Overyielding in mixed forests decreases with site productivity

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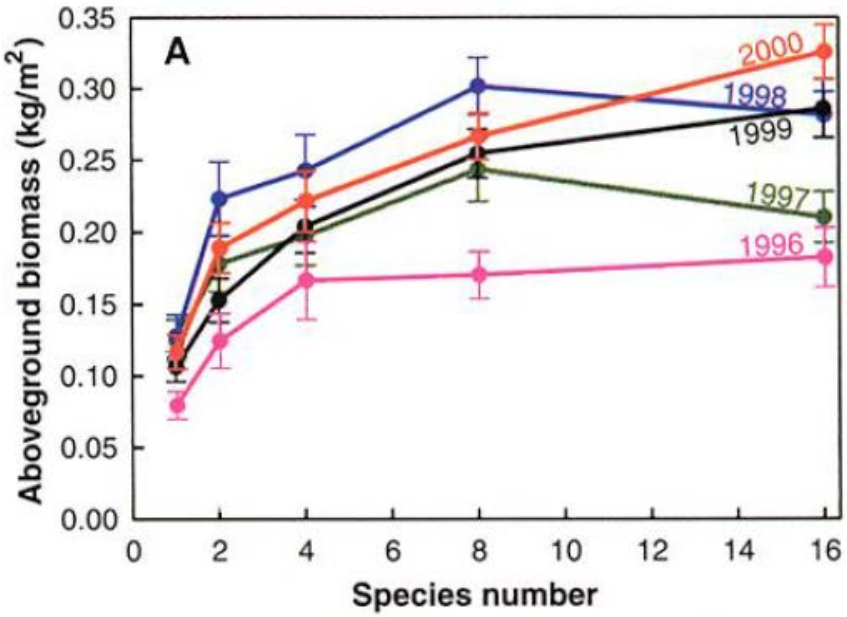
Ecology, silviculture and management of spruce species in mixed forests conference

11-13 August 2015, Edmonton, Canada

Diversity – productivity relationship

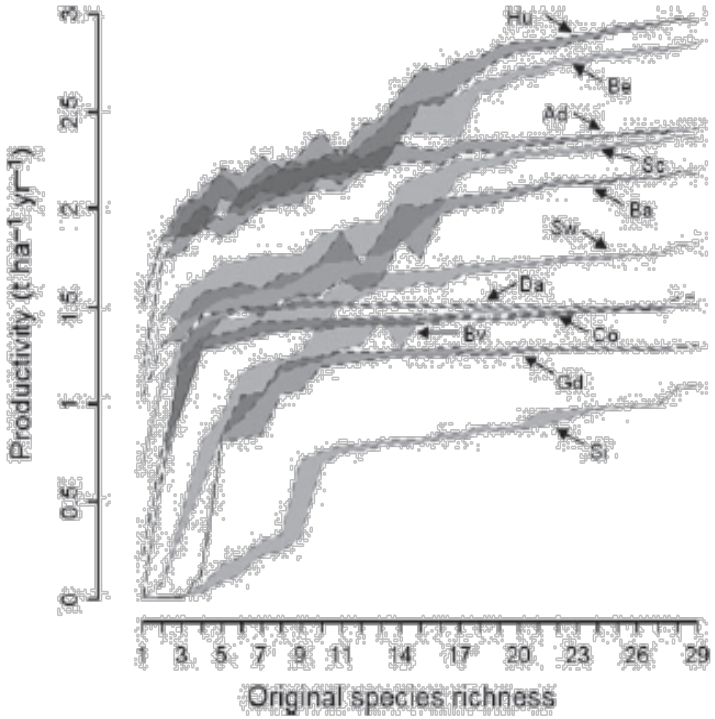
A SATURATING INCREASING RELATIONSHIP

Herbaceous species (Experimentation)



