Variation latitudinales des effets du changement climatique sur la composition des forêts Européennes

Julien Barrere, Marc Grünig, Maxime Jaunatre, Werner Rammer, Björn Reineking, Rupert Seidl, Cornelius Senf, Georges Kunstler
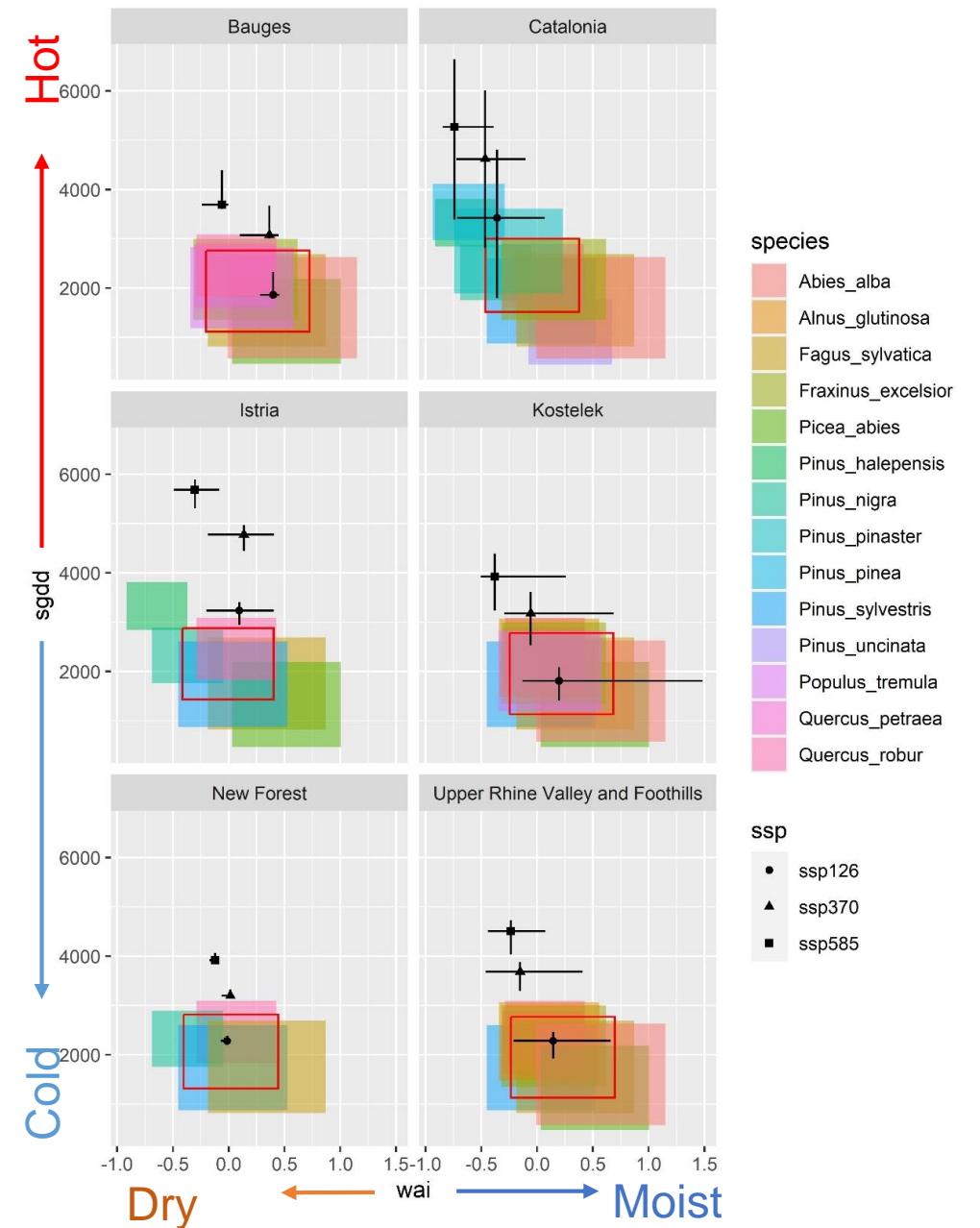
FOREM – Agroparistech Nancy – 03/04/2024

General context

Species composition shift under climate change

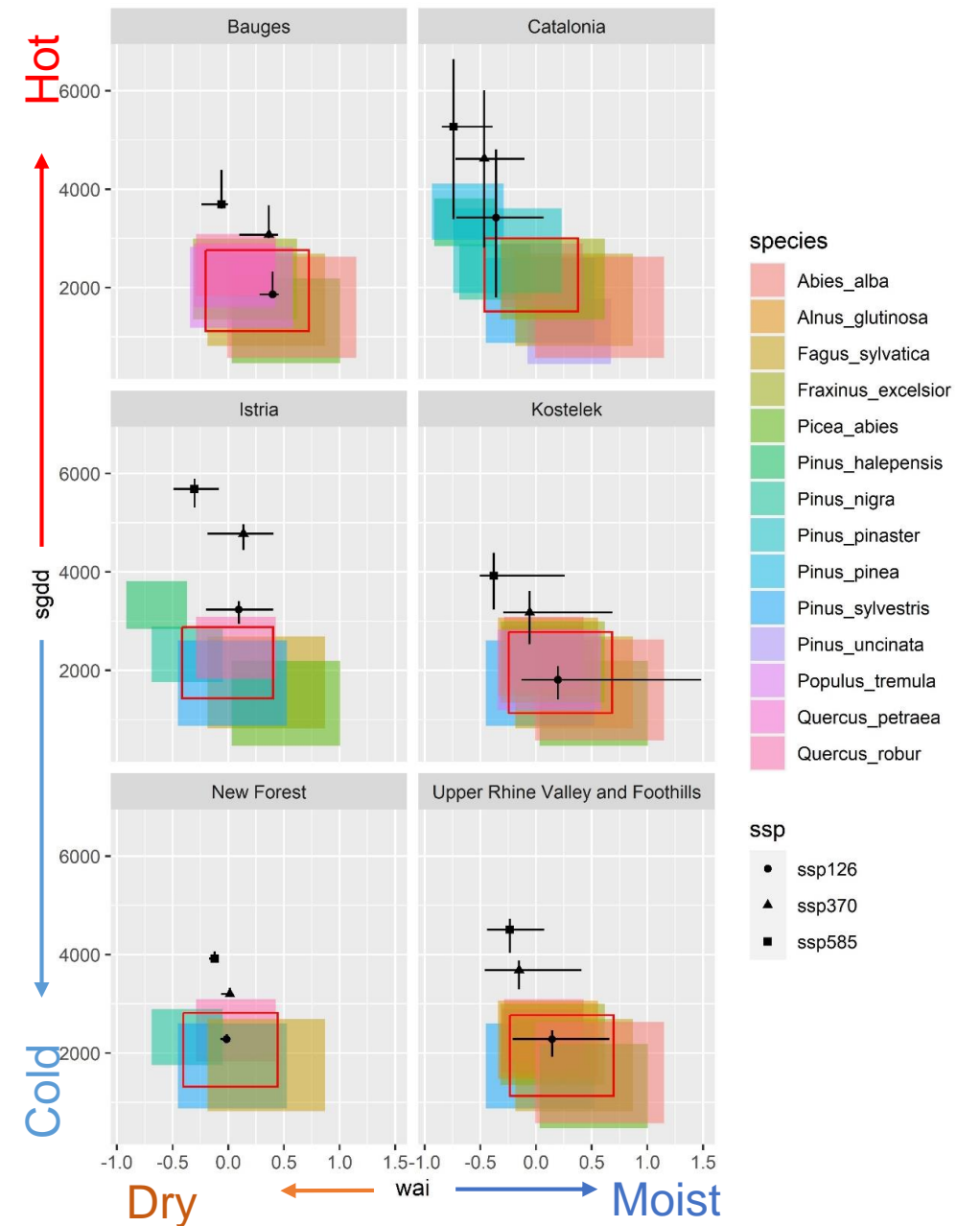o Climate projections beyond local species margins

