Forest storm resilience depends on the interplay between functional composition and climate - insights from European-scale simulations

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INRAE, LESSEM Research Unit, Grenoble (France)

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Belfast, 15/12/2023

Introduction

Storm disturbances in a changing world

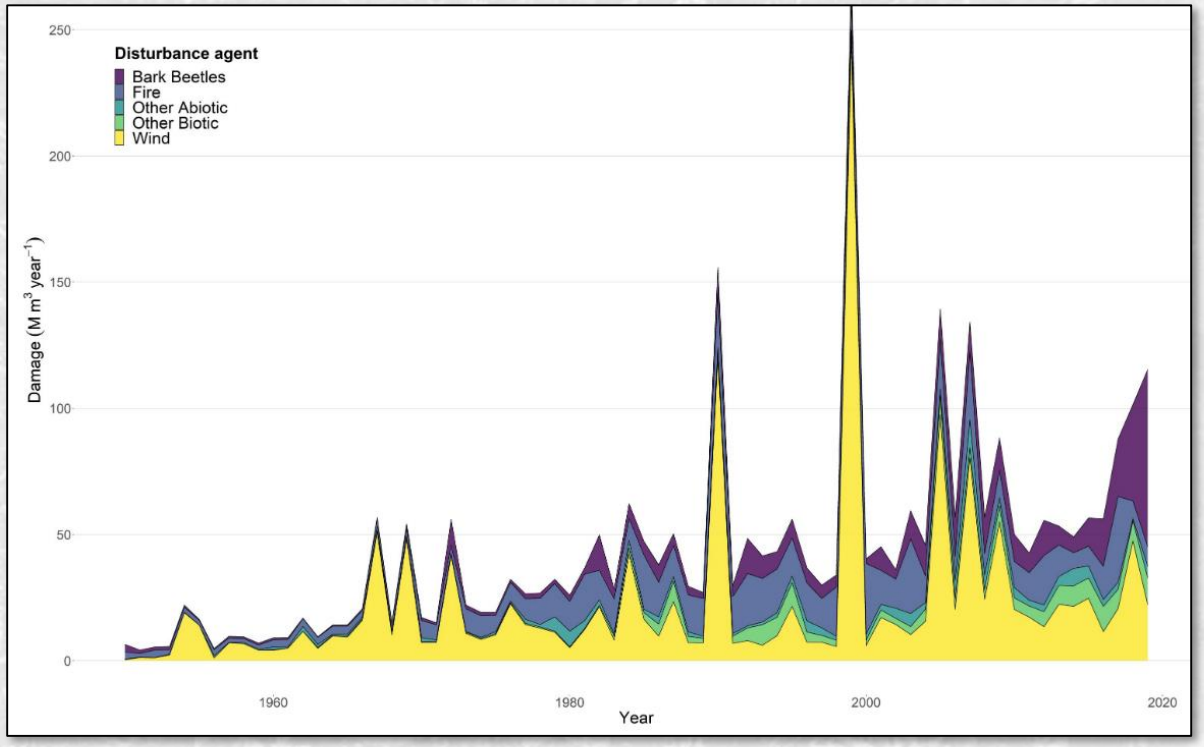
- Windstorms: main disturbance agent in Europe [1]

[1] Senf et al. 2021 – Nature Sustainability

Introduction

Storm disturbances in a changing world

- Windstorms: main disturbance agent in Europe [1]
- Over the past decades, increasing rates of storms disturbances observed across Europe [1,2,3]



[1] Senf et al. 2021 – Nature Sustainability

[2] Patacca et al. 2022 – Global Change Biology

[3] Seidl et al. 2011 – Global Change Biology

Introduction

Storm disturbances in a changing world

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Importance to identify the factors driving the resilience of European forests to storms

→ Forest composition ?

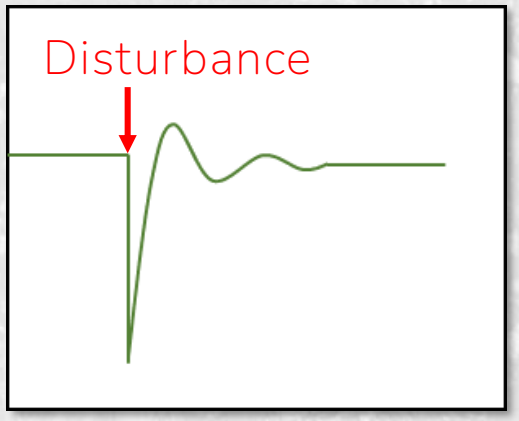
[1] Senf et al. 2021 – Nature Sustainability

[2] Patacca et al. 2022 – Global Change Biology

[3] Seidl et al. 2011 – Global Change Biology

Introduction

The concept of resilience to disturbances

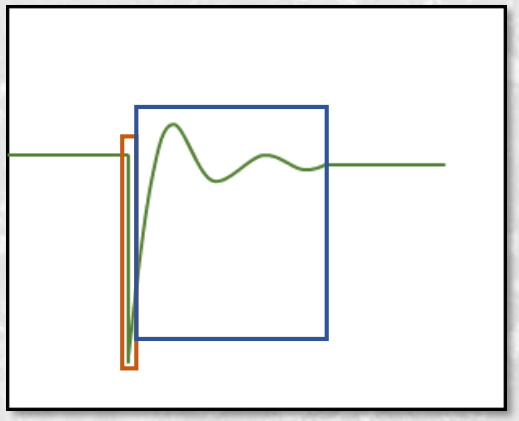


- Resilience: Many definitions, but common features[1].

[1] Lloret et al. *2023 – Resonate WP1 report*

Introduction

The concept of resilience to disturbances



Resistance
Immediate impact of the disturbance

Recovery
Subsequent recuperation

- Resilience: Many definitions, but common features[1].
  → Can be decomposed in two phases

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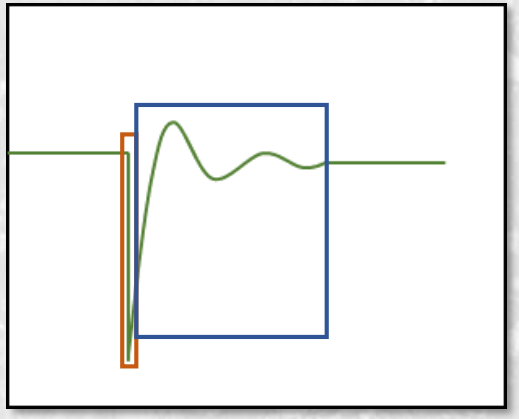
The concept of resilience to disturbances



Resistance
Immediate impact of the disturbance

Recovery
Subsequent recuperation

Survival

Growth

Recruitment

- Resilience: Many definitions, but common features[1].
  → Can be decomposed in two phases
- These metrics are driven by different demographic processes[2]

[1] Lloret et al. *2023 – Resonate WP1 report*

[2] Falk et al. 2022 – *For Ecol & Man*

Introduction

The effect of diversity on resilience

Diversity

Recovery

Resistance

- Diversity can improve recovery via two mechanisms [1,2]

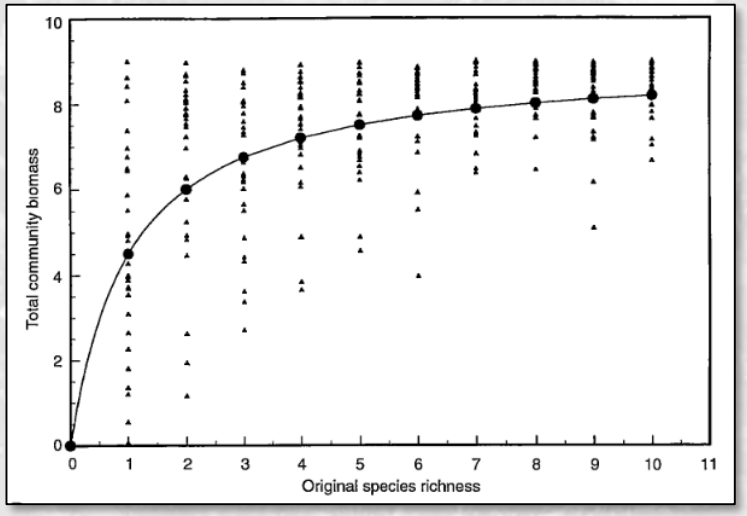
[1] Tilman 2001

[2] Loreau et al. 2001 – *Science*

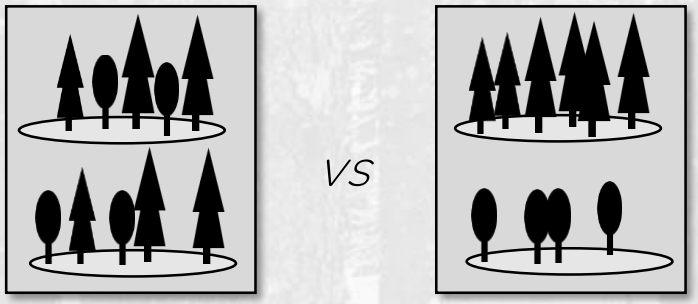
Introduction

The effect of diversity on resilience

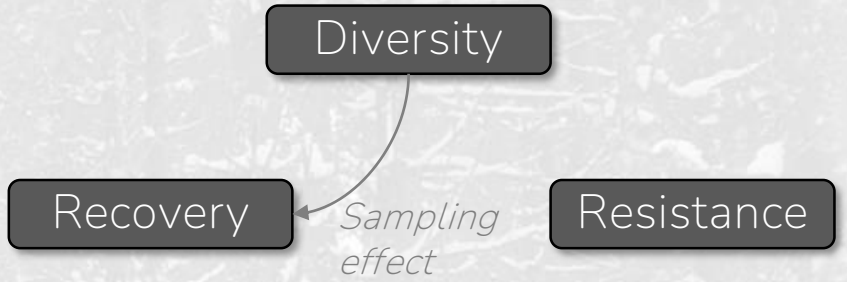
1. The sampling effect



Higher chances of having fast-growing species in a diverse stand



vs



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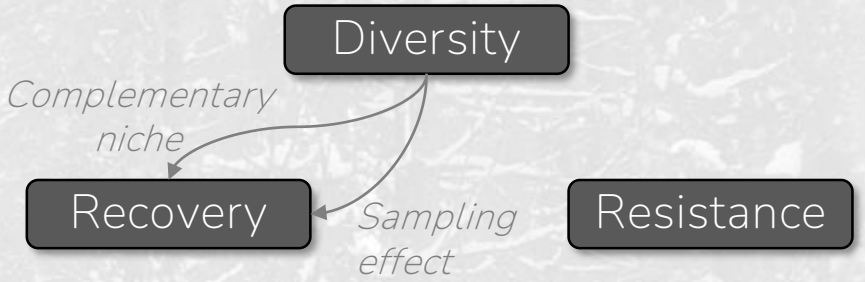
Introduction

