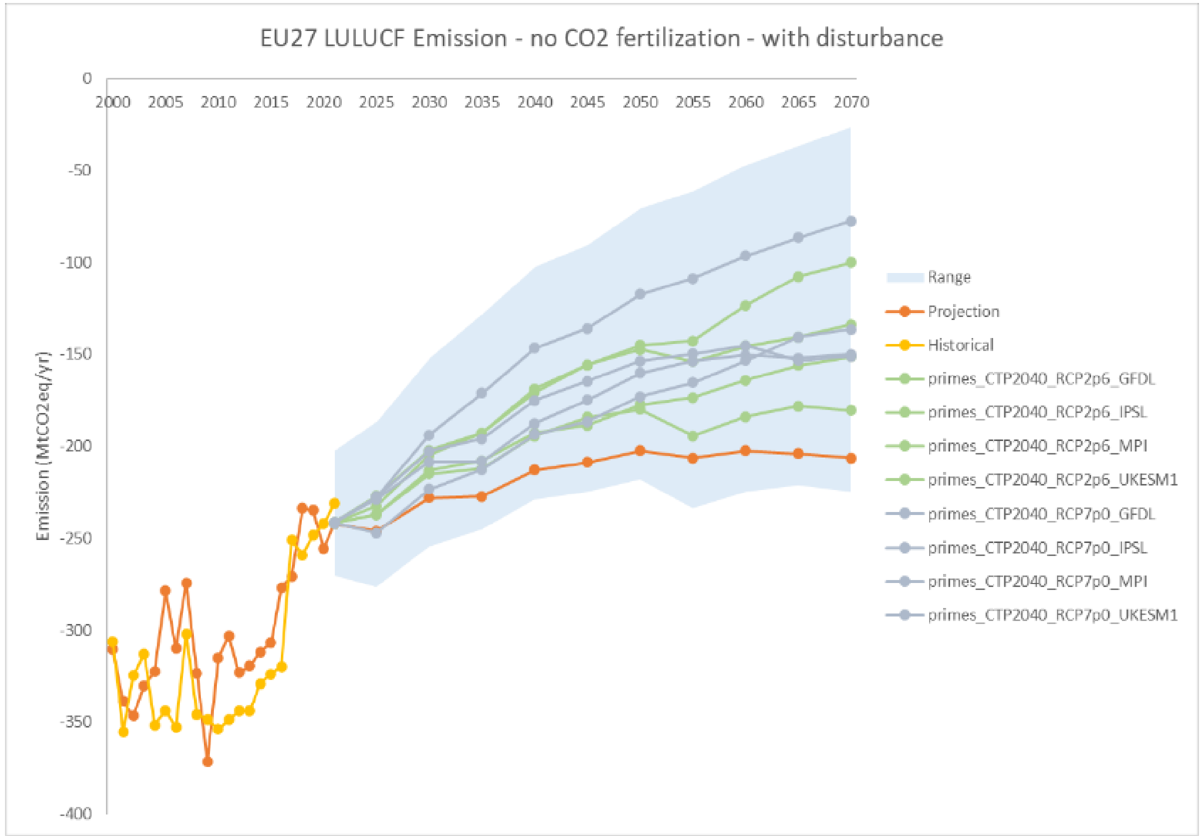
<u>Data exchange with GLOBIOM</u>

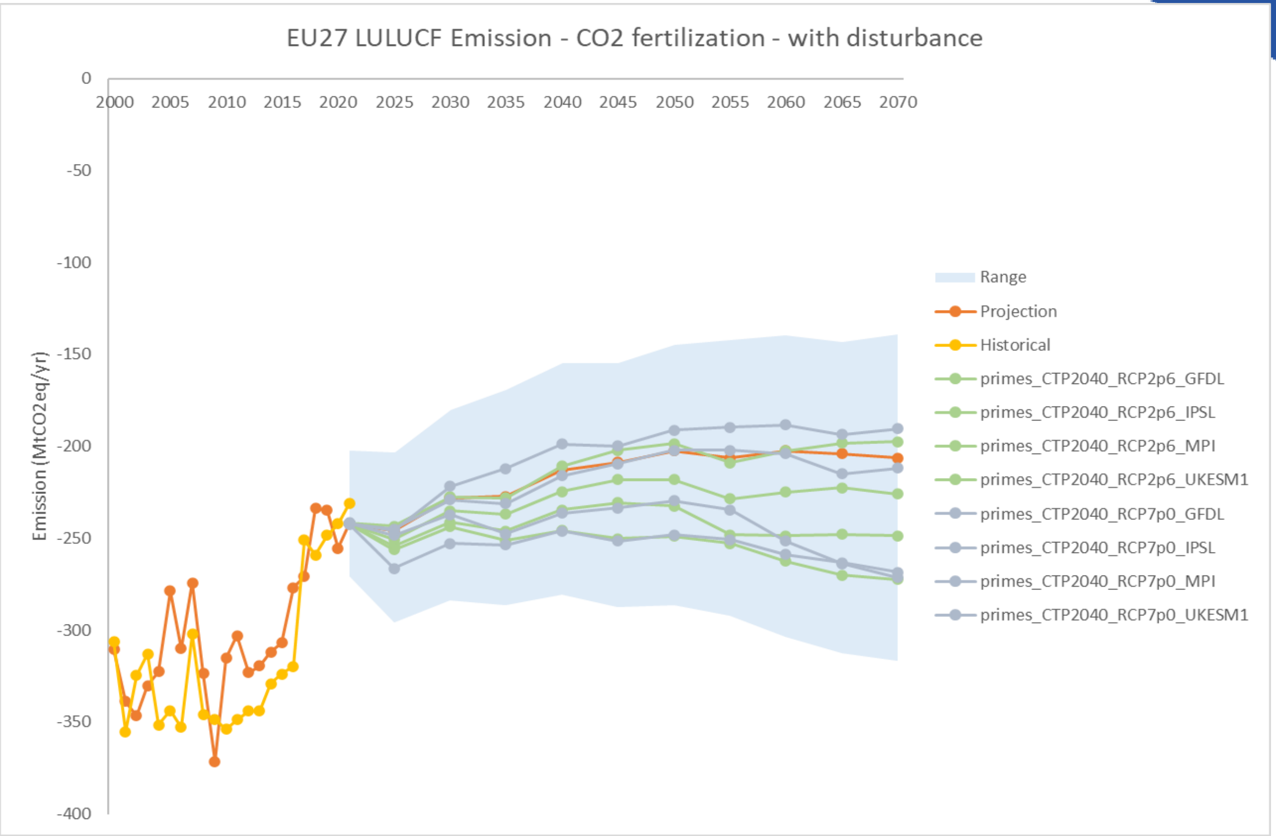
Forest Simulator by G.Kindermann (2013)