Modélisation des variations latitudinales des effets du CC sur les forêts Européennes
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General context

Species composition shift under climate change

o Climate projections beyond local species margins

o Across Europe, differences in the magnitude of climate change and in the potential for species composition shift

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General context

Disturbance regimes

- o Additional agent of species composition shift : disturbance regimes

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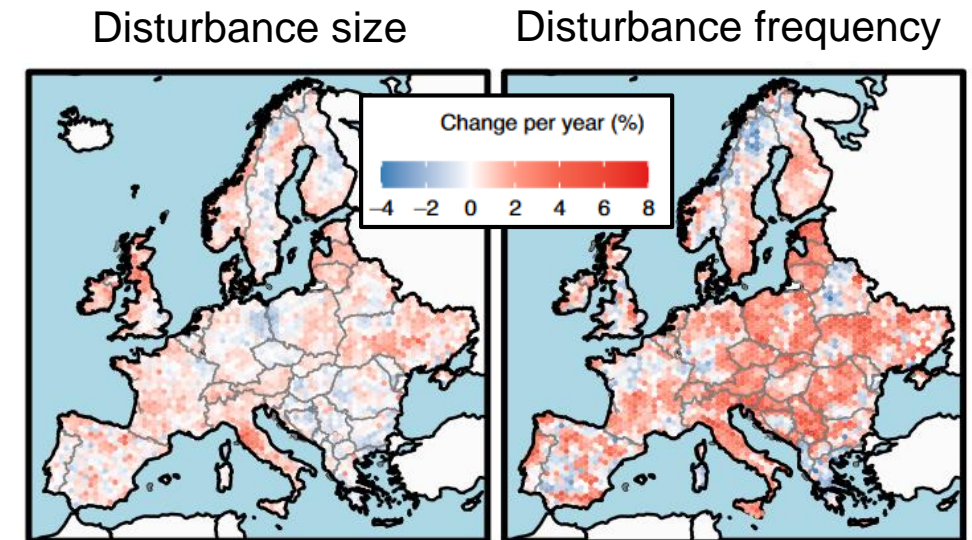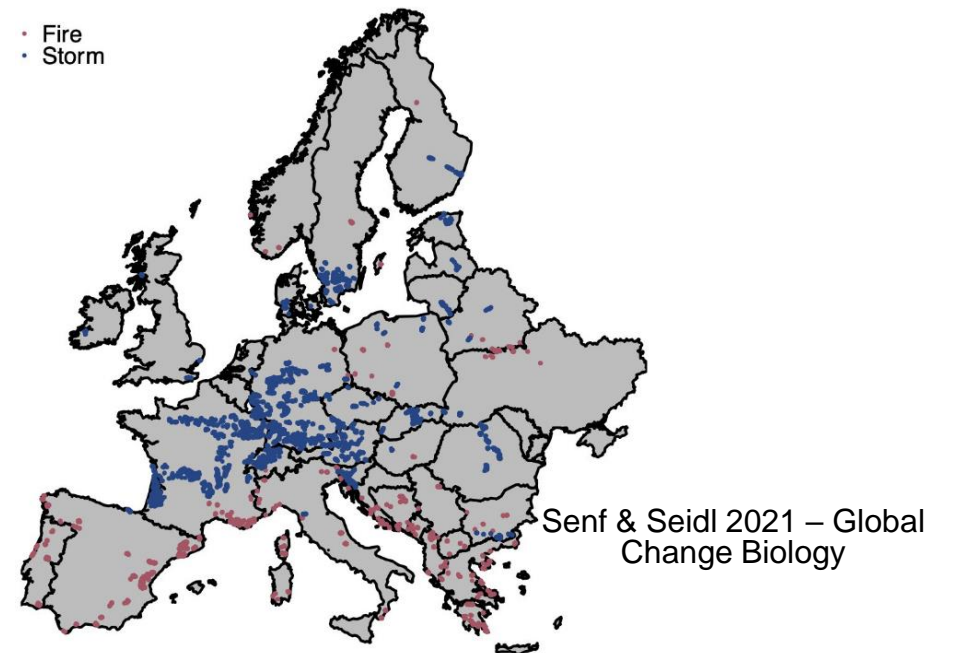
General context