The effect of diversity on resilience



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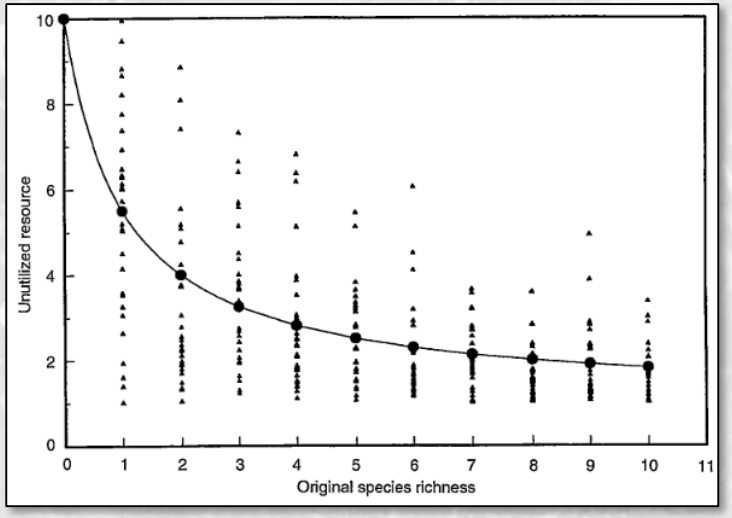
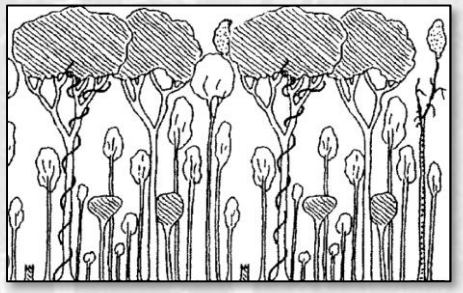
2. Complementarity niche



More efficient use of resources with diverse species



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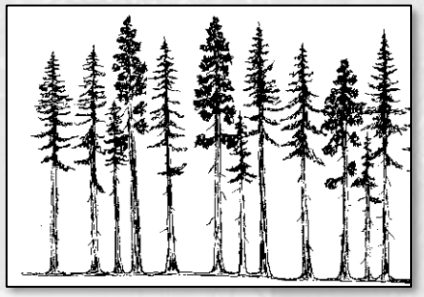


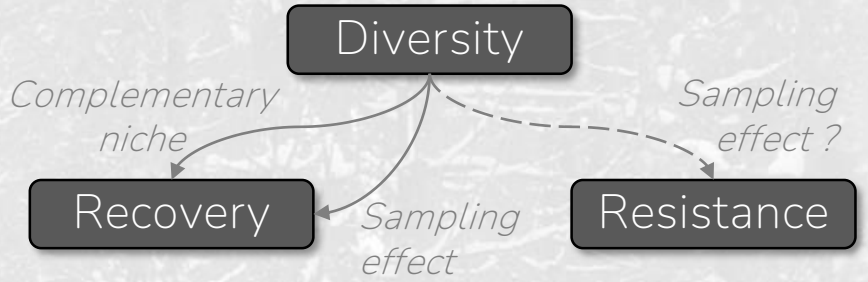
[1] Tilman 2001

[2] Loreau et al. 2001 – *Science*

Introduction

The effect of diversity on resilience

Higher chances of having resistant species in a diverse stand ?



- Diversity can improve recovery via two mechanisms [1,2]

- Resistance : higher in more diverse system [2,3]
  → *in analogy with sampling effect ?*

[1] Tilman 2001

[2] Loreau et al. 2001 – *Science*

[3] Isbell et al. 2015 – *Nature*

Introduction

Additional effect of the functional composition

- It’s not all about diversity: does the functional composition matter ?

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Additional effect of the functional composition

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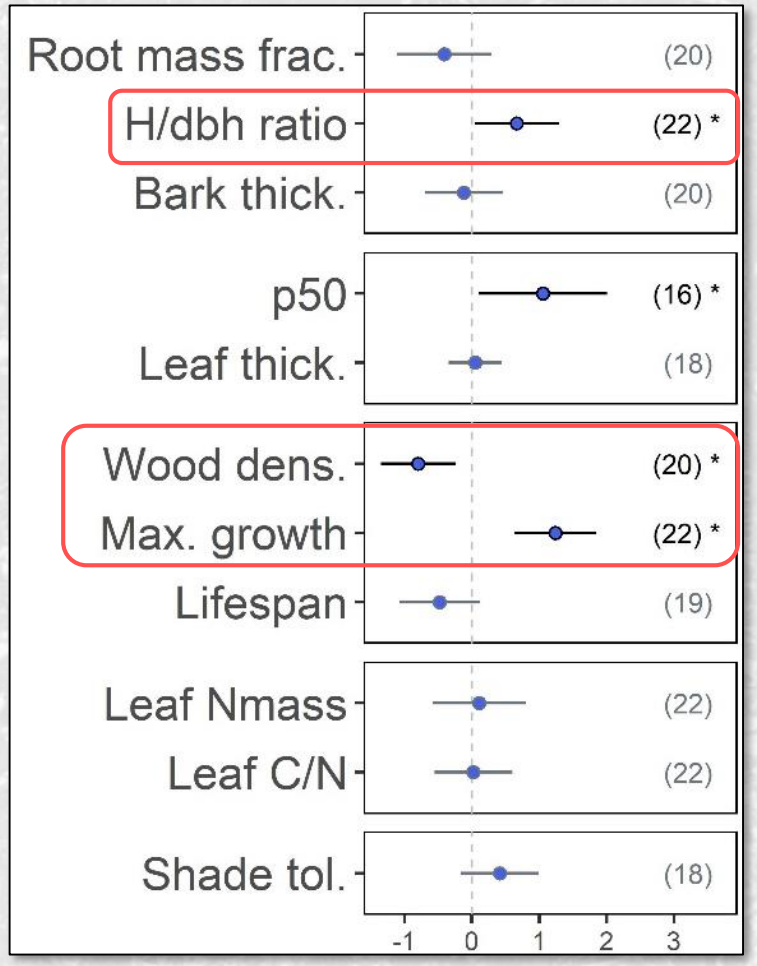
- For instance: functional trade-off between high storm resistance and high growth rate [1]

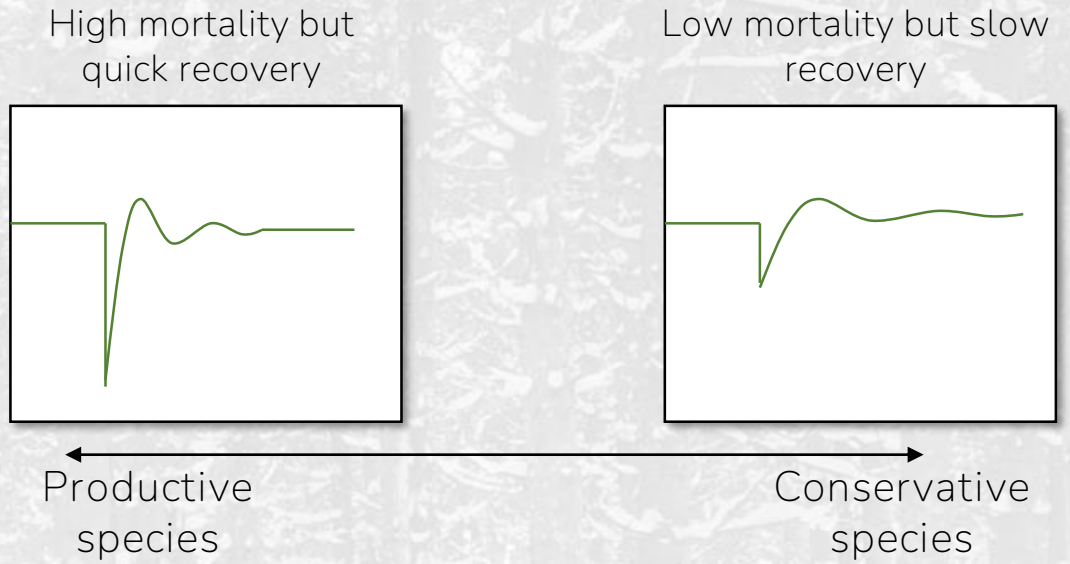


[1] Barrere et al. 2023 – *Global Change Biology*

Introduction

Additional effect of the functional composition

- It's not all about diversity: does the functional composition matter ?
- For instance: functional trade-off between high storm resistance and high growth rate [1]
- Analogous to a trade-off between resistance and recovery → which strategy best promotes resilience ?



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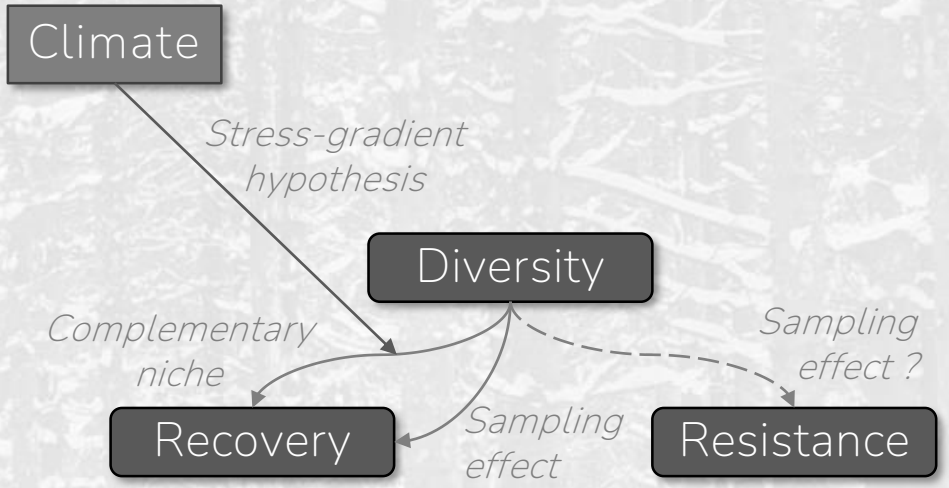
Introduction

The role of climate

On the *diversity effect*. Stress-gradient hypothesis: higher diversity effect in stressful environments [1]