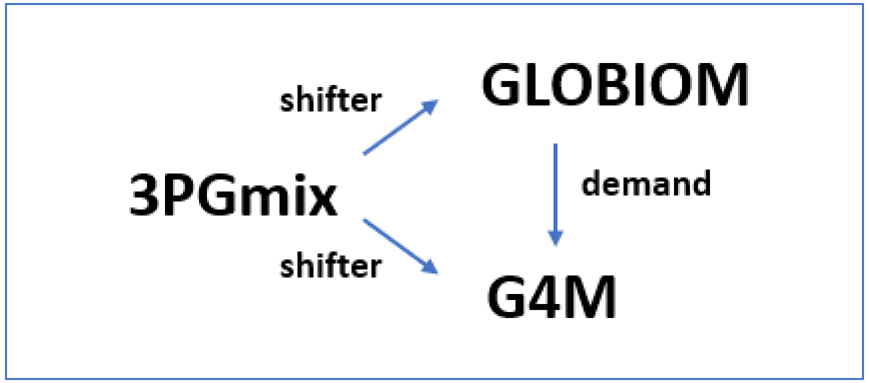
Climate change impacts – 3PGmix



Modelling long-term climate change impacts on forests: LULUCF emissions







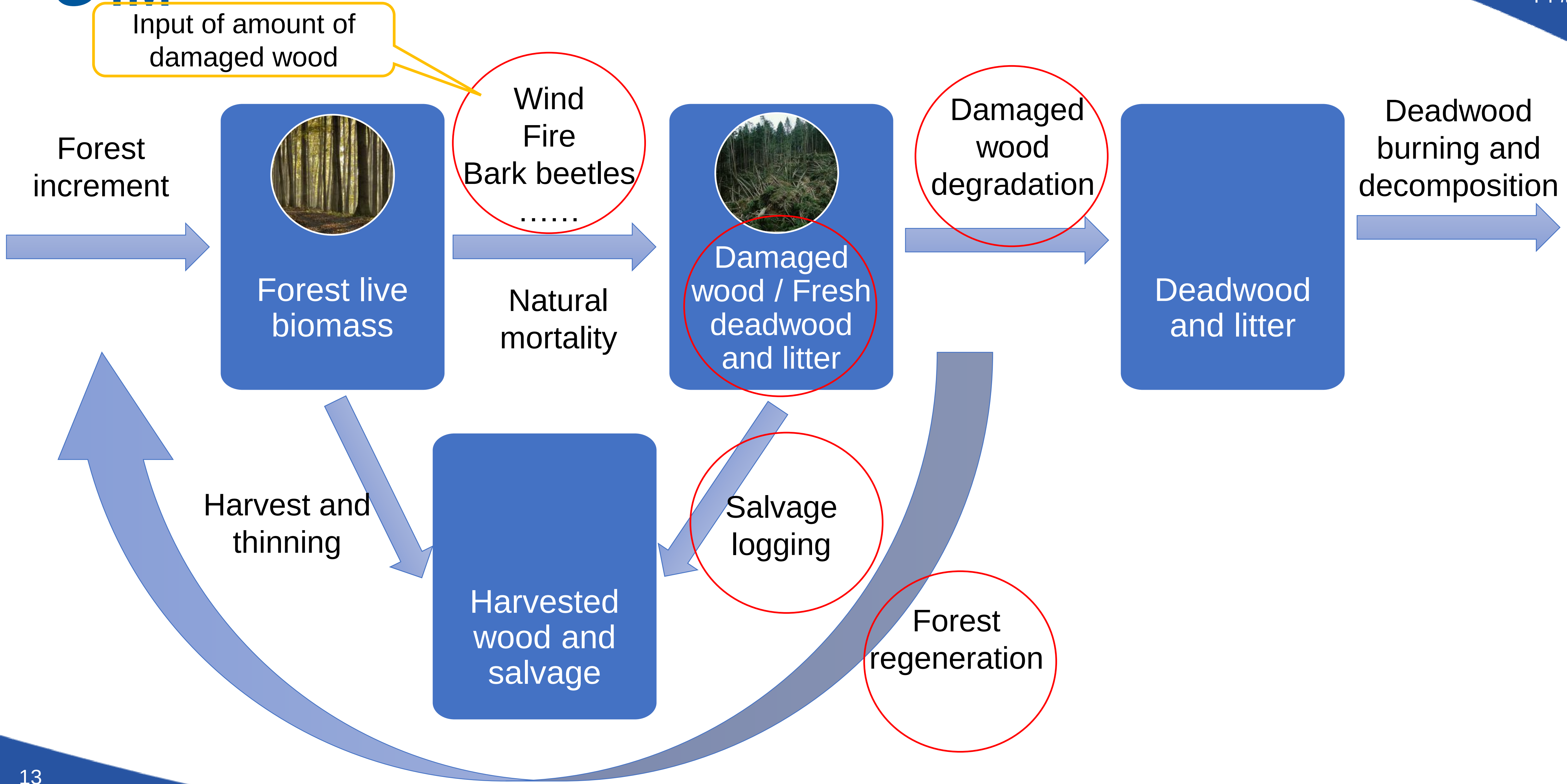
Ranking

1) CO2 Fertilization
2) Climate Model
3) RCP

Climate change impact on LULUCF emissions: Key messages

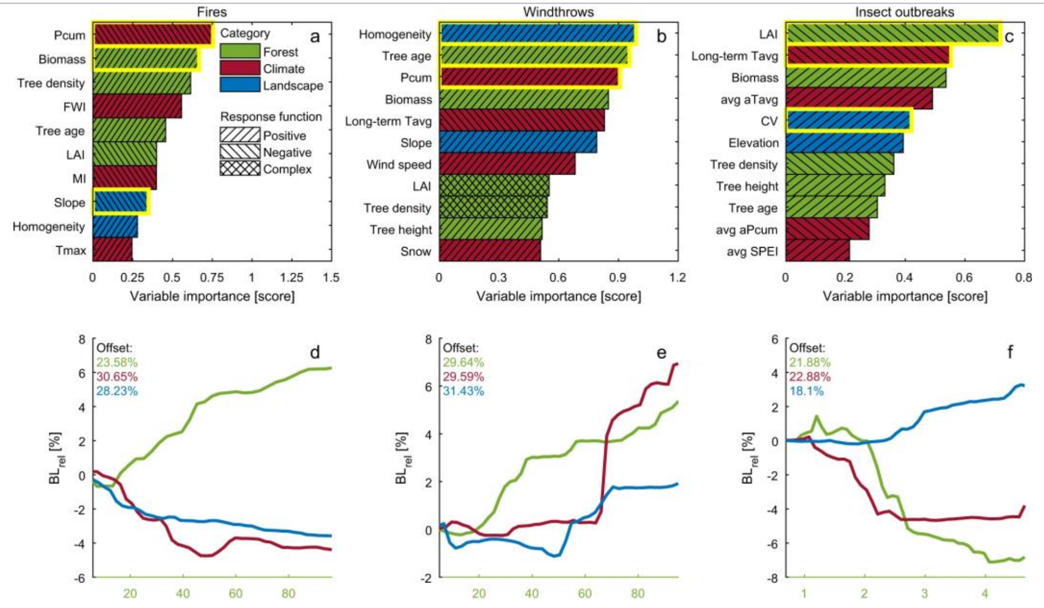
- LULUCF emissions increase by 2070 in 10 of 16 scenarios
- No big difference in LULUCF emissions under RCP2.6 and RCP7.0 scenarios
- High uncertainty in climate change (CC) projections
- The uncertainty in the CO_2 fertilization effect determines the CC impact on LULUCF emissions:
  - No CO2 fertilization: LULUCF emissions increase under all RCP and all climate model scenarios
  - With CO2 fertilization: LULUCF emissions decrease in 6 out of 8 RCPxCCP scenarios