Disturbance regimes

o Additional agent of species composition shift : disturbance regimes

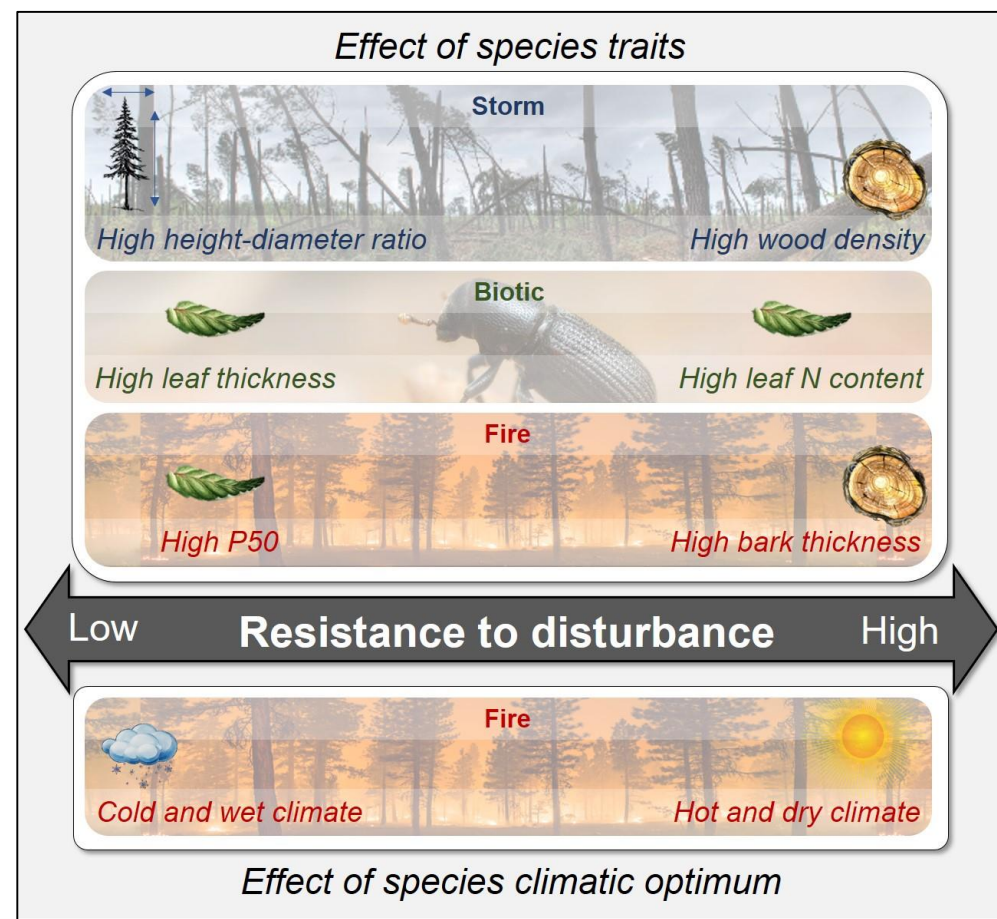o Here again, spatial variation in their distribution and expected change

Senf & Seidl 2021 – Global Change Biology

Disturbance size   Disturbance frequency

Senf & Seidl 2021 – Nature sustainability

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General context

Expected changes in species composition

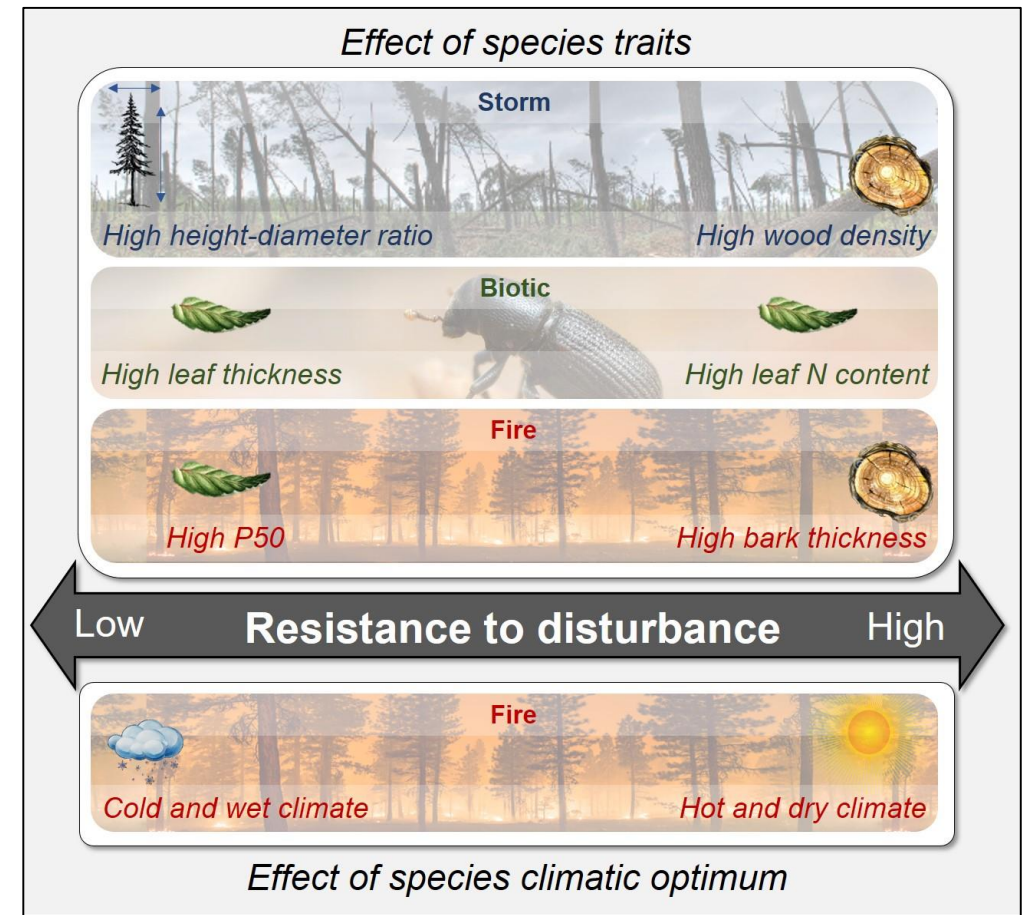o Convergence between traits promoting resistance to disturbance and adaptation to warmer conditions

Barrere et al. 2023 – Global Change Biology

General context

Expected changes in species composition

o Convergence between traits promoting resistance to disturbance and adaptation to warmer conditions

o Towards an increased dominance of slow-growing and drought-resistant species ?

Barrere et al. 2023 – Global Change Biology

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o What is the relative effect of climate change and disturbances on species composition shift at European scale ?

o How these effects vary across biogeographic regions of Europe ?