[1] Bertness & Callaway 1994 – TREE

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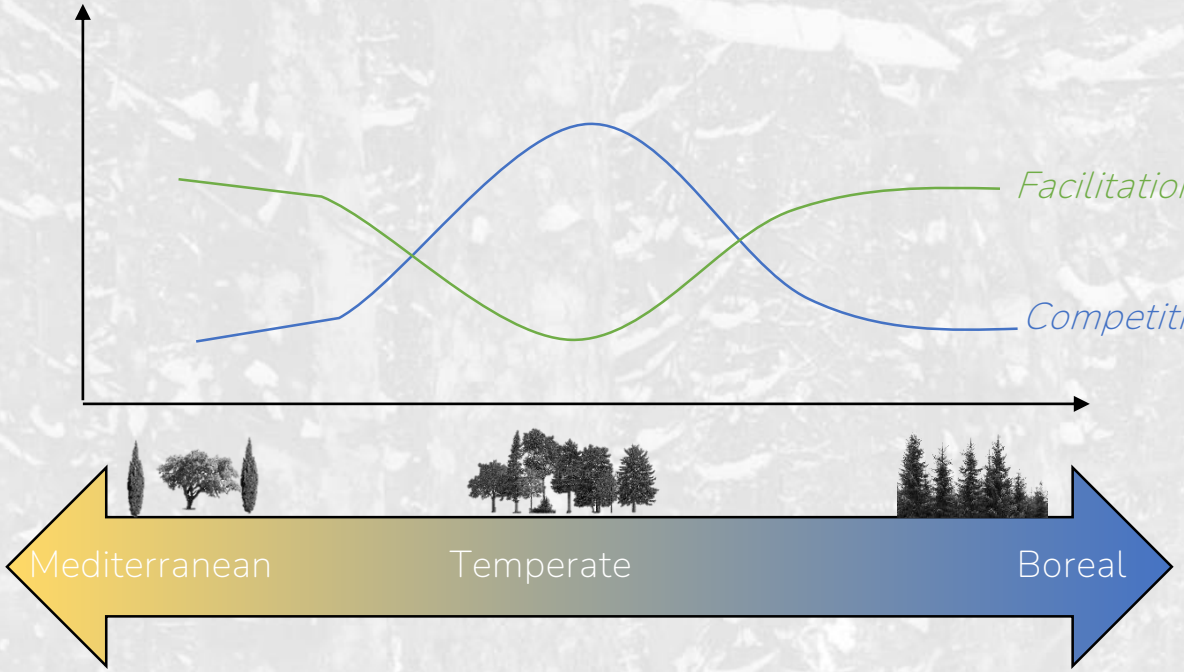
The role of climate



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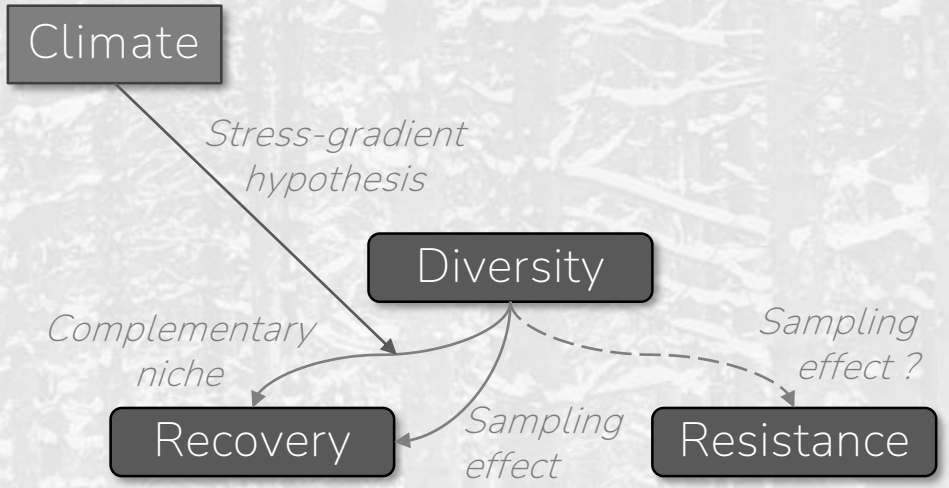

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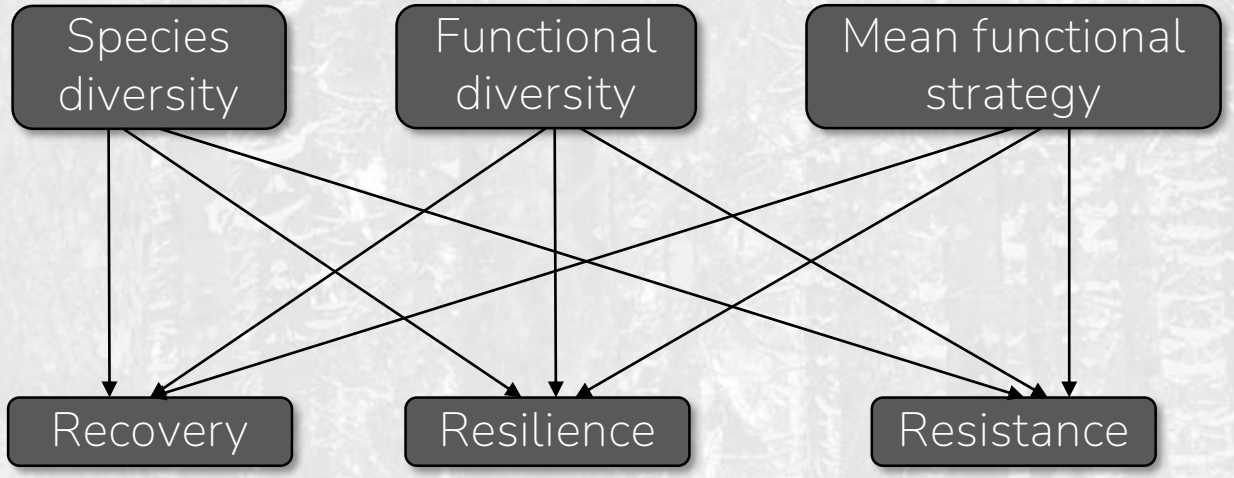
Introduction

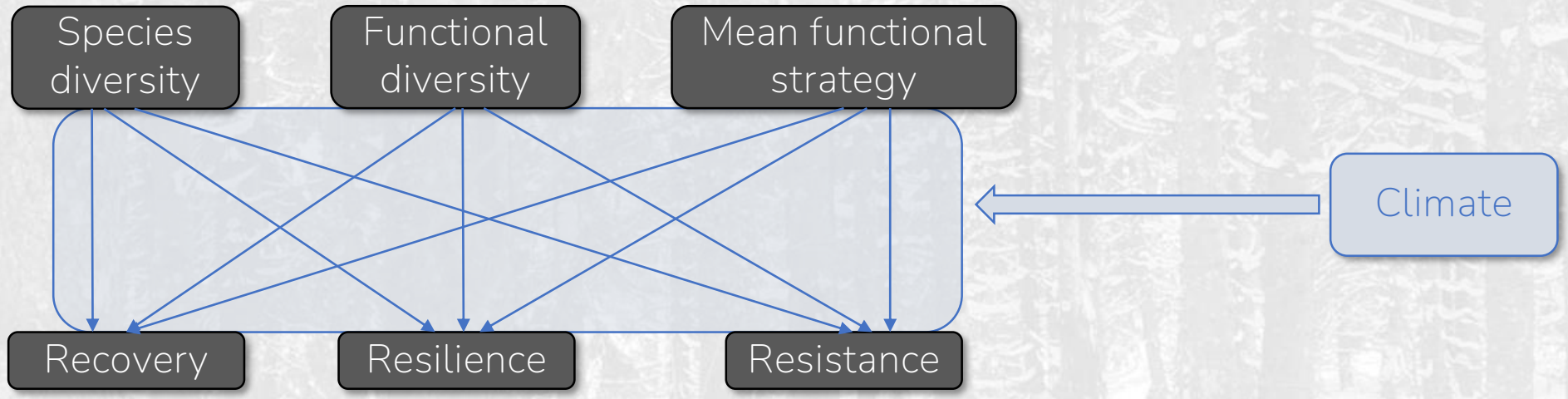
1) How does species composition (i.e., species diversity, functional diversity and mean functional strategy) affect resistance, recovery and resilience ?



Introduction

1) How does species composition (i.e., species diversity, functional diversity and mean functional strategy) affect resistance, recovery and resilience ?

2) Are these effects consistent across a climatic gradient ?



Methodological approach

- Simulation based, with an integral projection model (IPM) model [1,2]

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

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

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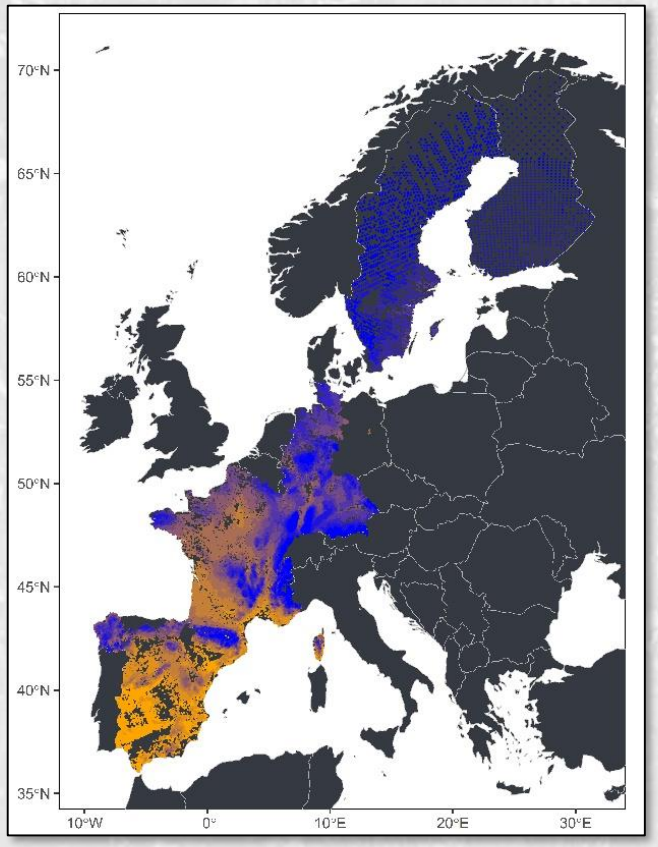

Network of NFI permanent plots (FUNDIV)