Disturbances, deadwood and salvage logging in G4M



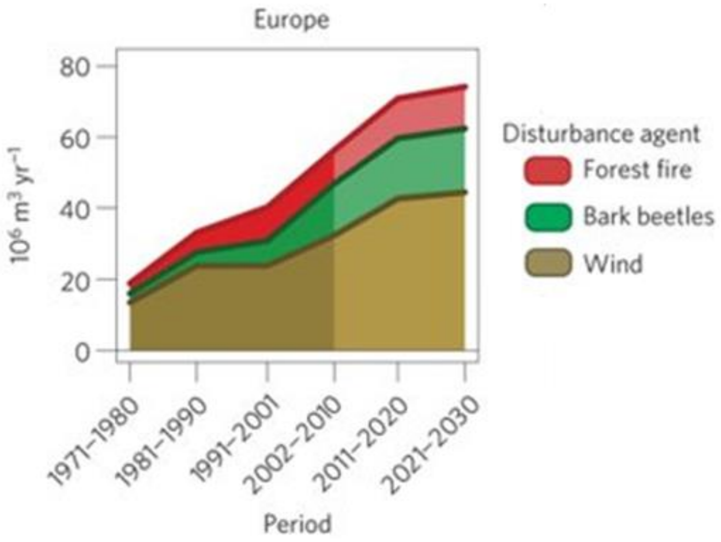
Disturbance damage

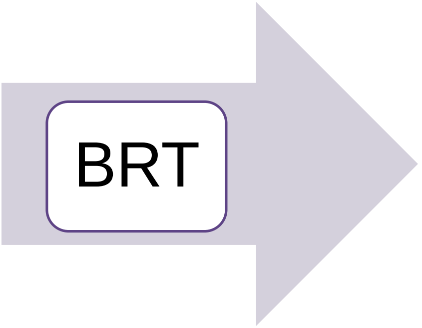
- Spatial allocation - vulnerability

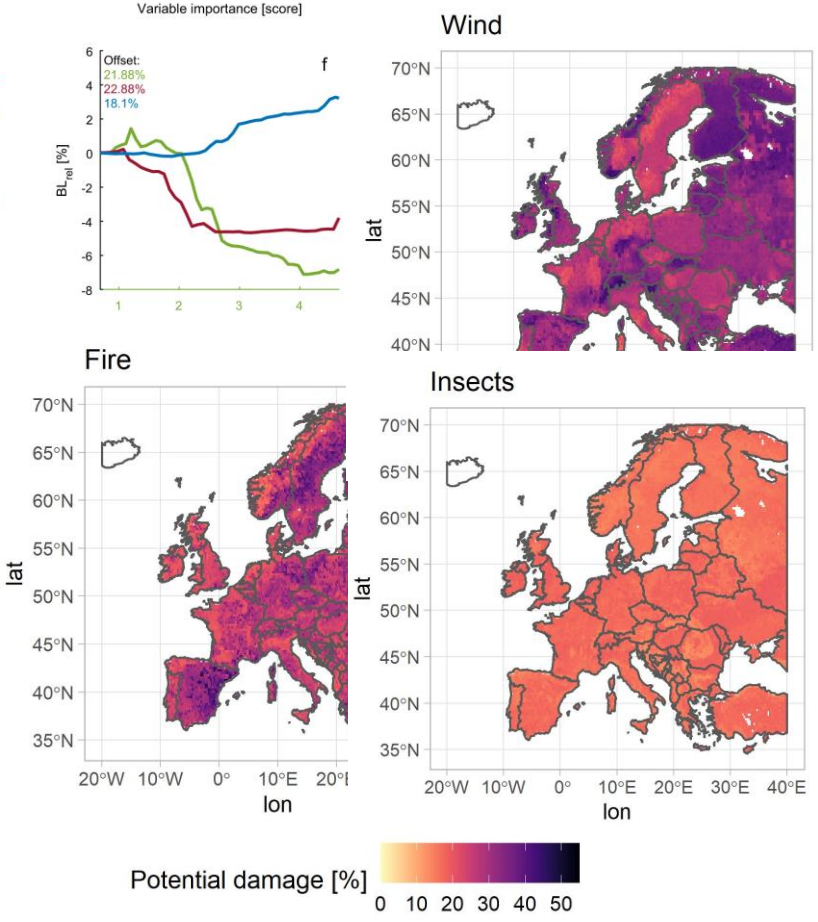


Forzieri et al. 2021

Disturbance activity (Patacca et al. 2023) and Damage projection Seidl et al. 2014