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Modélisation des variations latitudinales des
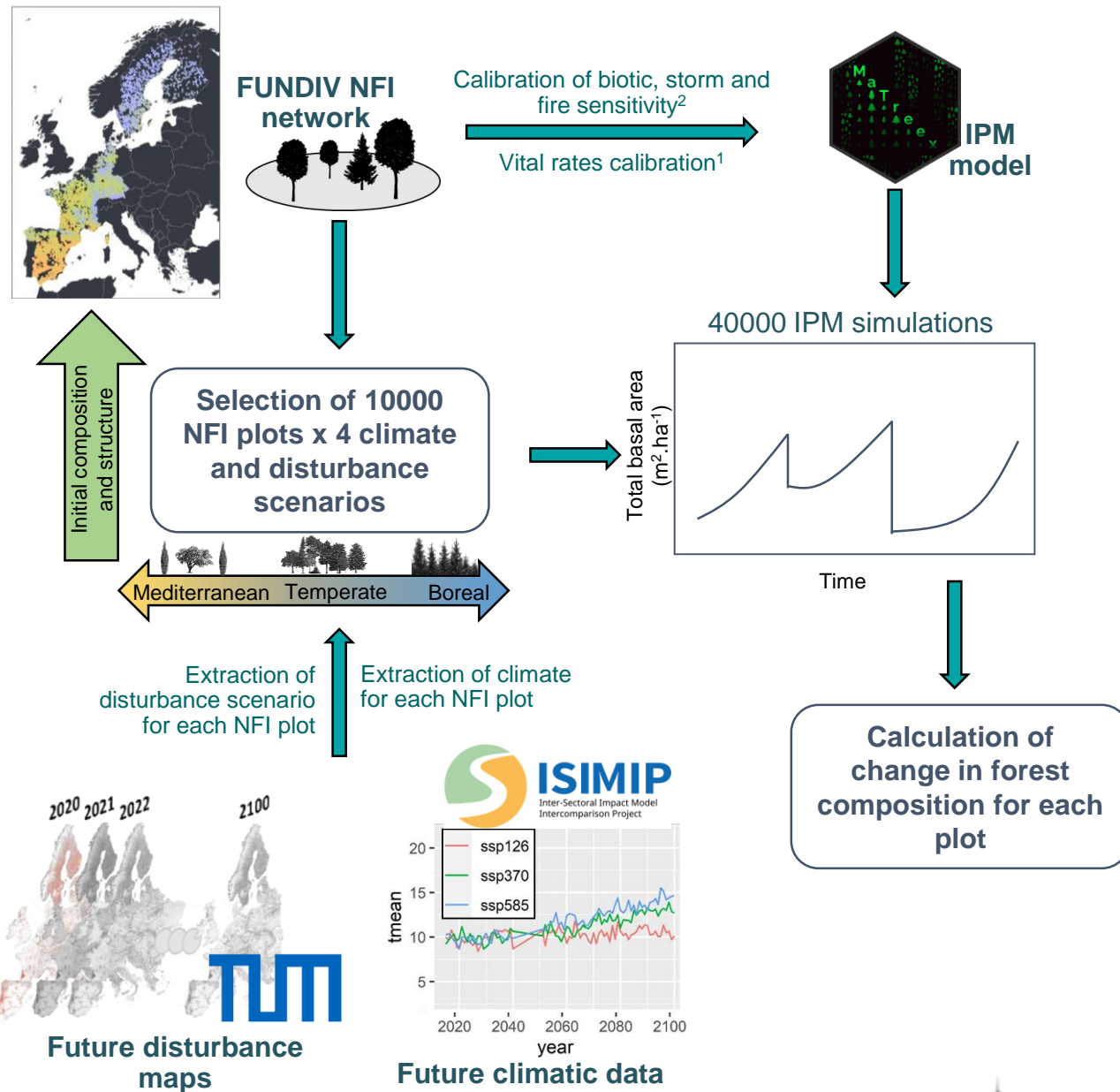effets du CC sur les forêts Européennes
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Methods

Overall picture

FUNDIV NFI network

Calibration of biotic, storm and fire sensitivity[2]

Vital rates calibration[1]

IPM model

Initial composition and structure

Selection of 10000 NFI plots x 4 climate and disturbance scenarios

Mediterranean   Temperate   Boreal

40000 IPM simulations

Total basal area (m².ha⁻¹)

Time

Extraction of disturbance scenario for each NFI plot

Extraction of climate for each NFI plot

Calculation of change in forest composition for each plot

2020 2021 2022   2100

Future disturbance maps

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

ssp126
ssp370
ssp585

tmean

2020 2040 2060 2080 2100
year

Future climatic data

[1] Kunstler et al. 2020 – Journal of Ecology
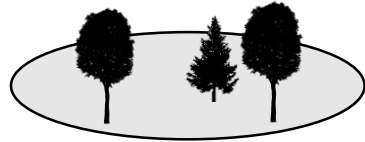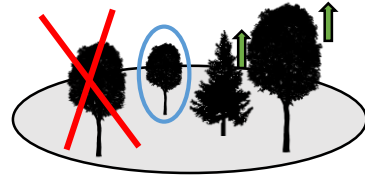[2] Barrere et al. 2023 – Global Change Biology

Methods

Calibration of the IPM Model

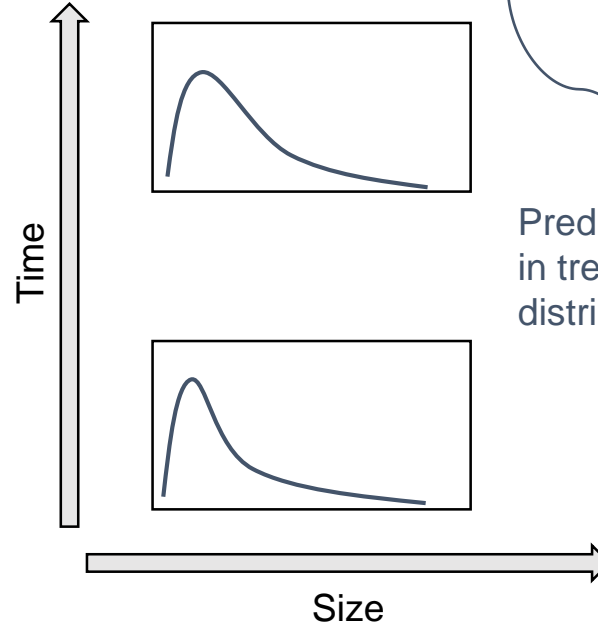Network of NFI permanent plots (FUNDIV)