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

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

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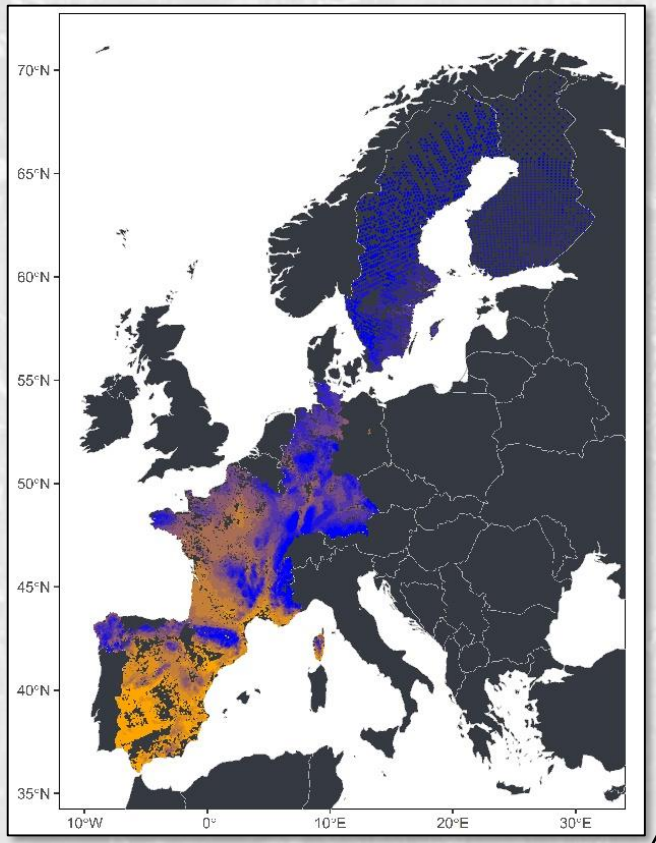
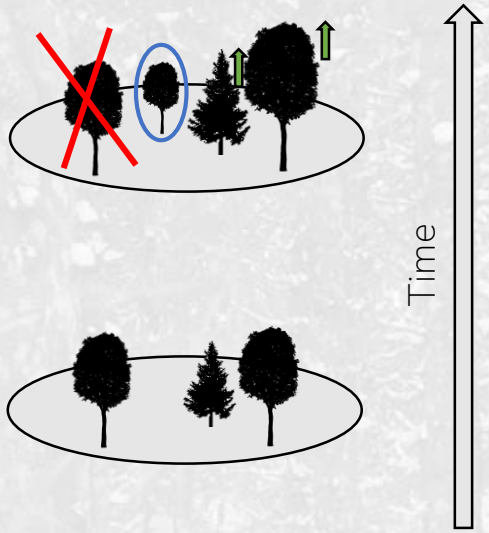


Network of NFI permanent plots (FUNDIV)

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



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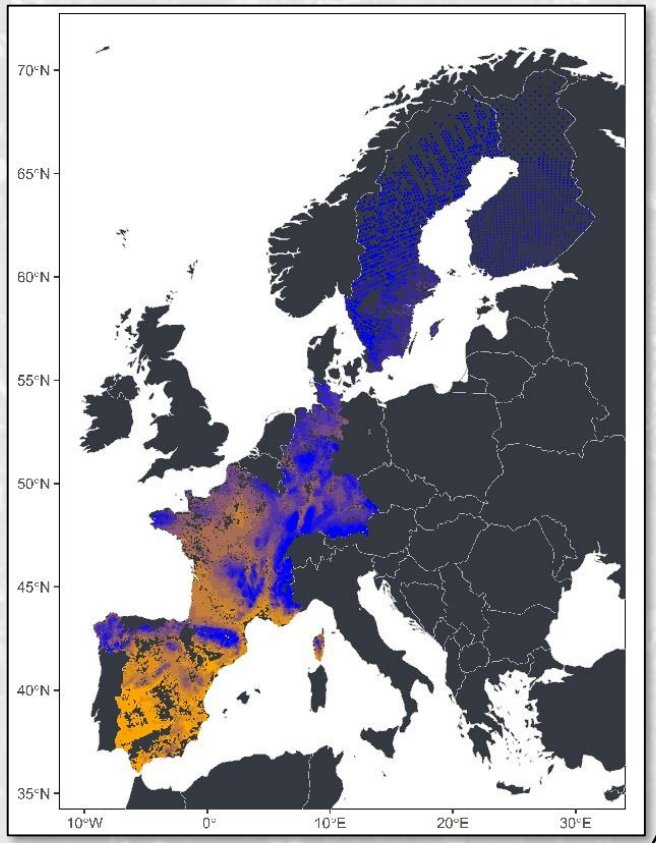

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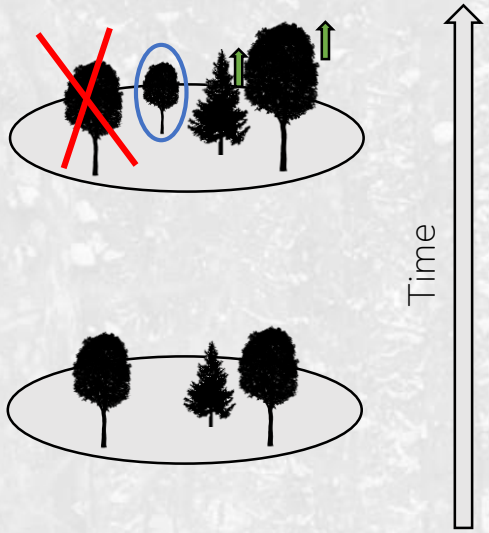

Integration of demographic functions to build IPM model

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

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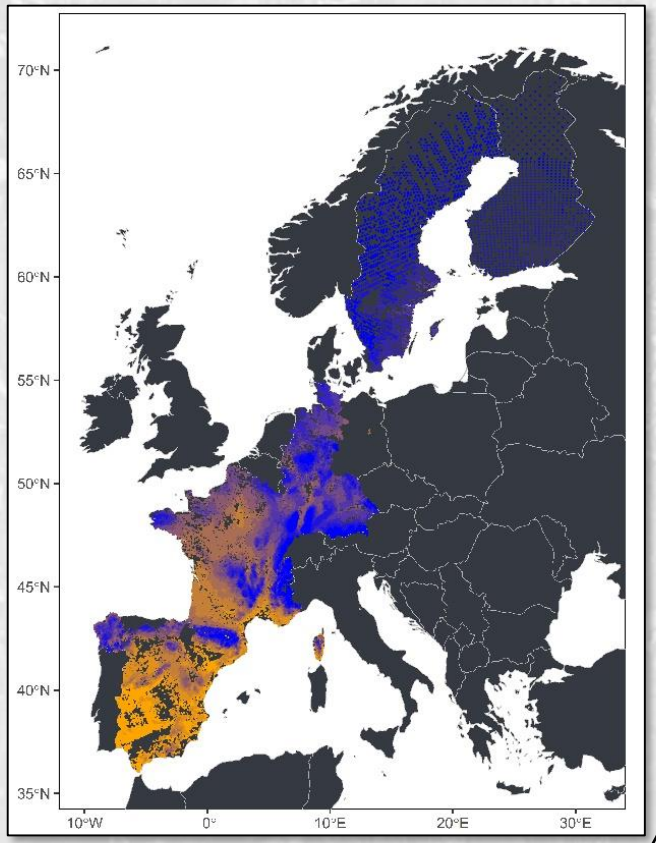

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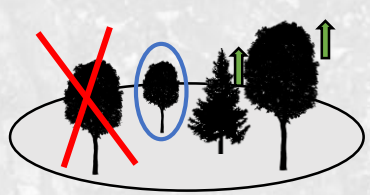
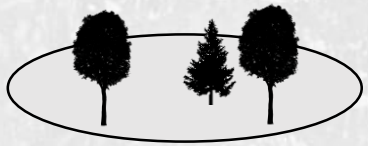
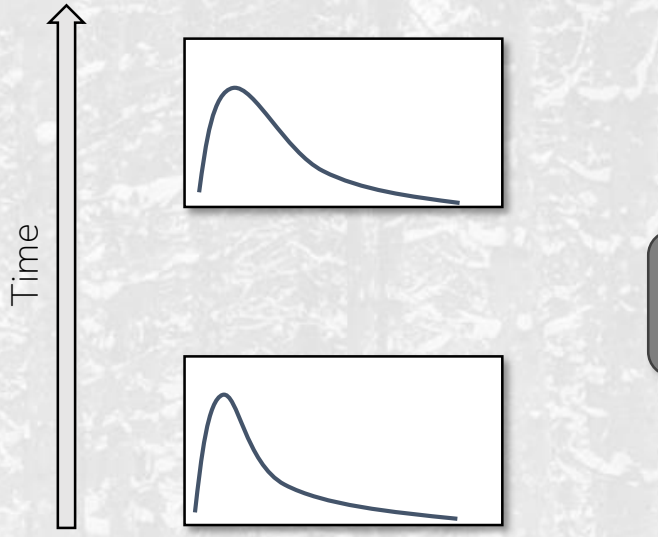






Predict changes in tree size distribution

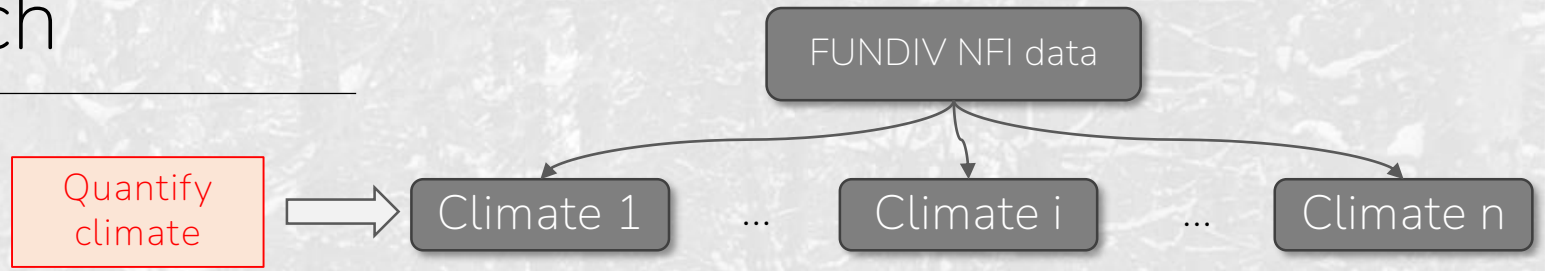
[1] Guyennon et al. 2023 – *Global Ecol. & Biogeo.*