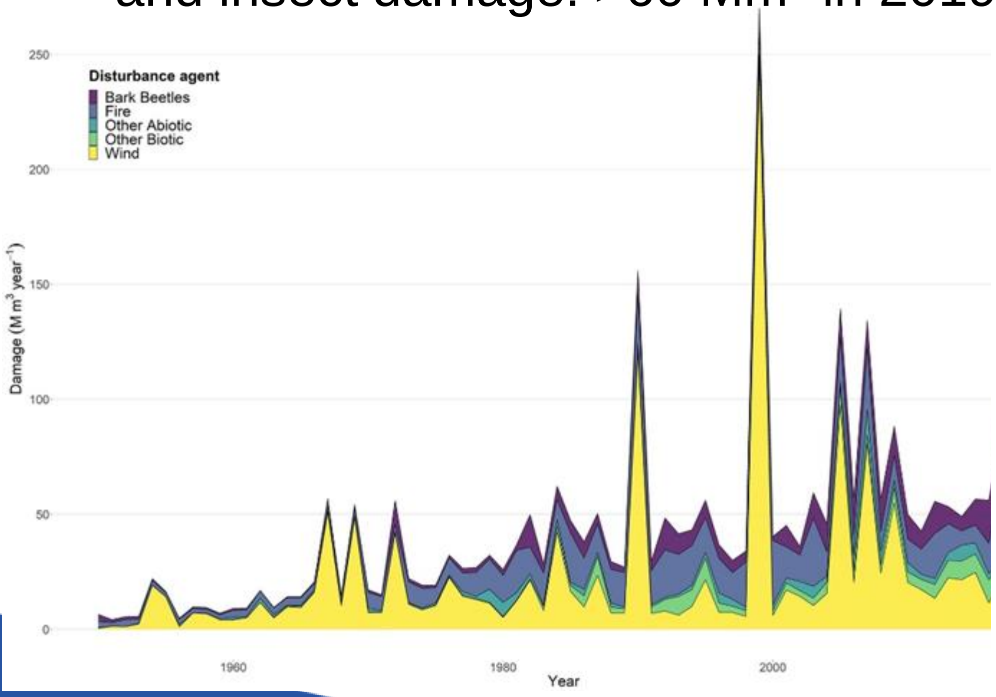




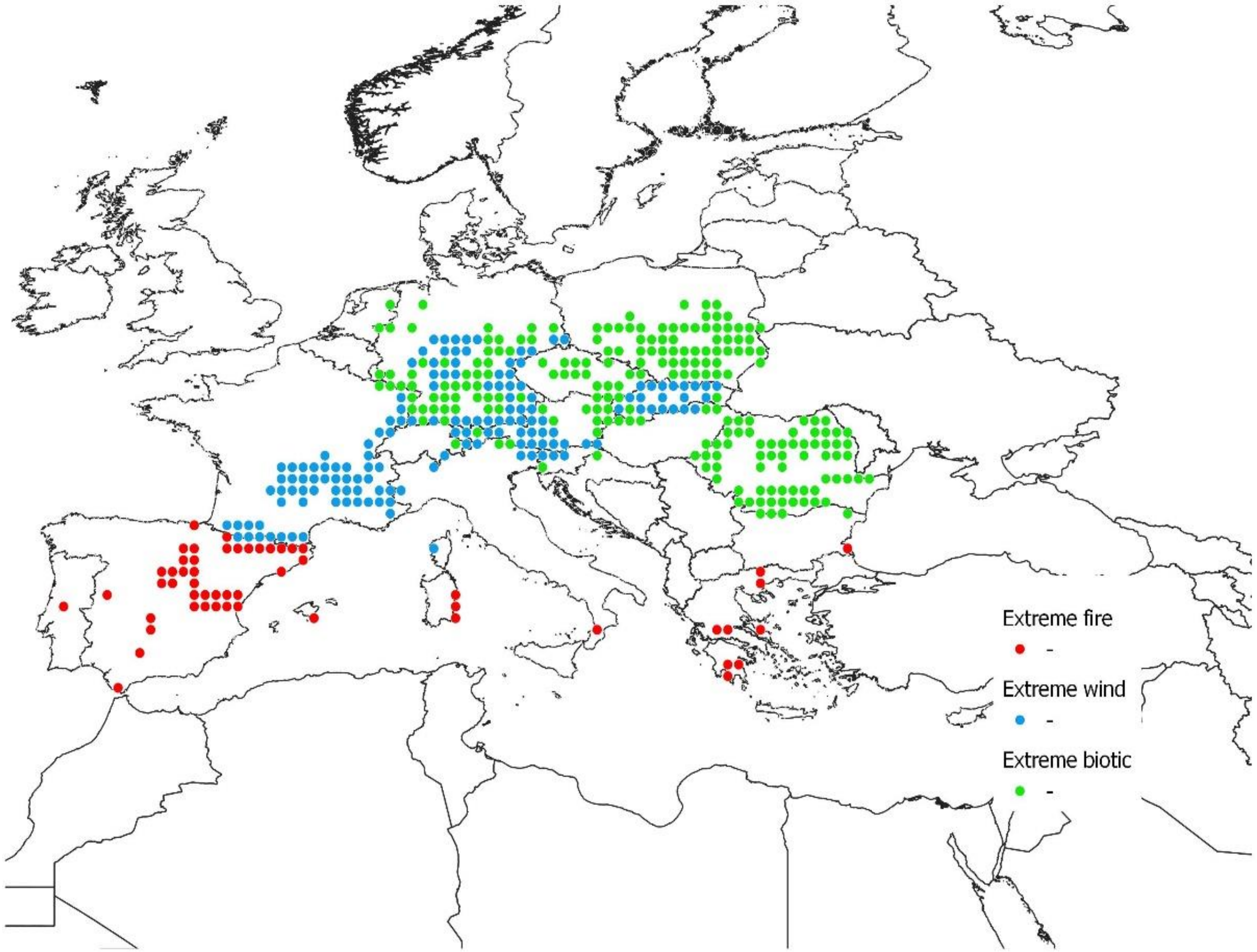
Modelling extreme disturbance events – G4M

The greatest historically observed damage by wind, fire and insect outbreaks from the disturbance database by Patacca et al. (2023) in 1950-2019:

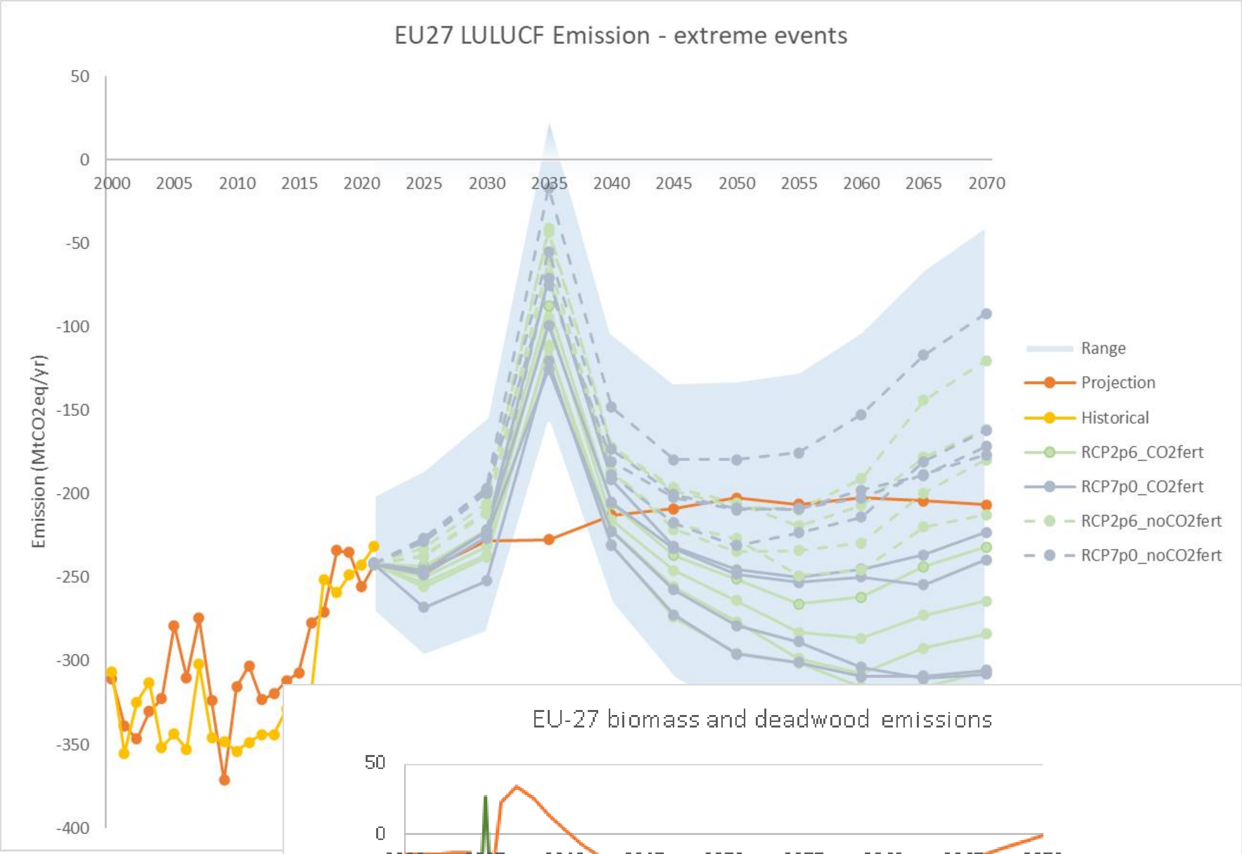
- wind damage: >250 Mm^3 in 1999,
- fire damage: >30 Mm^3 in 2018
- and insect damage: >60 Mm^3 in 2019