Calibration of growth, survival and recruitment functions
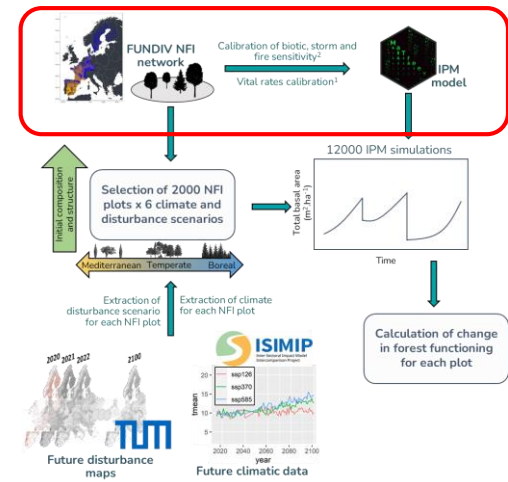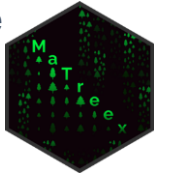**f(climate, competition, species)**

$$n(z', t + 1) = \int [s(z)G(z', z) + F(z', z)]n(z, t)dz$$

Integration of demographic functions to build IPM model

Predict changes in tree size distribution

Now implemented in R package matreex

Time

Size

[1] Guyennon et al. 2023 – *Global Ecol. & Biogeo.*

[2] Kunstler et al. 2020 – *Journal of Ecology*

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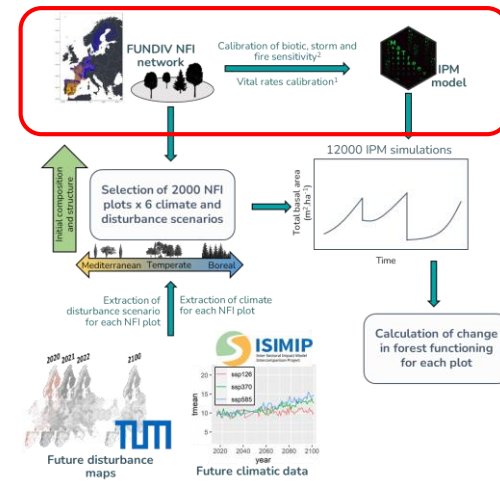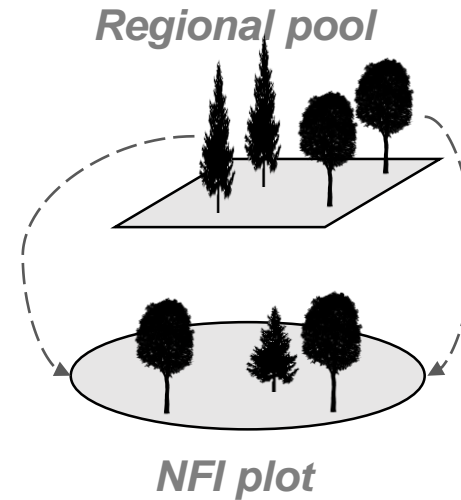Julien BARRERE – LESSEM (INRAE Grenoble)

Methods

Focus on the recruitment model

Regional pool

Structure of the recruitment model in the IPM

$$\log(R) = a_0 + a_1 Comp + a_2 Fec + f(clim)$$

NFI plot
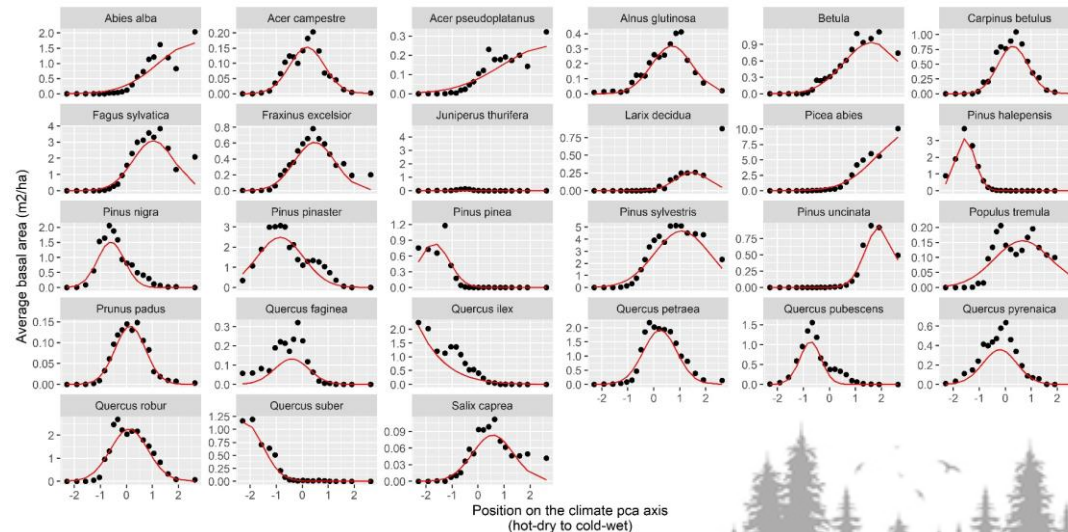
Initial model : Fecundity only function of the local basal area

Integration of dispersal kernel from Bullock et al. 2017

New model : Inclusion of a regional component of fecundity

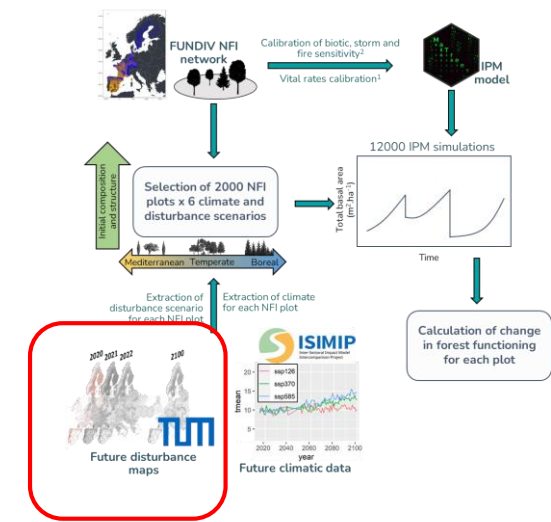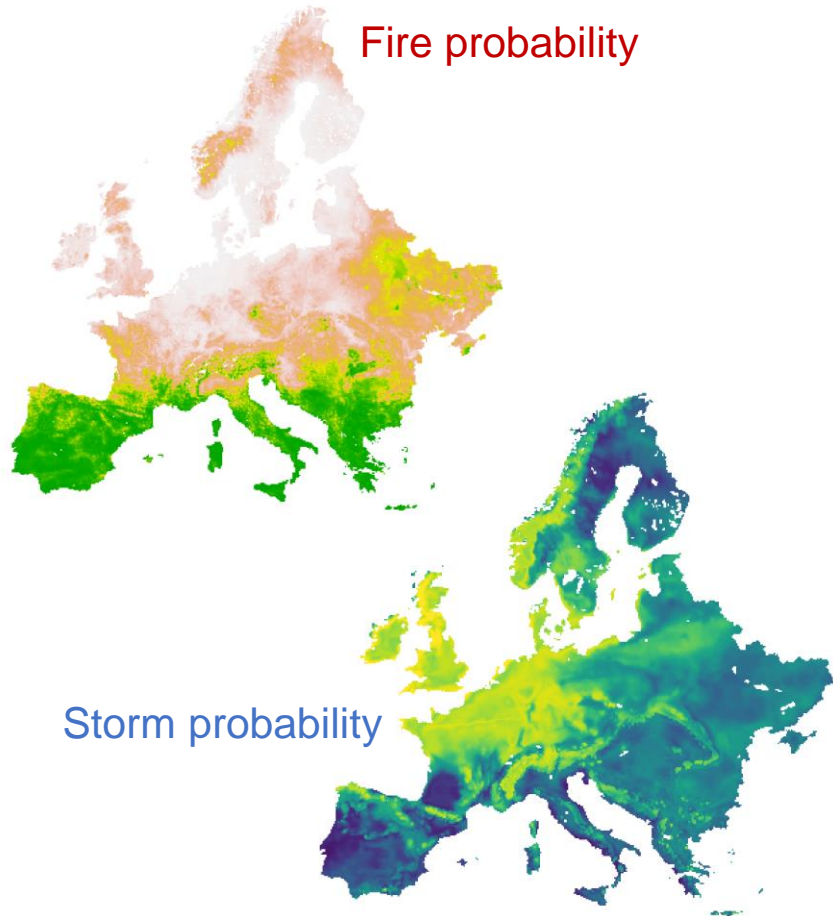$$Fec = p_{30}BA_{local} + (1 - p_{30})BA_{reg}F_{cover}$$