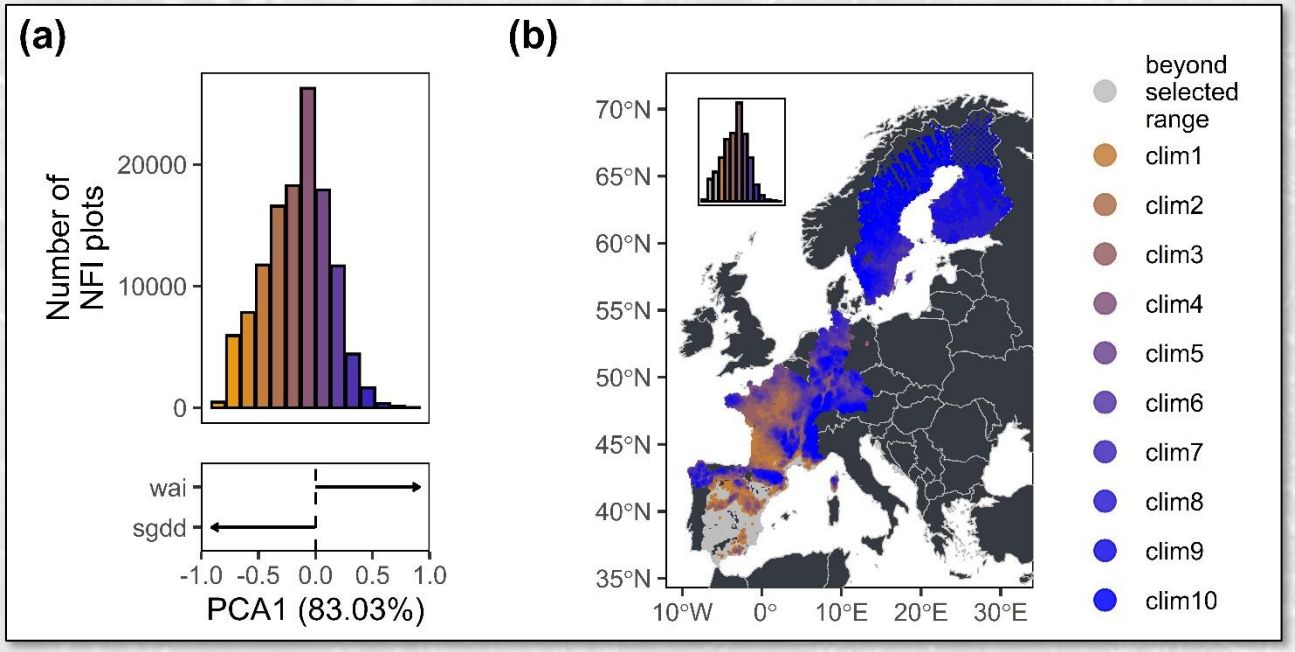
[2] Kunstler et al. 2020 – *Journal of Ecology*

Methodological approach

FUNDIV NFI data

Methodological approach

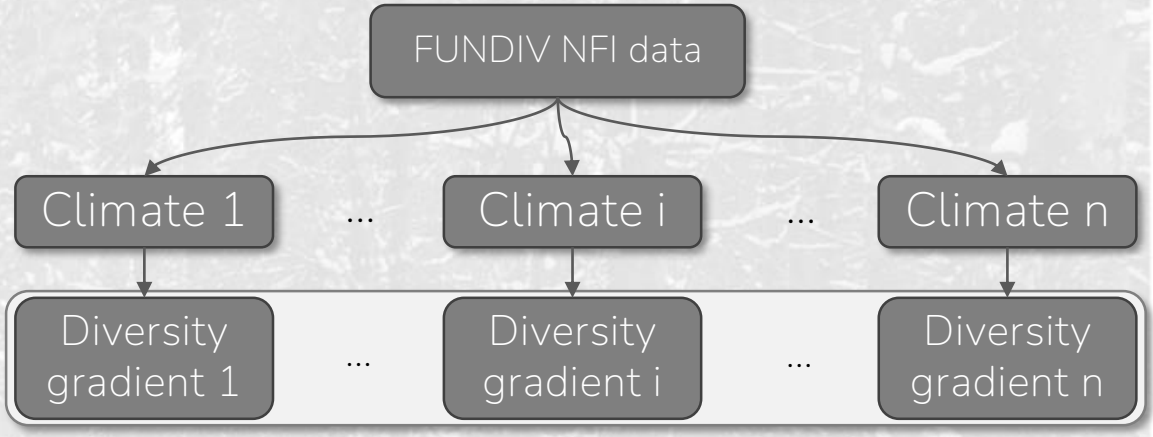




- Climate treated as the coordinate of the first axis of PCA sgdd – wai as in Kunstler et al. (2020)

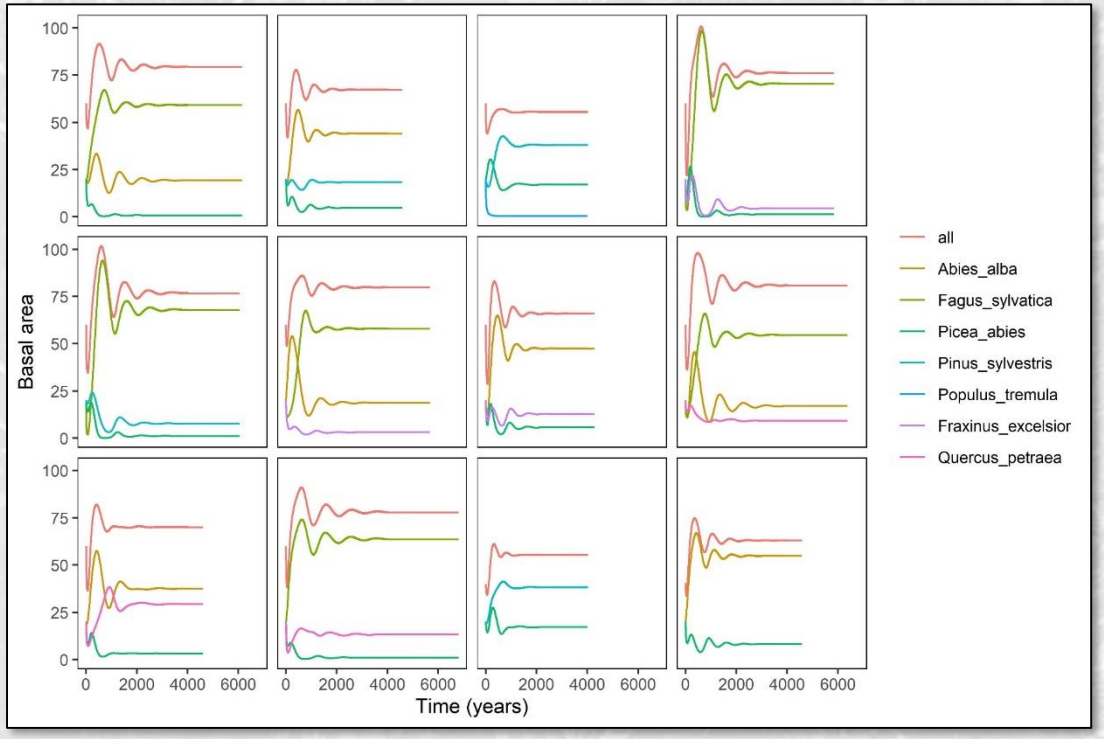
Methodological approach

Quantify climate



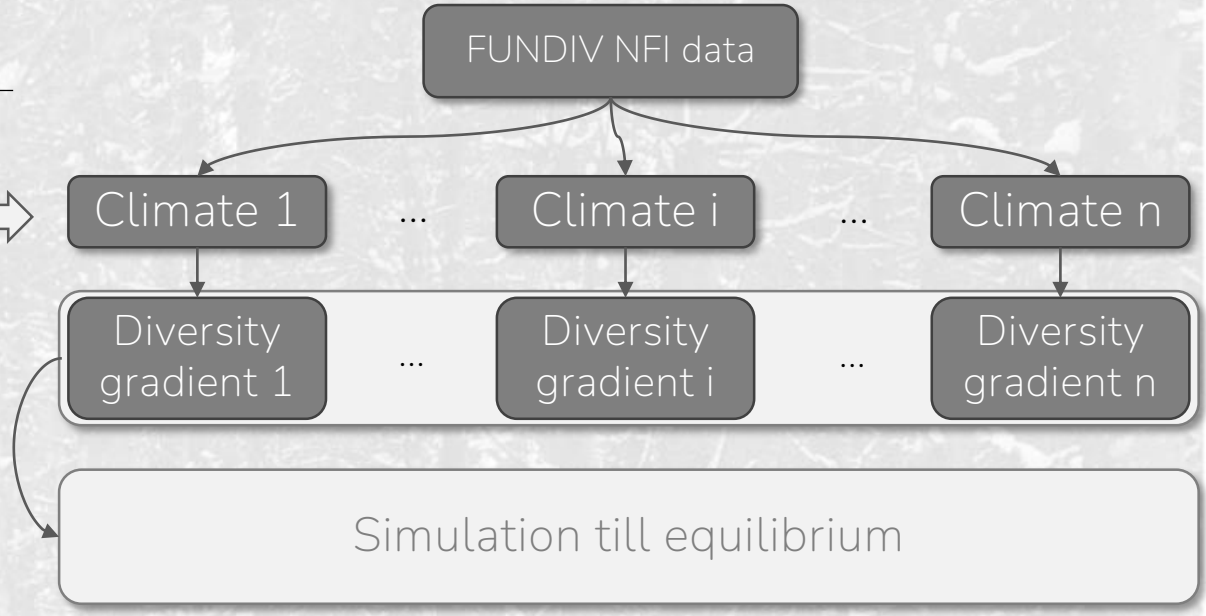
Selection of the 10 most frequent assemblages of 1, 2, 3, 4, ..., 6/7 species