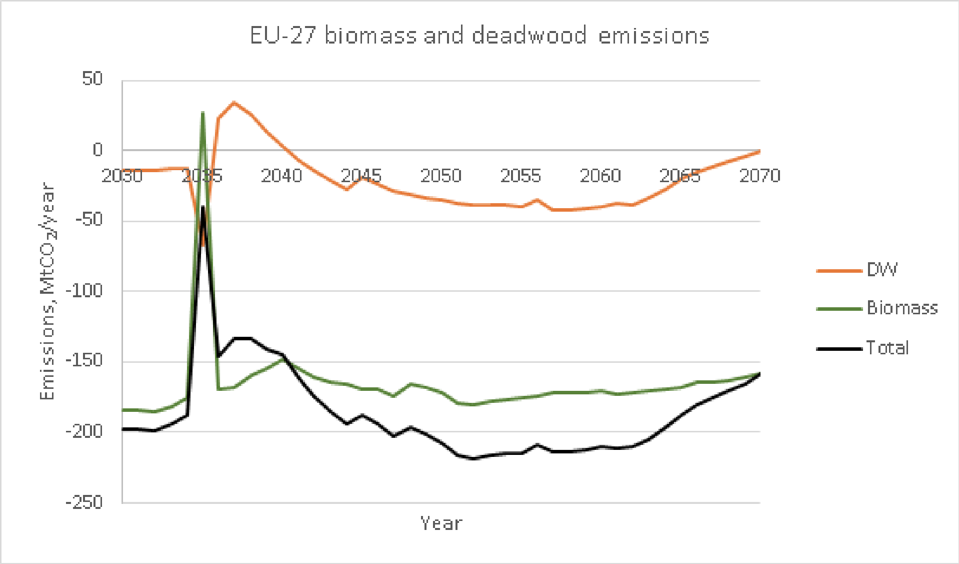


Simulated occurrence of the extreme natural disturbances in 2035



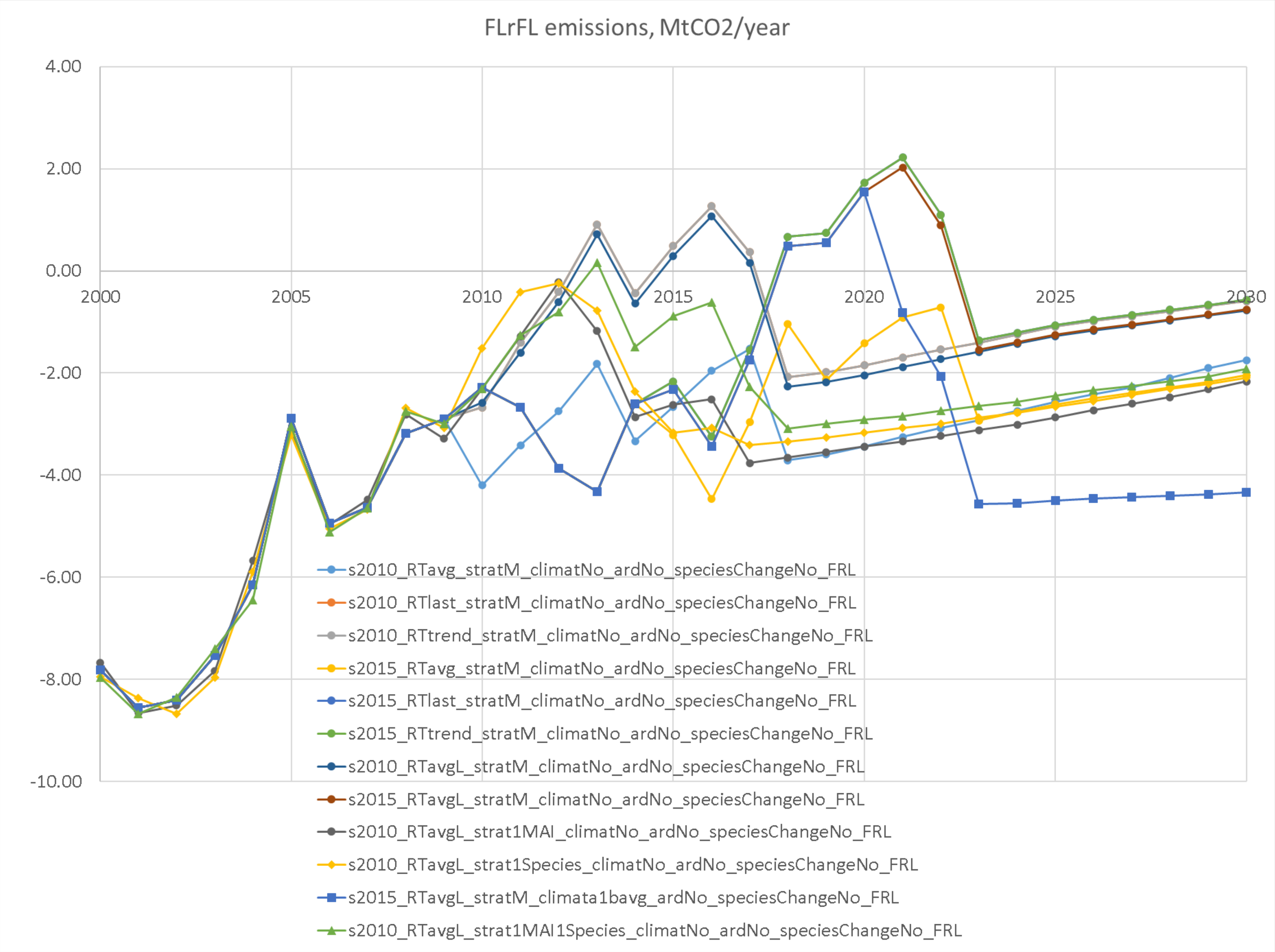
Modelling extreme disturbance events





- The total damaged biomass is about 300 Mm^3 which is about half of the usual harvest
- Salvage logging can replace a large share of the total harvest
- Deadwood emissions dampen the live biomass emissions as a share of damaged wood is moved to the deadwood pool
- Fast recovery
  - damages mostly older trees which are more vulnerable
  - assumption of enough capacity to salvage and replant within next few years
- LULUCF sink after the disturbance can be greater than without the disturbance because of the regrowth of young trees in case of prompt cleaning and regeneration

G4M application examples: FRL sensitivity



Thank you!

Supplementary

Potential data and model problems

- Increment, biomass, and age structure must be consistent for initialising the virtual forest correctly
  - Rate the input data by uncertainty and give the model some flexibility to initialise correctly.
- In a balance model, the initial size of the pools must be consistent with input and output flows, otherwise we'll observe the transition effect instead of the model response to the studied driver.
  - Spin up and check that the equilibrium is reached.
- A map (RS product) declares a certain statistical accuracy but does not promise that any particular place is correct. Usually, finer resolution increases the risk of inconsistency of spatial layers.
  - Model resolution should be coarser than the input data, so we average multiple input cells for one model cell.
- Time consistency of input data (what year(s) does a RS product / forest inventory represent? Does harvest statistics represent wood removals?)
- Wrong reporting and miscommunication (roundwood in FAOSTAT sometimes changes a few times per year; roundwood reported overbark or underbark? EUROSTAT uses a definition of gross increment as net increment; When we ask for increment data what do we get, gross / net / mean / current / periodic? What is growing stock? What forest area is correct FAO FRA / UNFCCC / Forest Europe / RSs? Why does not forest product statistics match roundwood statistics?)
  - Always clarify with your partners….