Modelled from climate

Prevent colonization by external species !

Average basal area (m2/ha)

Position on the climate pca axis
(hot-dry to cold-wet)

Abies alba, Acer campestre, Acer pseudoplatanus, Alnus glutinosa, Betula, Carpinus betulus, Fagus sylvatica, Fraxinus excelsior, Juniperus thurifera, Larix decidua, Picea abies, Pinus halepensis, Pinus nigra, Pinus pinaster, Pinus pinea, Pinus sylvestris, Pinus uncinata, Populus tremula, Prunus padus, Quercus faginea, Quercus ilex, Quercus petraea, Quercus pubescens, Quercus pyrenaica, Quercus robur, Quercus suber, Salix caprea

FUNDIV NFI network — Calibration of biotic, storm and fire sensitivity[2] — IPM model
Vital rates calibration[1]

12000 IPM simulations

Selection of 2000 NFI plots x 6 climate and disturbance scenarios

Total basal area (m² ha⁻¹) — Time

Mediterranean Temperate Boreal

Extraction of disturbance scenario for each NFI plot — Extraction of climate for each NFI plot

ISIMIP

Calculation of change in forest functioning for each plot

Future disturbance maps — Future climatic data

Methods

Maps of future disturbances

Fire probability

Storm probability

o Prediction of yearly probability of fire and storm disturbances by Technical University of Munich (Seidl, Senf, Grunig, Rammer et al.) calibrated with satellite data.

o Storm disturbance probability modelled as a function of historical occurrence, return interval and wind speed (no climate sensitivity)

o Fire disturbance probability modelled as a function of historical occurrence and VPD
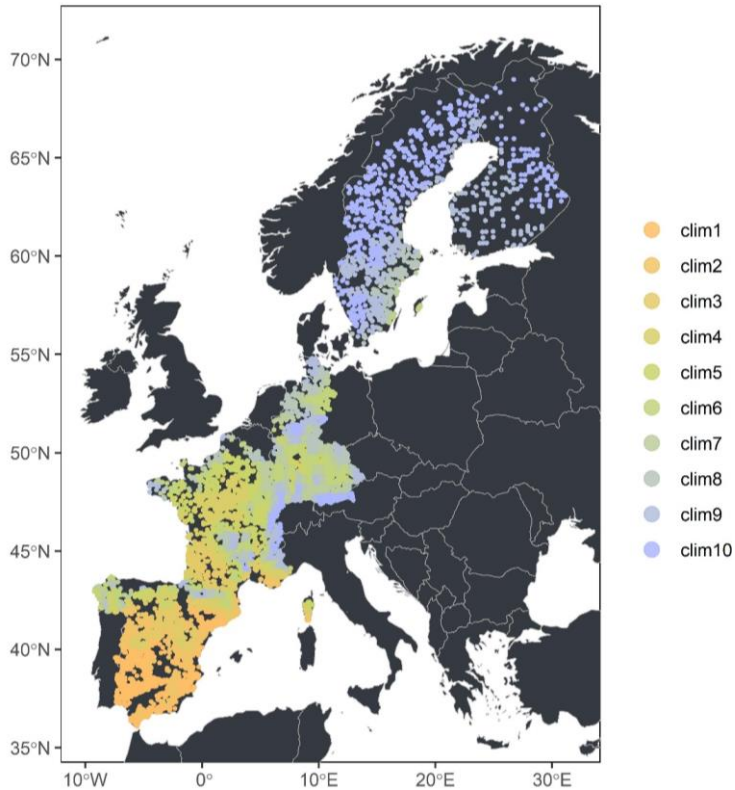
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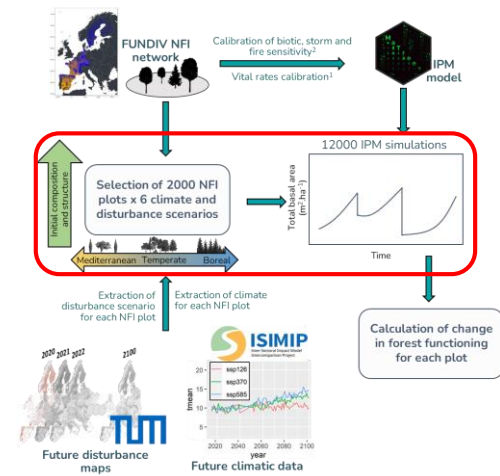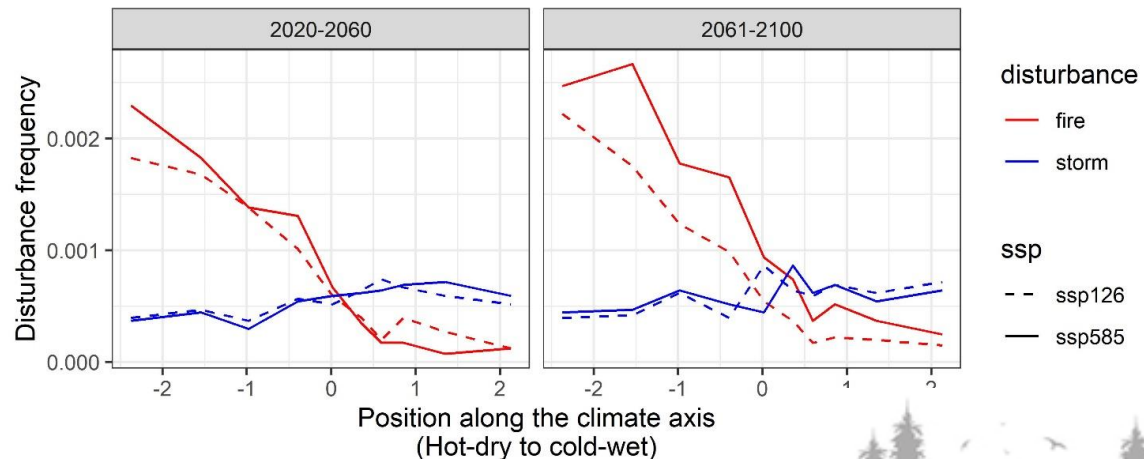
> **Methods**