Methodological approach



Equilibrium : total basal area stable in time

Quantify climate



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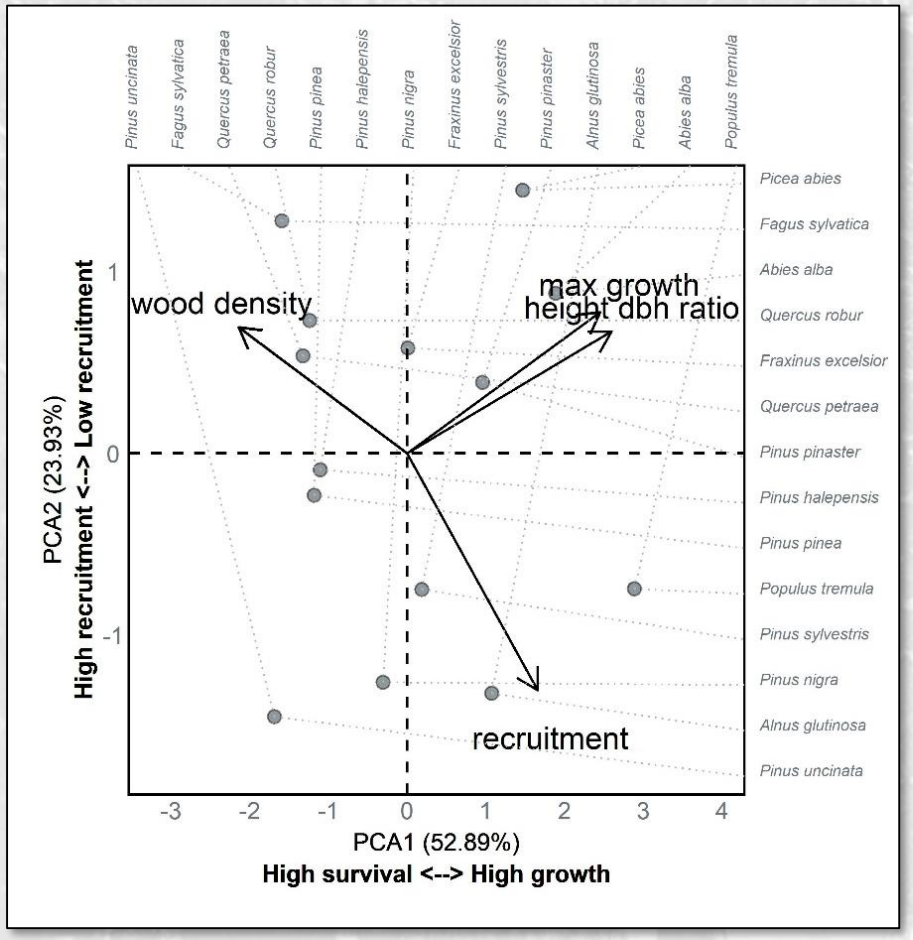
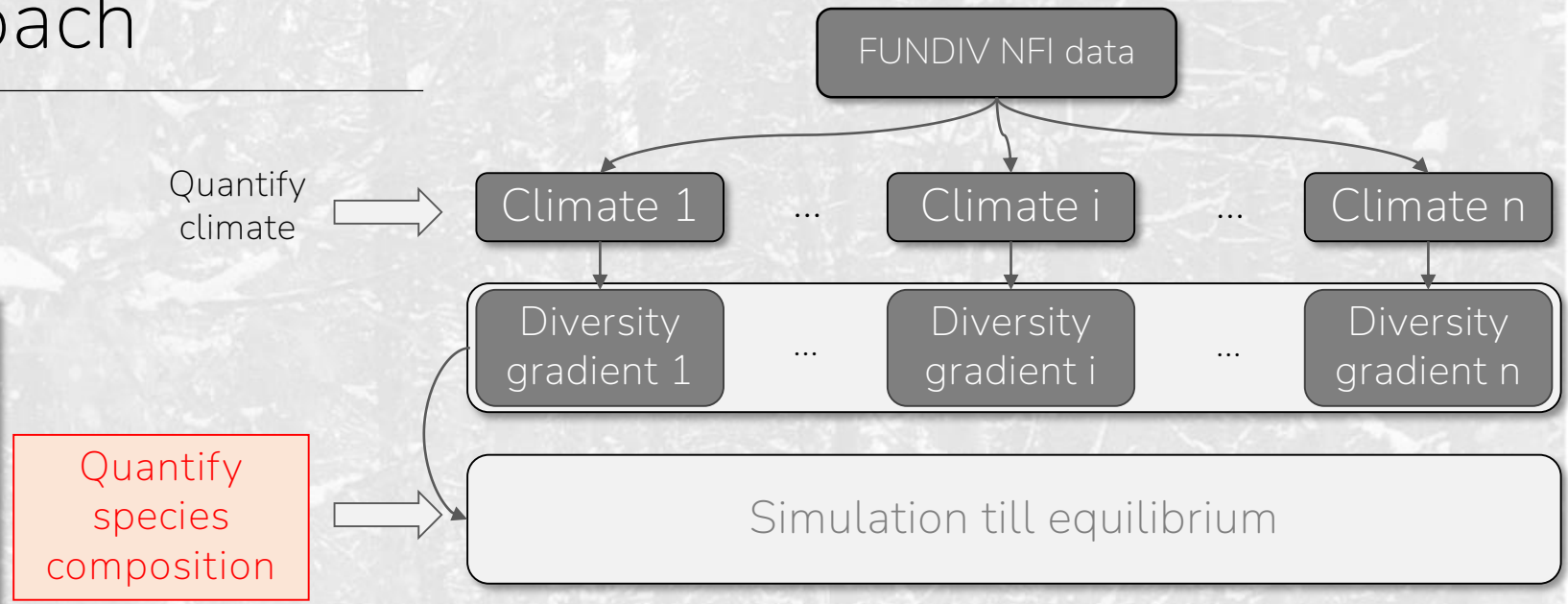
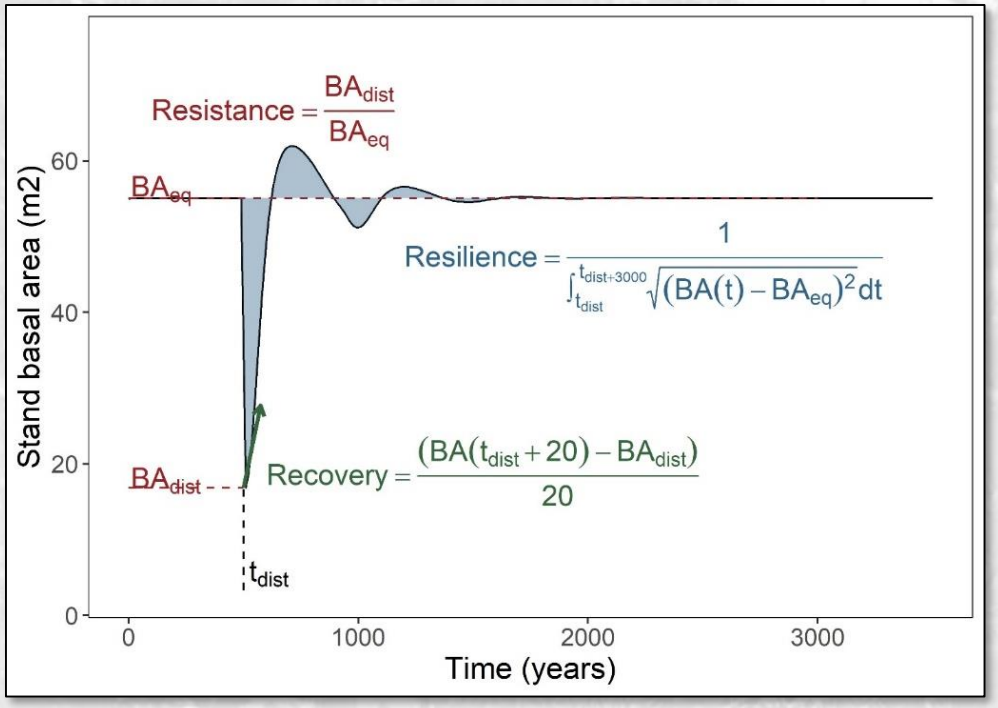
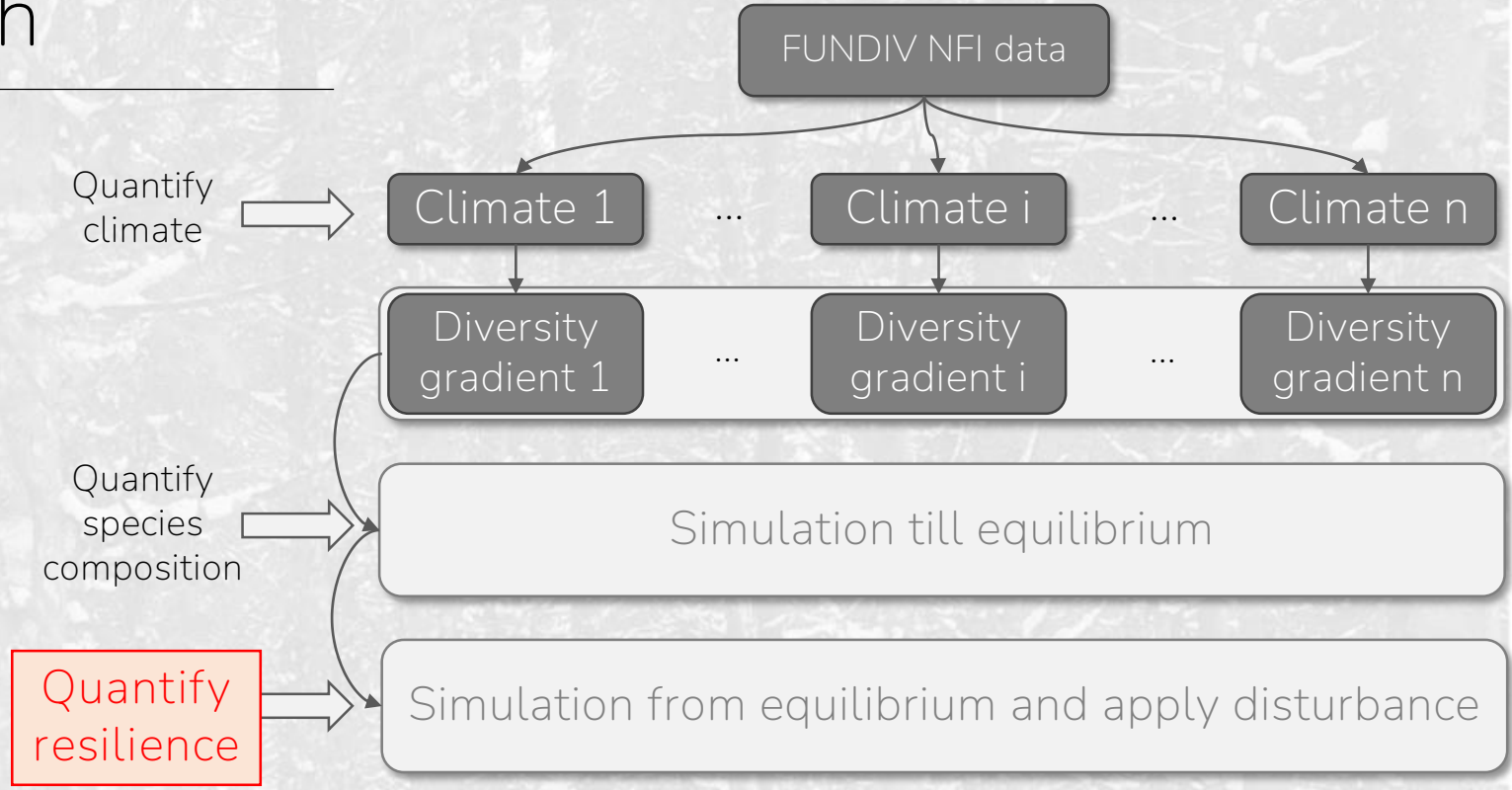




- *Species diversity (H)* = Shannon index
- *Functional strategy (CWM)* = mean weighted by species abundance at equilibrium
- *Functional diversity (FD)* = Functional dispersion (Laliberté & Legendre 2010)