Important factors: initialisation

Wood demand Statistics, FL-FL GHG UNFCCC
Harvest=Demand, FL-FL GHG = FL-FL GHG UNFCCC

Harvest ≈ f(Rotation) + thinning

FL-FL GHG as given

FL-FL GHG ≈ f(Rotation)

Harvest as given

Harvest = 0

FL-FL GHG = 0

Intensively managed

Non-intensively managed

Protected, non-accessible

Harvest location (map by Verkerk et al. 2015)

Forest area available for wood supply

Other forest area

Important factors: dynamics

Wood demand (time), FL-FL GHG (time), **Rotation & Area of Int.Mng -> Harvest=Demand**

NPV(RotNew)≥α·NPV(Rotation)

NPV(Non-int .-> Int.)>0

Harvest ≈ f(**Rotation**) + thinning

FL-FL GHG as given

FL-FL GHG ≈ f(RotationConst)

Harvest as given

Harvest = 0

FL-FL GHG = 0

Intensively managed

Non-intensively managed

Protected, non-accessible

Harvest location (map by Verkerk et al. 2015)

Forest area available for wood supply

Other forest area

Important factors: dynamics, C price

Wood demand (time), FL-FL GHG (time), **Cprice** -> **Rotation maximizing NPV**

Rotation & Area of Int.Mng -> Harvest=Demand

NPV(RotNew,Cprice)≥α·NPV(Rotation,Cprice)

NPV(Non-int .-> Int.)>0

Harvest ≈ f(**Rotation**) + thinning

FL-FL GHG as given

FL-FL GHG ≈ f(RotationConst)
Harvest as given

Harvest = 0

FL-FL GHG = 0

Intensively managed

Non-intensively managed

Protected, non-accessible

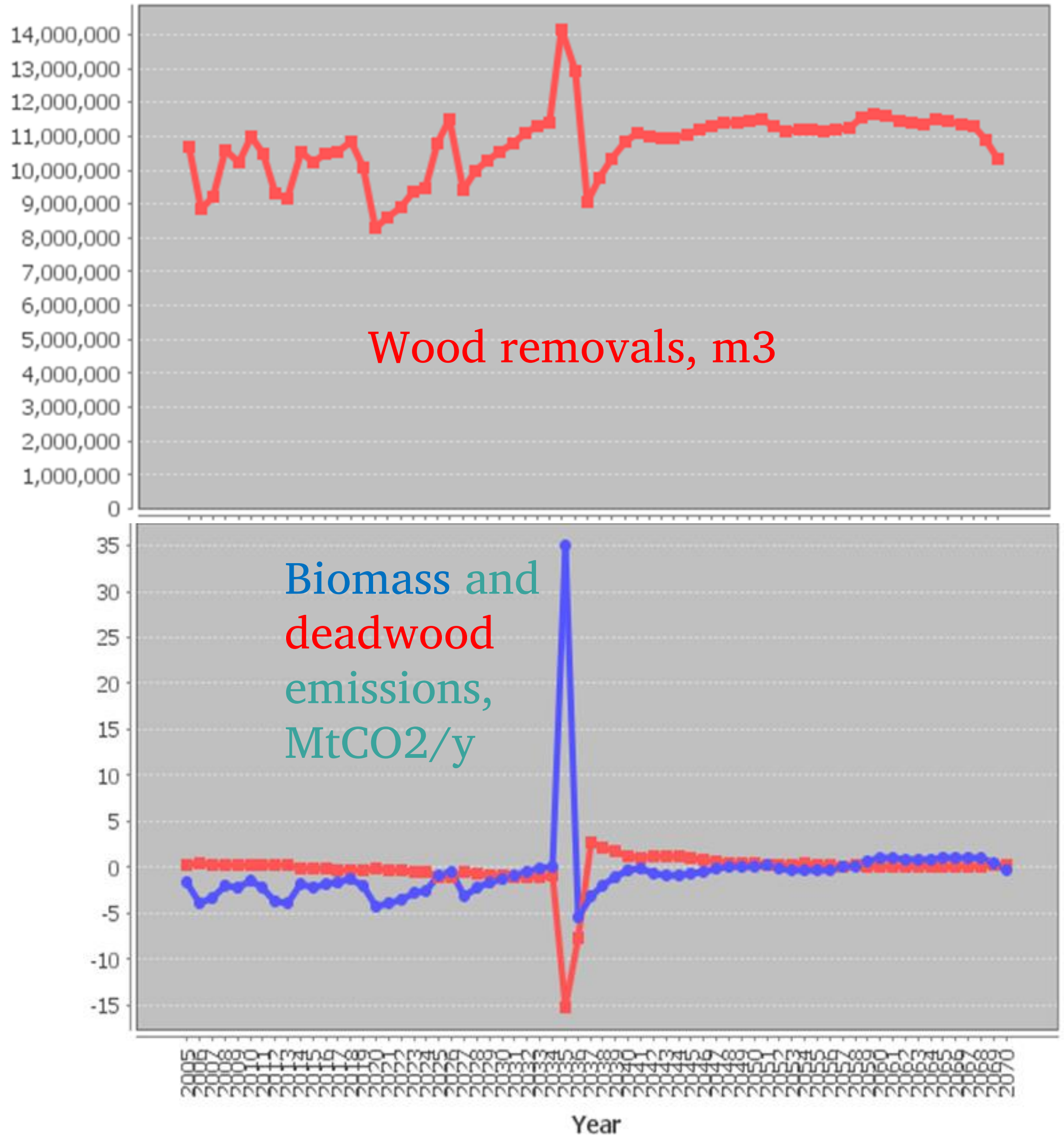
Harvest location (map by Verkerk et al. 2015)

Forest area available for wood supply

Other forest area

Salvage logging and CO_2 emissions

- Capacity to do salvage logging – removals increases 1.5 - 2 times
- Uncertainty in the harvestable share of damaged wood:
    - Wind – 0.86 [0.55 - 0.95]
    - Biotic – 0.72 [0.2 – 0.95]
    - Fire – 0.5 [0.2 – 0.5]
- Long legacy effect on age structure and future harvest
- Need for proper accounting of living biomass, deadwood, litter (soil) and HWP pools



Disturbances and damaged wood

Windthrows

- ForestGALES with default parametrization
- Weather: wind speed and direction
- Site: soil type
- Forest: species, DBH, height, crown length, spacing