Scenarios and simulations

Selection of 10000 NFI plots
from 10 sub-climates

For each NFI plot, simulation from
2020 to 2100 with 4 scenarios

	ssp126	ssp585
Disturbance	Disturbance only	CC and disturbance
No disturbance	Reference	CC only

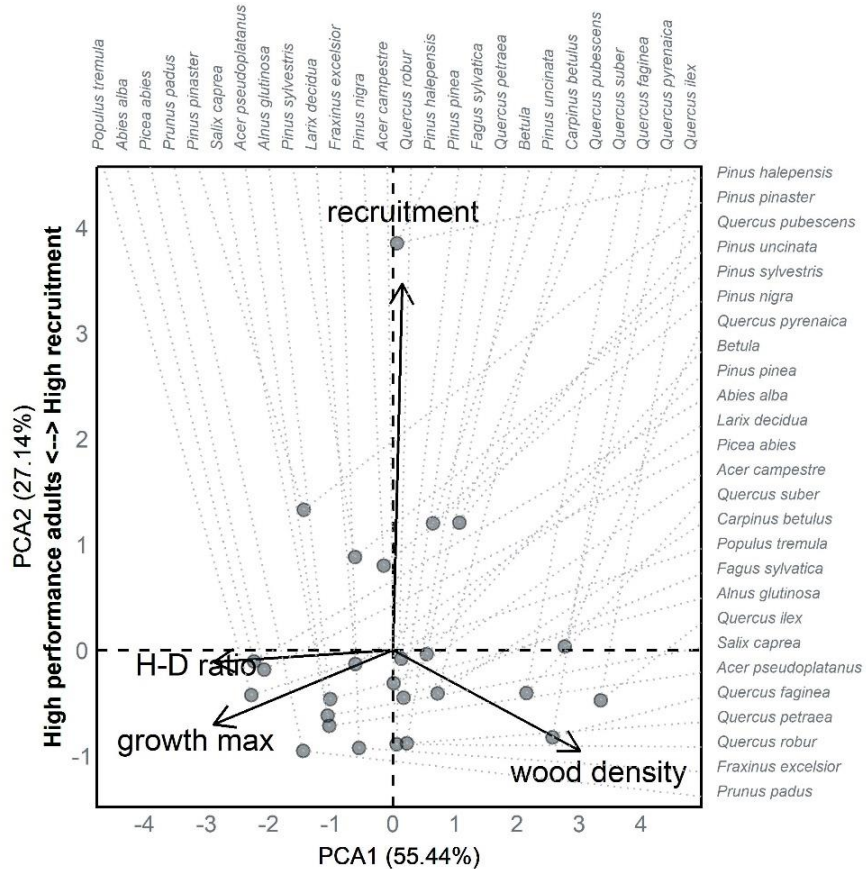**Disturbance occurrence : Yearly Bernoulli trial from storm and fire probabilities**

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Modélisation des variations latitudinales des
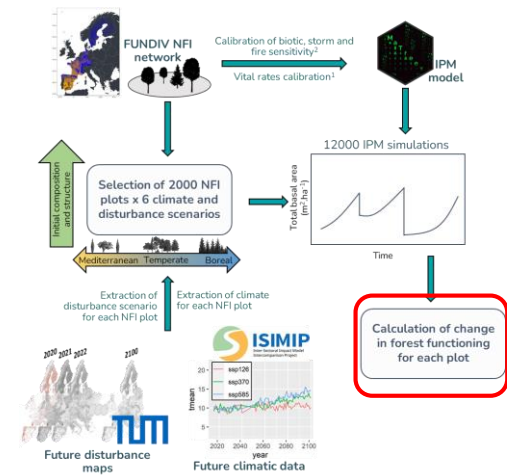effets du CC sur les forêts Européennes
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Methods

Species composition metrics

- Species diversity (Shannon index)

- Average climatic optimum (weighted by abundance)

- Community weighted means based on two functional axes analogous to Rüger et al. (2018)