Methodological approach



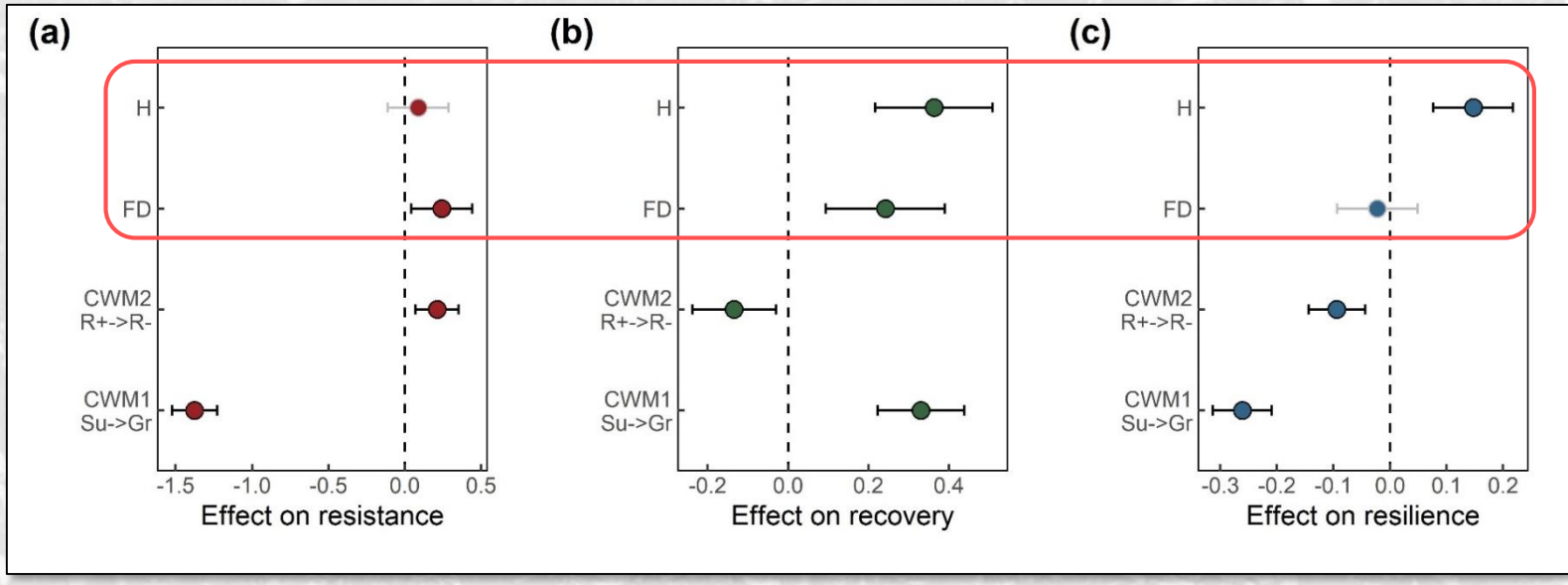


- *Resilience* = change in basal area compared to undisturbed state
- *Recovery* = slope of post-disturbance change in basal area
- *Resistance* = percentage of basal area that survived disturbance

Results

General effect of species composition on resilience

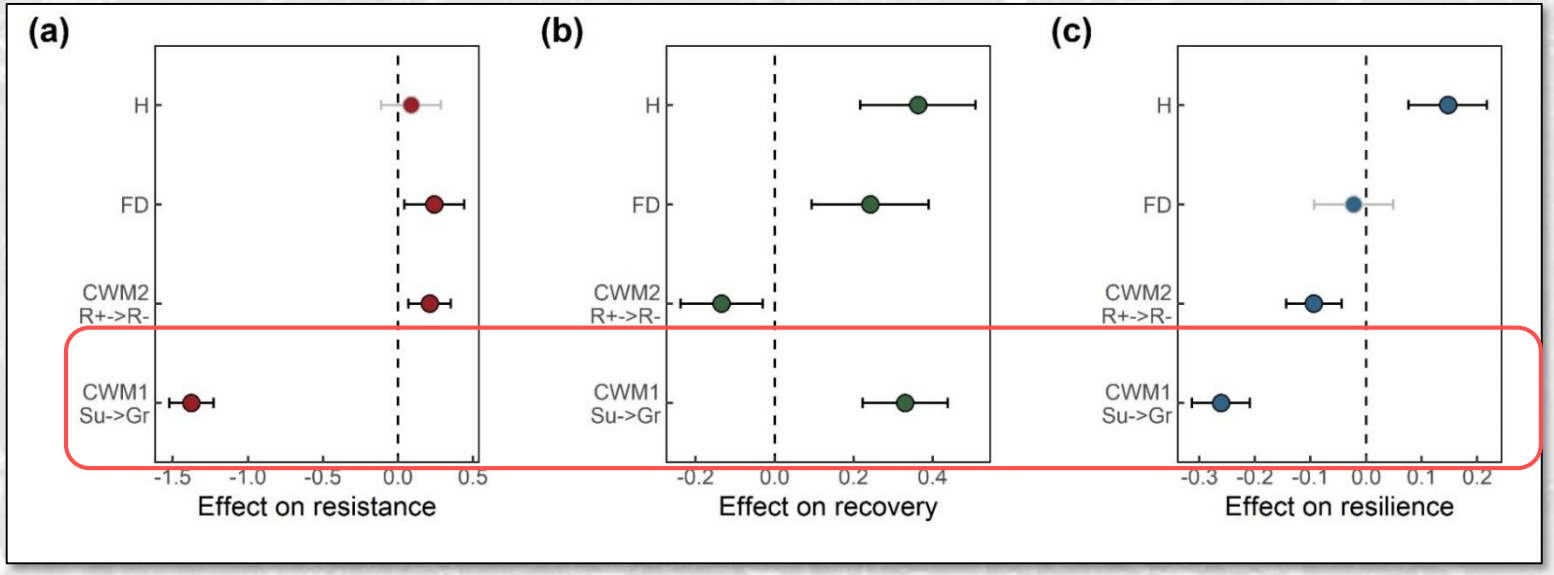
- Diversity (both in species and functional) improves all resilience metrics



Results

General effect of species composition on resilience

- Diversity (both in species and functional) improves all resilience metrics
- Higher effect of mean functional strategy than diversity



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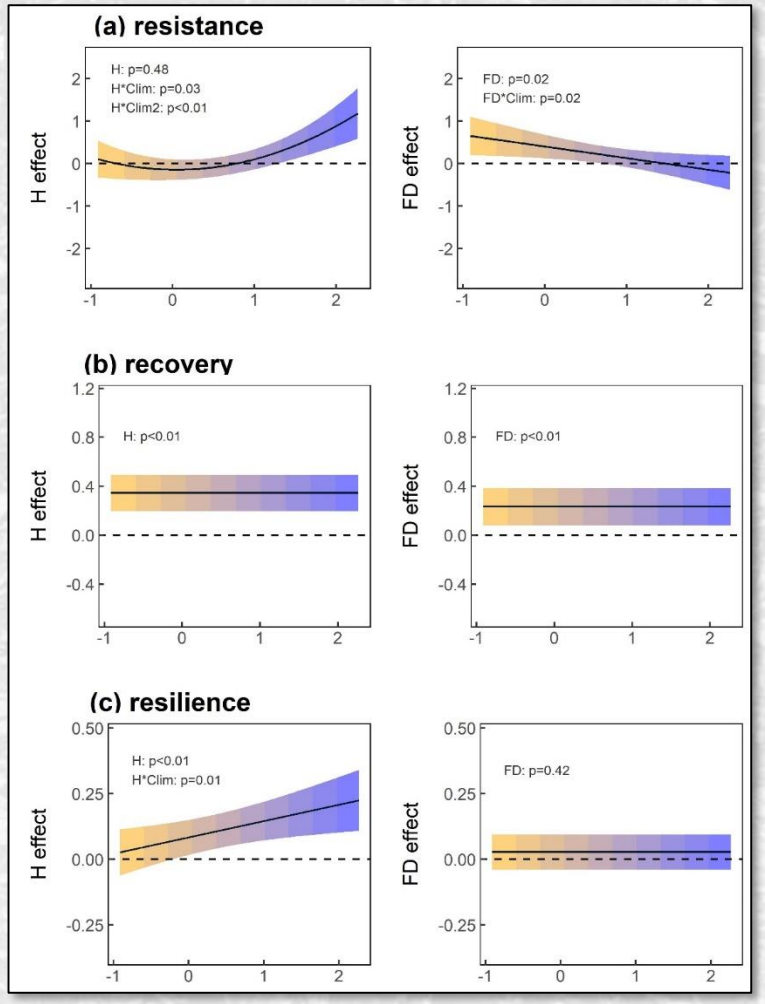


Coordinates on the wai-sgdd PCA

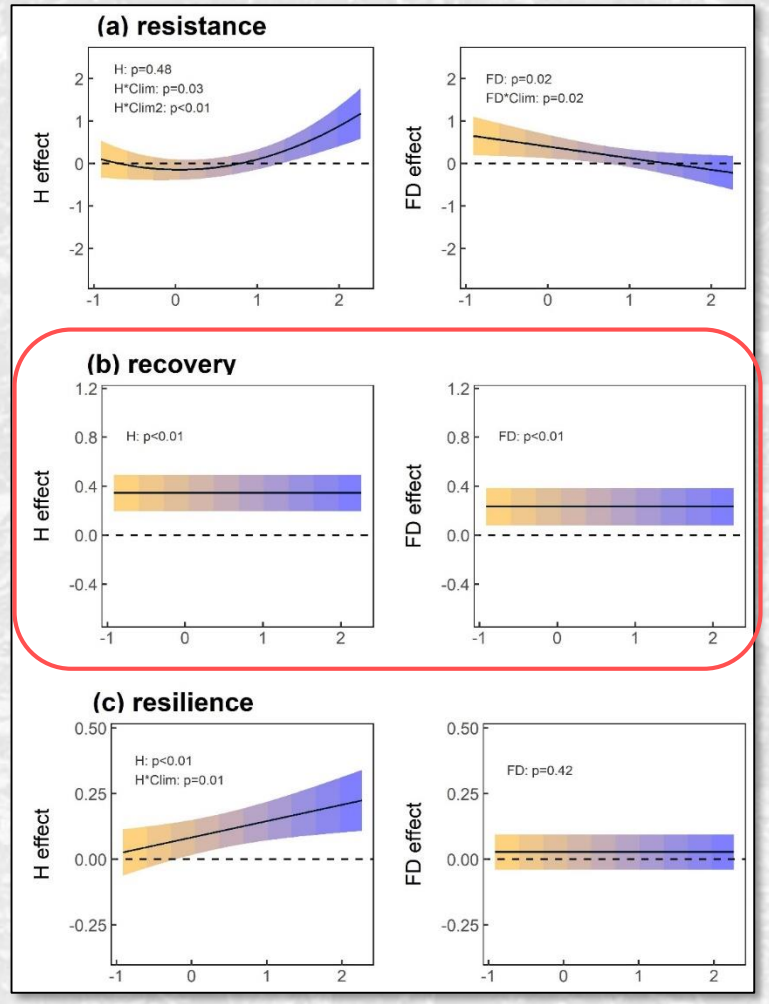
Hot and dry edge

Cold and wet edge

Results

General effect of species composition on resilience

- The effect of diversity on recovery is constant along the climatic gradient
  → low competition in post-disturbance conditions ?