Bark beetles

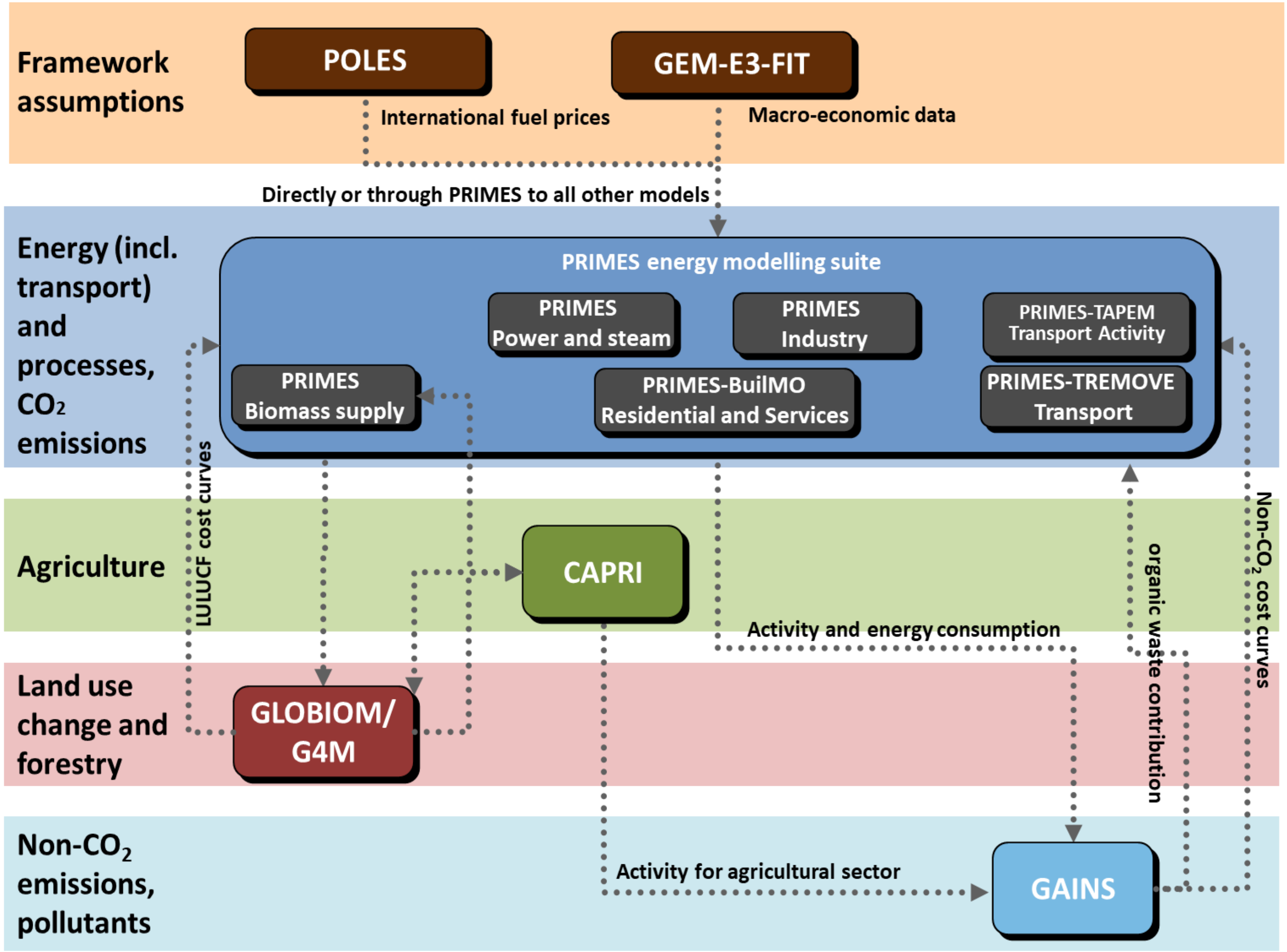
- Based on LandClim with the additions from Marie et al. (2023)
- Weather: temperature, precipitations, seasonal patterns
- Site: soil type
- Forest: species composition, age, DBH, stress, density and spatial distribution

Fire

- FLAM model
- Weather: wind speed and direction, temperature, precipitations, relative humidity, seasonal patterns
- Site: altitude, slope, aspect
- Forest: fuel type, fuel load, fuel moisture content, fuel continuity,….

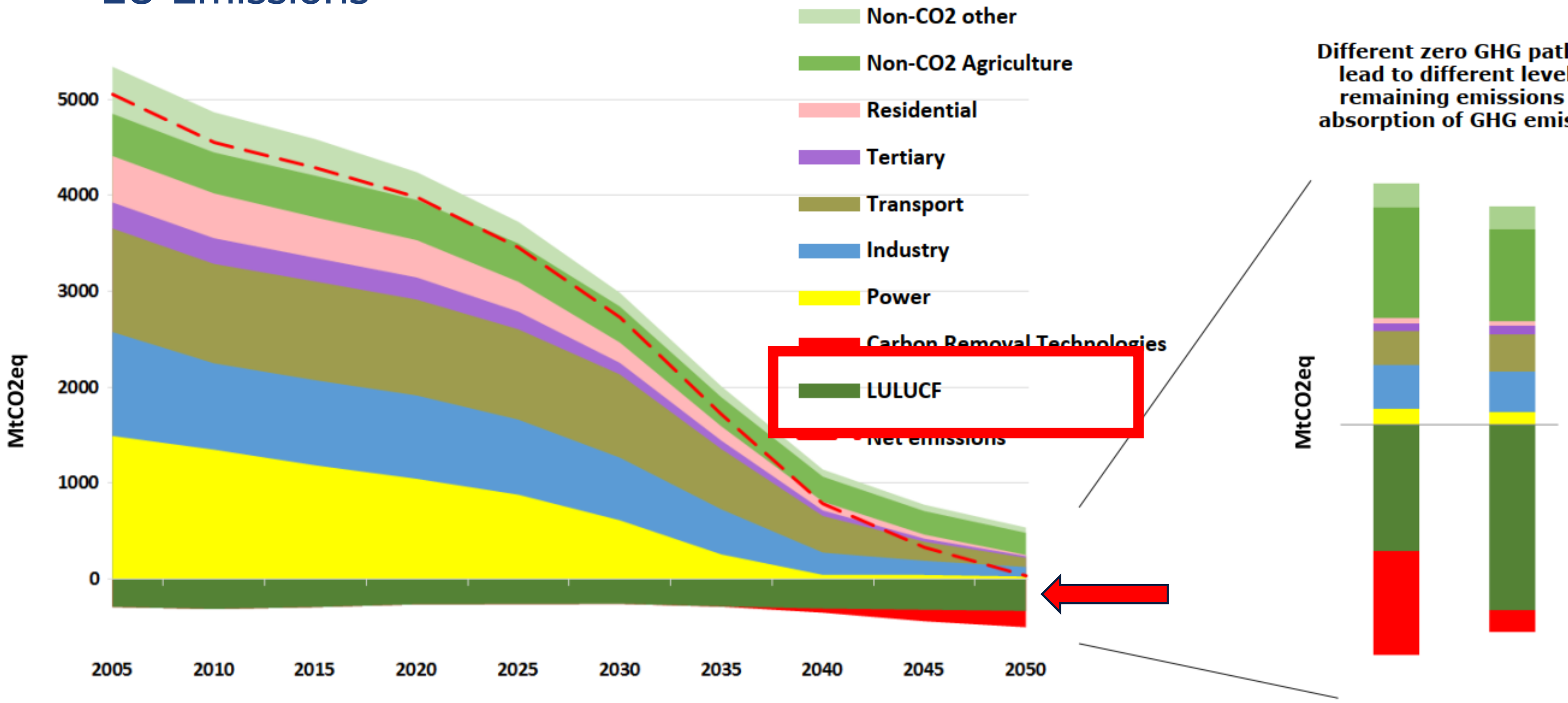
Background: DG CLIMA policy support

Modelling suite for the EU Reference Scenario and impact assessments



LULUCF in the long-term strategy

EU Emissions



Source: COM(2018) 773 final – A clean planet for all.