- Functional diversity based on the same axes

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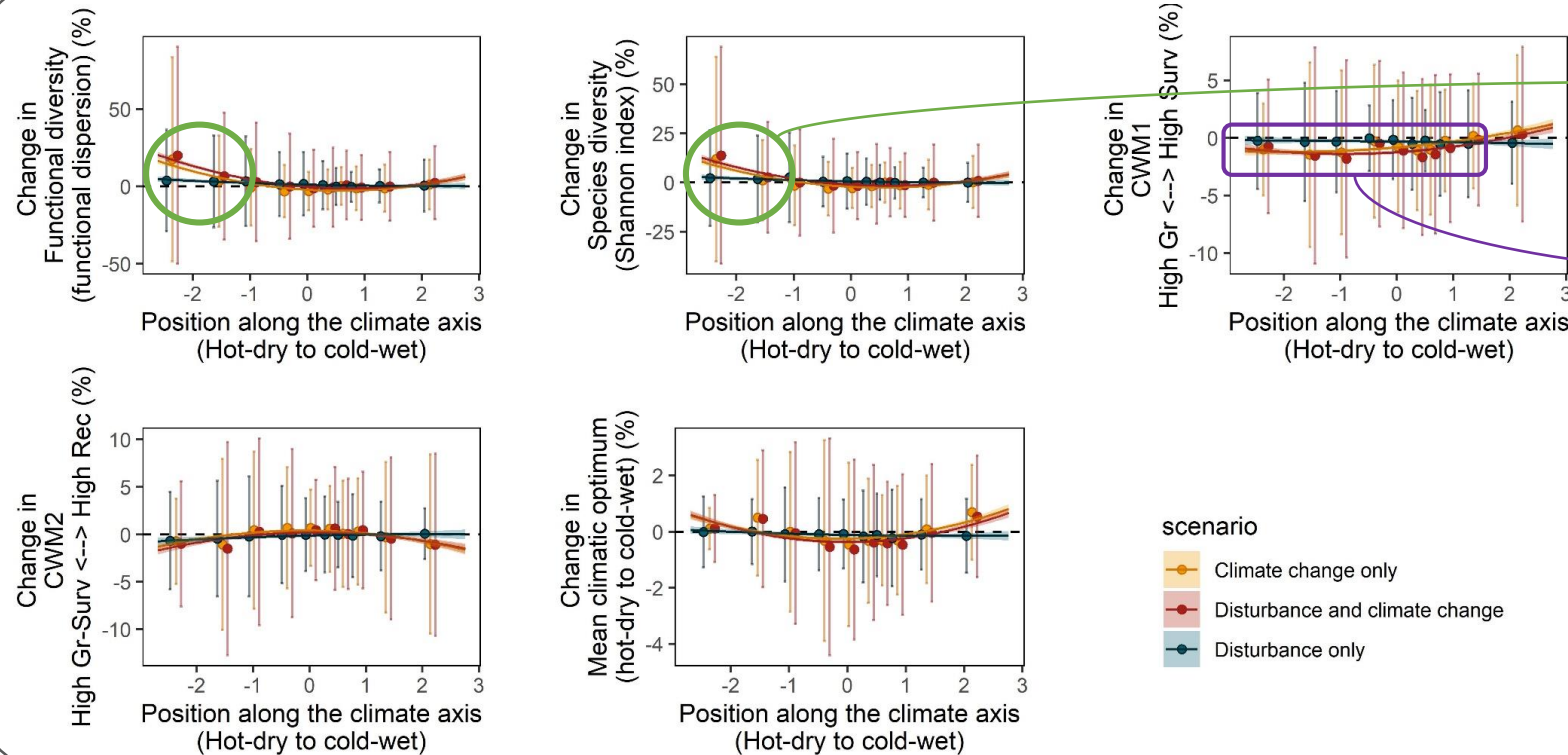Modélisation des variations latitudinales des effets du CC sur les forêts Européennes
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Preliminary results

Effect on forest composition across climates

Effect of disturbances negligible compared to the effect of climate change

Increased species and functional diversity in the Mediterranean area

In most climates, increased dominance of fast-growing rather than resistant species

scenario
- Climate change only
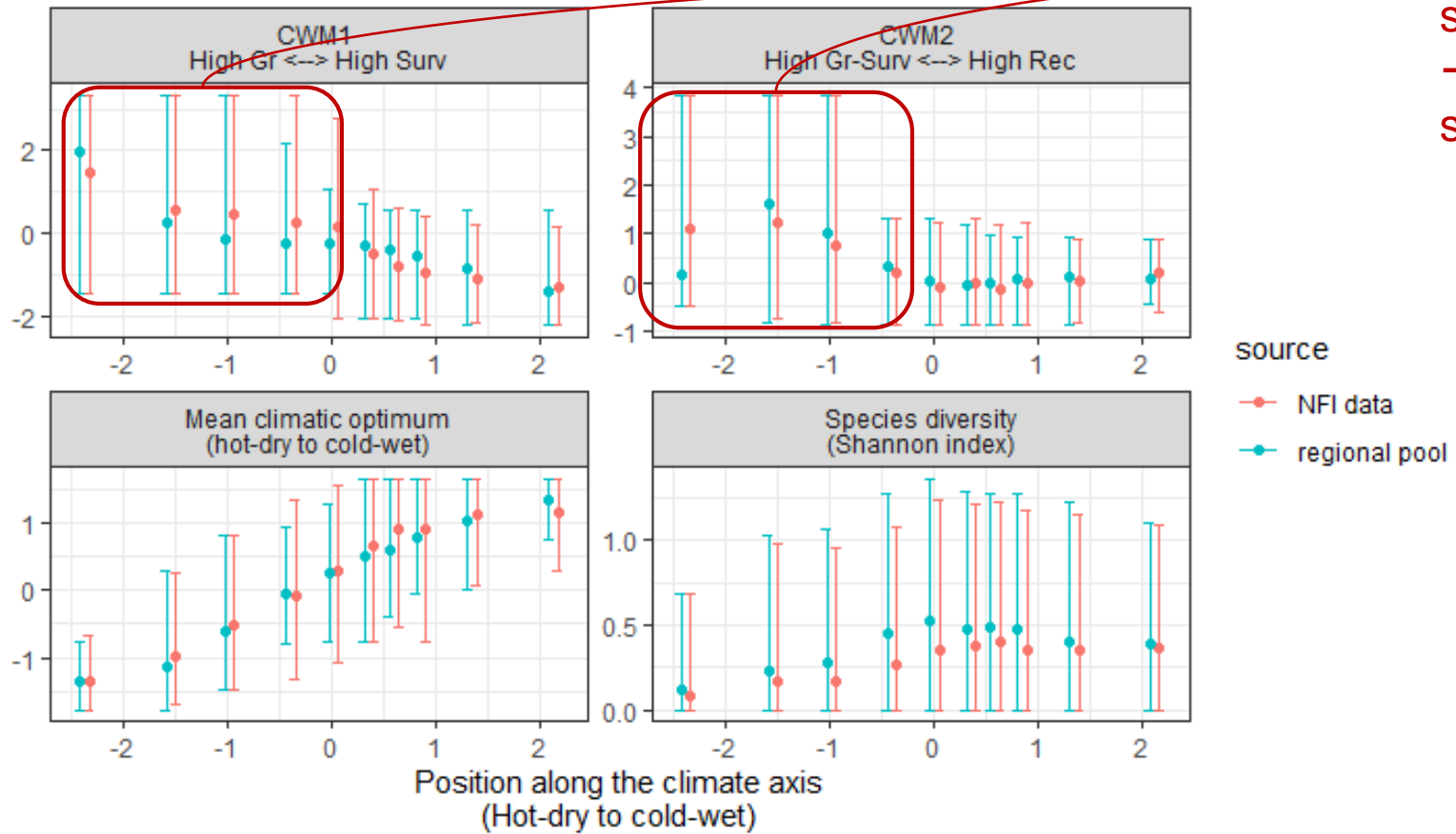- Disturbance and climate change
- Disturbance only

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Modélisation des variations latitudinales des effets du CC sur les forêts Européennes
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> Preliminary results

Possible interpretation

Wider functional spectrum in drier climates → facilitate composition shift ?

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Conclusions

o Suggest that "natural" forest adaptation in term of composition might not be fast enough

o Limitations : model assumptions, one climatic model, ignored "small" disturbances

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