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Hot and dry edge

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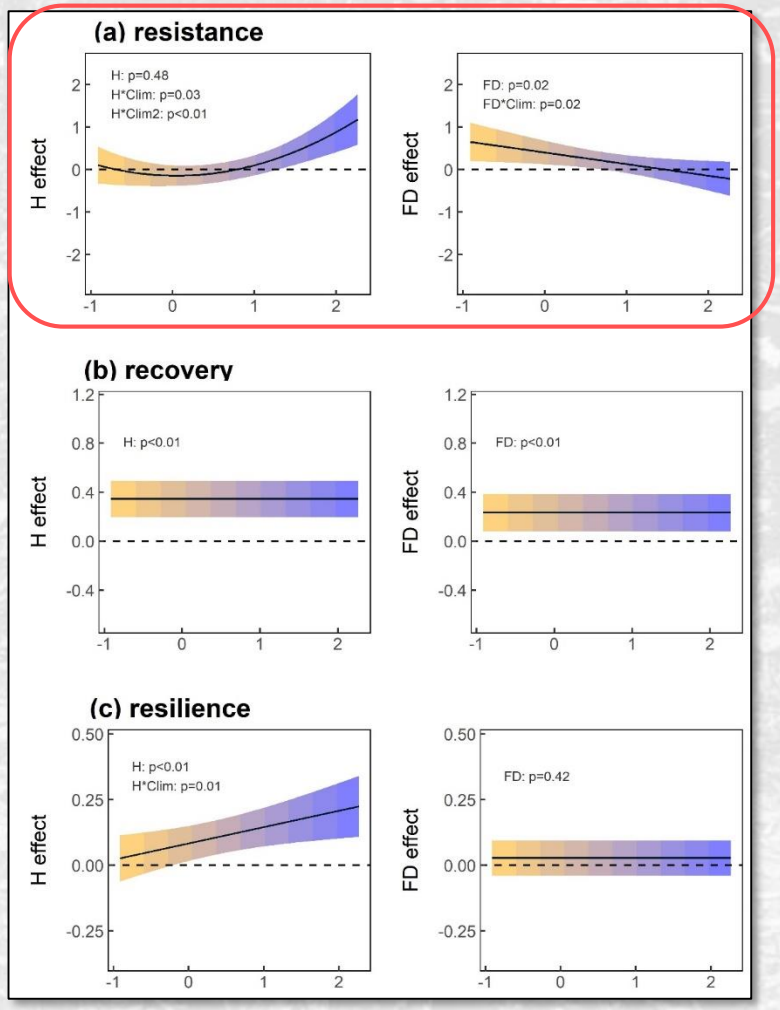
Results

General effect of species composition on resilience

- The effect of diversity on recovery is constant along the climatic gradient
  → low competition in post-disturbance conditions ?

- Effect of diversity on resistance higher in extreme climates
  → Stronger sampling effect at climatic margins ?



Coordinates on the wai-sgdd PCA

Hot and dry edge

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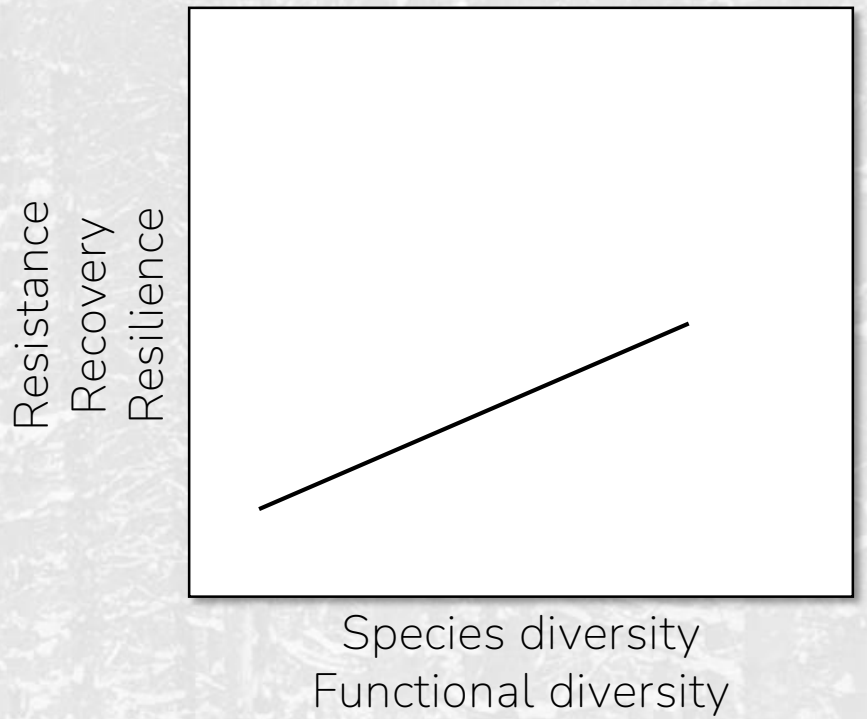
Take-home message

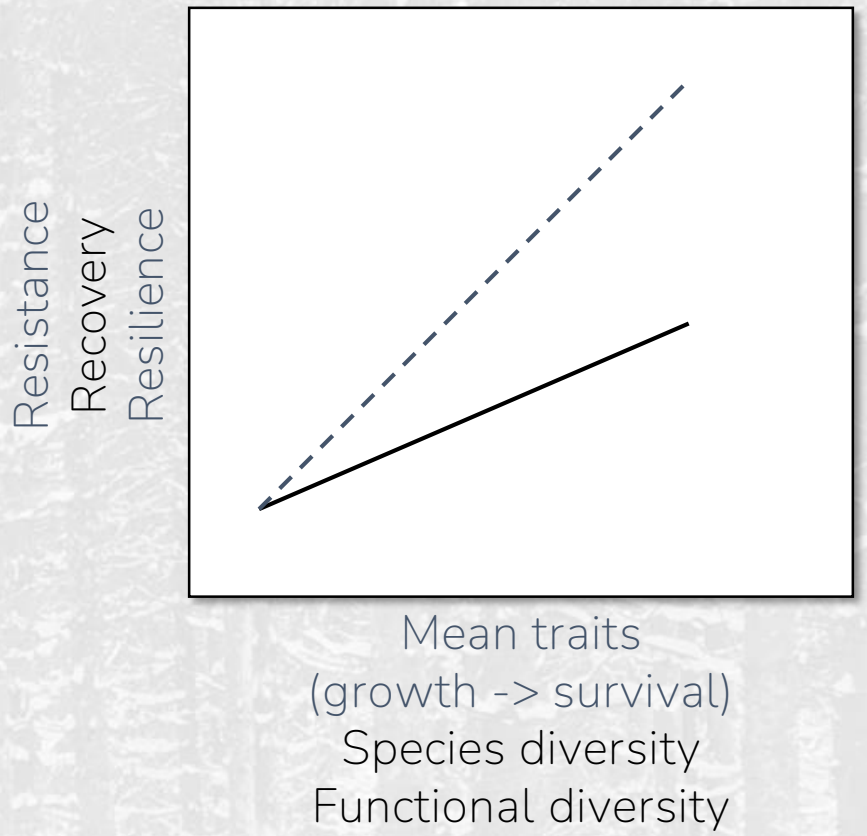
- Diversity (species and/or functional) improves resistance, recovery and resilience



Take-home message

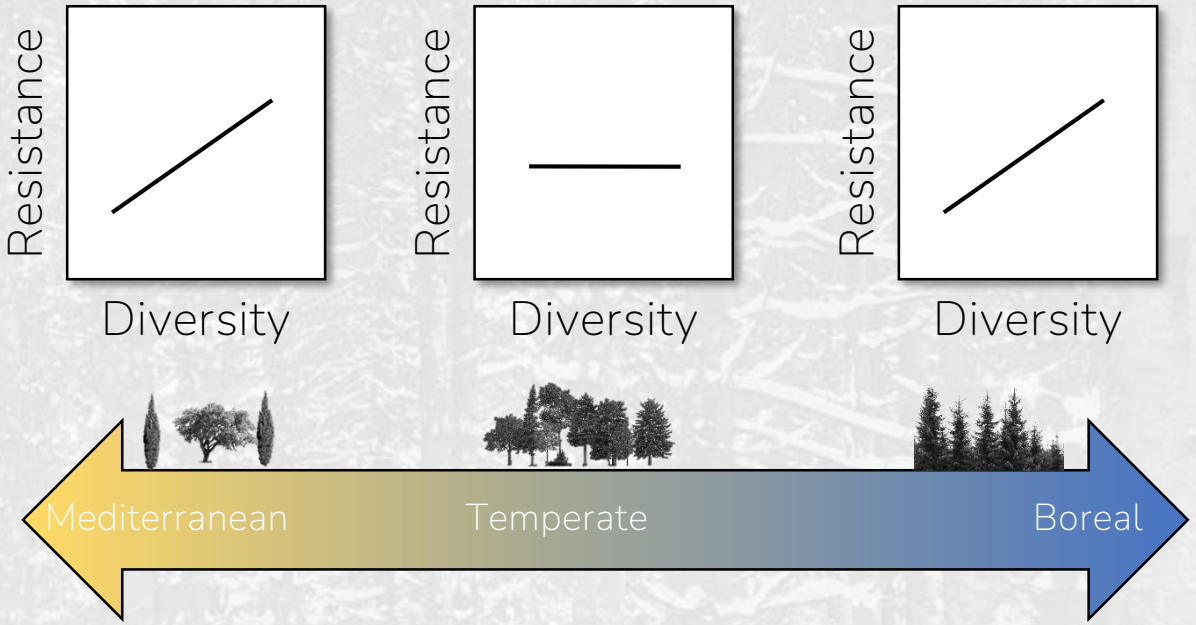
- Diversity (species and/or functional) improves resistance, recovery and resilience

- The traits of the species dominating the community have a stronger effect on resilience than diversity



Take-home message

- Diversity (species and/or functional) improves resistance, recovery and resilience
- The traits of the species dominating the community have a stronger effect on resilience than diversity
- These effects may vary along climatic gradient



QUESTIONS ?

For more on this study, read:

Barrere, J., Reineking, B., Jaunatre, M. & Kunstler G. (2024). Forest storm resilience depends on the interplay between functional composition and climate - insights from European-scale simulations. *Functional Ecology* (in press).

Or contact us !

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