Comparison of Forest Land emission projections for S2 scenario

- FSCM = the forest carbon model (EU-CBM-HAT) and the harvested wood products (HWP) module run by JRC
- GLOBIOM-G4M applies CO2 price of 50 Euro/tCO2
- FSCM – no CO2 price; mimics forest management of G4M

Year	Emission projection (FSCM), MtCO2/year	Emission projection (GLOBIOM-G4M), MtCO2/year
2030	-334	-345
2040	-331	-298
2050	-347	-333

Source: Impact Assessment Report, SWD(2024) 63 final

2040 Recommendations and Impact assessment


EUROPEAN
COMMISSION

Strasbourg, 6.2.2024
COM(2024) 63 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

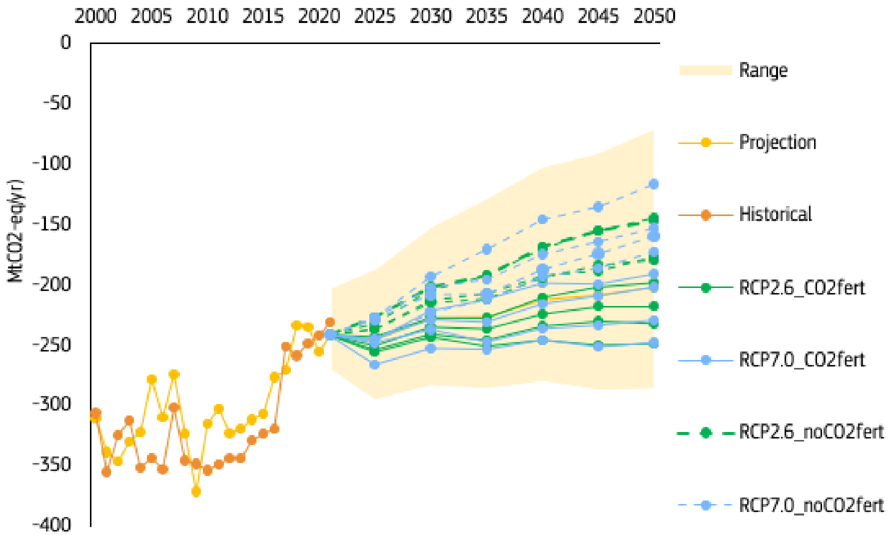
Securing our future

Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society

{SEC(2024) 64 final} - {SWD(2024) 63 final} - {SWD(2024) 64 final}

MtCO2-eq to the upper bound (maximum net removals level) and 111 MtCO2-eq to the lower bound (minimum net removals level). In 2050 the unsecurity increases further, resulting in a range with a deviation of 84 MtCO2-eq to the upper bound and 133 MtCO2-eq to the lower bound. Hence, depending on RCP, climate model and CO2 fertilisation, the analysis projects for 2050 a possible range of net removals between roughly -70 MtCO2-eq and -290 MtCO2-eq (in absence of additional LULUCF policies). The finding is corroborated by other analyses ([198]) and also roughly concurs with the identified range of -100 to -400 MtCO2-eq for the LULUCF net removal by 2050, as mentioned by the ESABCC, when taking future impacts of climate change into account.

Figure 96: Estimated climate change impacts on LULUCF net removal in EU



Note: The graph displays a model-based projection of the development of the LULUCF net removal in absence of dedicated mitigation policies [lower level]. The historical trajectory shows the historical inventory data based on UNFCCC 2023. and the 'projection' shows the trajectory of the LULUCF net removal without considering the impact of climate change. The different 16 trajectories show RCP 2.6 vs. 7.0 (2) X different climate models (4) X CO2 fertilisation vs. no fertilisation (2). The range illustrates the uncertainty due to climate change impacts across all trajectories including uncertainty on carbon storage in soils.

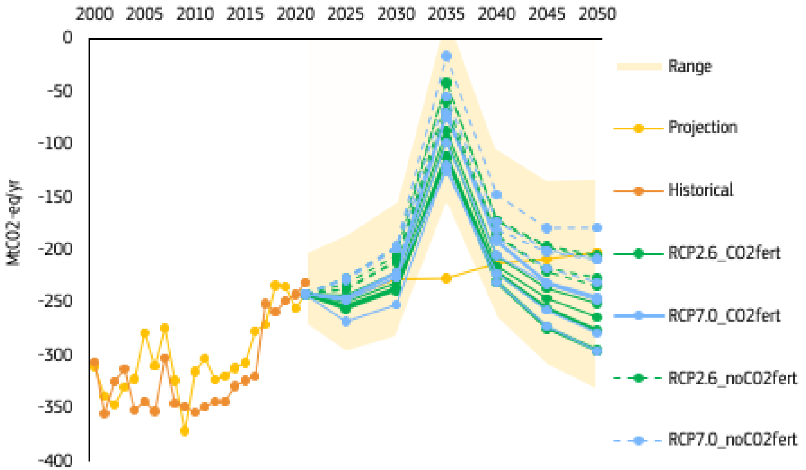
Source: GLOBIOM, UNFCCC 2023

Taking a closer look at the individual climate scenarios, one can see the important role of CO2 fertilisation ([199]) and its potential impact on the EU-wide LULUCF net removals. When considering no effect from CO2 fertilisation, all scenarios show a decline in the LULUCF net removals. When including assumptions on effective CO2 fertilisation, the

([198]) For example: Pilli, R., 'The European Forest carbon budget under future climate conditions and current management practices', *Biogeosciences*, 19, 3263–3284, 2022.

net removals. If these conditions are not met in a real event, the recovery of the LULUCF net removals might significantly impeded. The extreme events will cascade not only to the European forest carbon pool, but also to wood processing industry and markets, via changes in wood supply and market shocks ([207]).

Figure 98: Estimated climate change impacts and extreme events on LULUCF net removal



Note: The graph displays a model-based projection of the range of the LULUCF net removal under impacts from climate change and simulated extreme events. The 'historical' trajectory shows the inventory data based on UNFCCC 2023, the 'projection' shows the trajectory of the lower boundary of the LULUCF range (lower level net removal) without impacts from climate change and extreme events. The different 16 trajectories show RCP 2.6 vs. 7.0 (2) X different climate models (4) X CO2 fertilisation vs. no fertilisation (2). The range illustrates the range of uncertainty due to climate change impacts across all trajectories including uncertainty due to soil carbon removals. In 2035 a series of extreme events is simulated to illustrate its impact on the LULUCF net removal.

Source: GLOBIOM, UNFCCC 2023

In Figure 98 the impacts of a series of possible extreme events in one year for the LULUCF net removal are depicted through an uncertainty range that takes climate change impacts into account. The net removal level of the LULUCF sector drops to a range between -160 and +30 MtCO2-eq at the time of the disturbance but recovers relatively quickly in the next 5 years (-105 to -265 MtCO2-eq). Over the next 15 years the simulation provides a slightly higher range for the LULUCF net removals in 2050 (-130 to -330 MtCO2-eq) than a scenario without extreme events (-70 to -285 MtCO2-eq; see previous section), because of the enhanced forest regrowth of younger trees and under the assumption of immediate reforestation.

([207]) Gardiner, B., Schuck, A. R. T., Schelhaas, M. J., Orazio, C., Blennow, K., & Nicoll, B. (Eds.). 'Living with storm damage to forests', Vol. 3, pp. 129-p, Joensuu: European Forest Institute, 2013.