Tilman et al. 2001

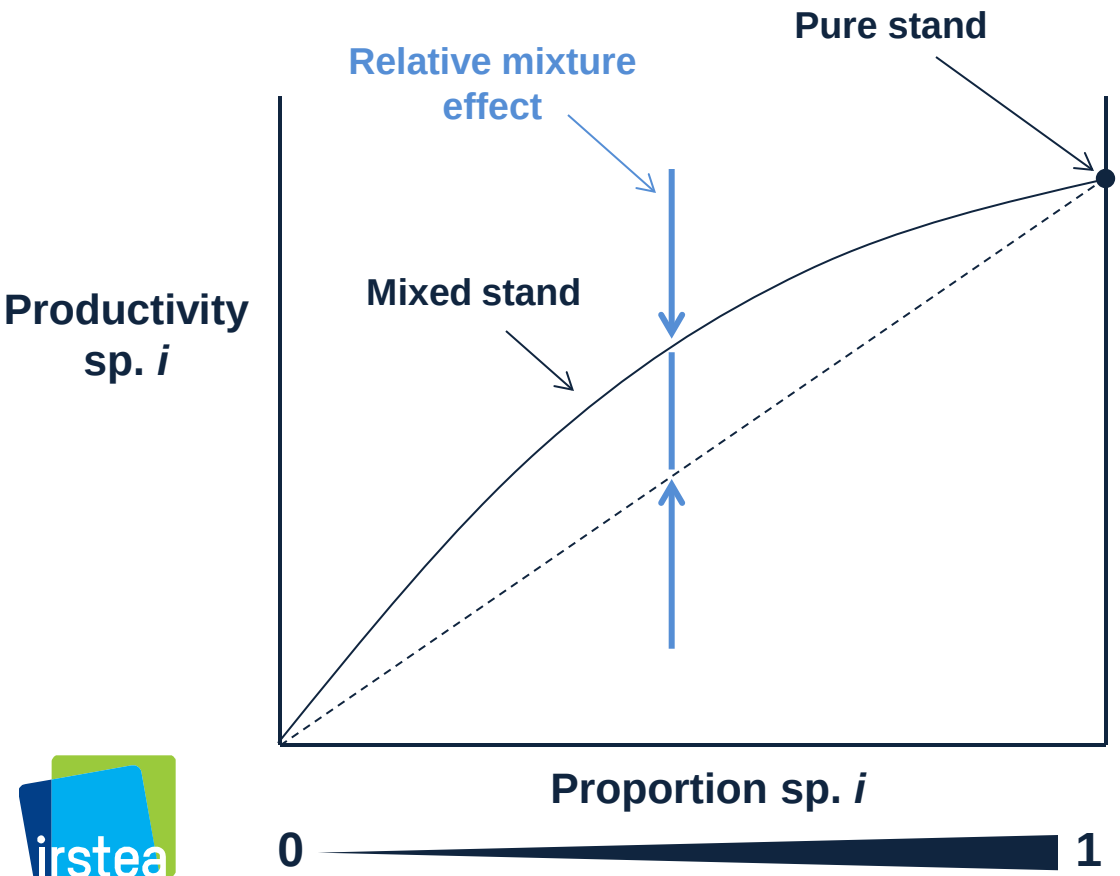
Forest (Simulation)



Morin et al. 2011

Diversity – productivity relationship

Productivity: an indicator of species interactions



Harper 1977

Niche complementarity

Facilitation

Competition

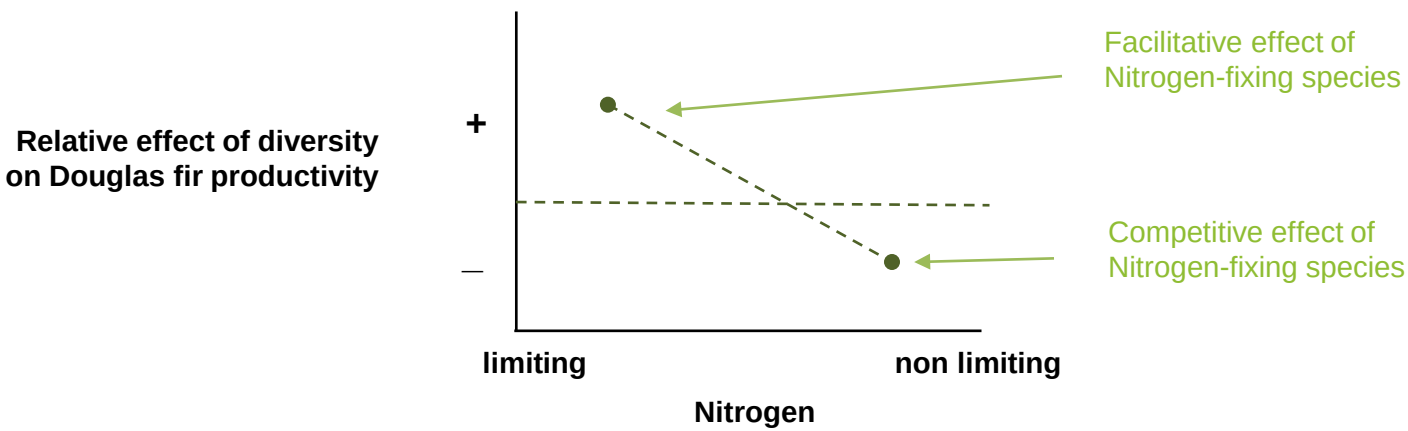
Loreau 1998

Diversity – productivity relationship

IMPORTANCE OF ABIOTIC CONDITIONS

- The relative importance of facilitation relative to competition increases with abiotic stress
  - A conceptualization: Stress Gradient Hypothesis (Bertness & Callaway 1994, herbaceous)

Douglas fir mixed with alder (Binkley et al. 2003)



- Various geographical contexts → Various species assemblage
  - Stress gradient different according to species and context
  - Productivity : an stress indicator, to harmonize stress gradients (Grime 1977)

Objective of this study

1. To characterize the limiting site conditions for several species
2. To analyze the diversity effects along these stress gradients

- Part of Maude Toïgo's PhD

100 YEARS Journal of Ecology
British Ecological Society
Journal of Ecology 2015, **103**, 502–512 doi: 10.1111/1365-2745.12353

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Maude Toïgo[1], Patrick Vallet[1]*, Thomas Perot[1], Jean-Daniel Bontemps[2,3], Christian Piedallu[2,3] and Benoit Courbaud[4]

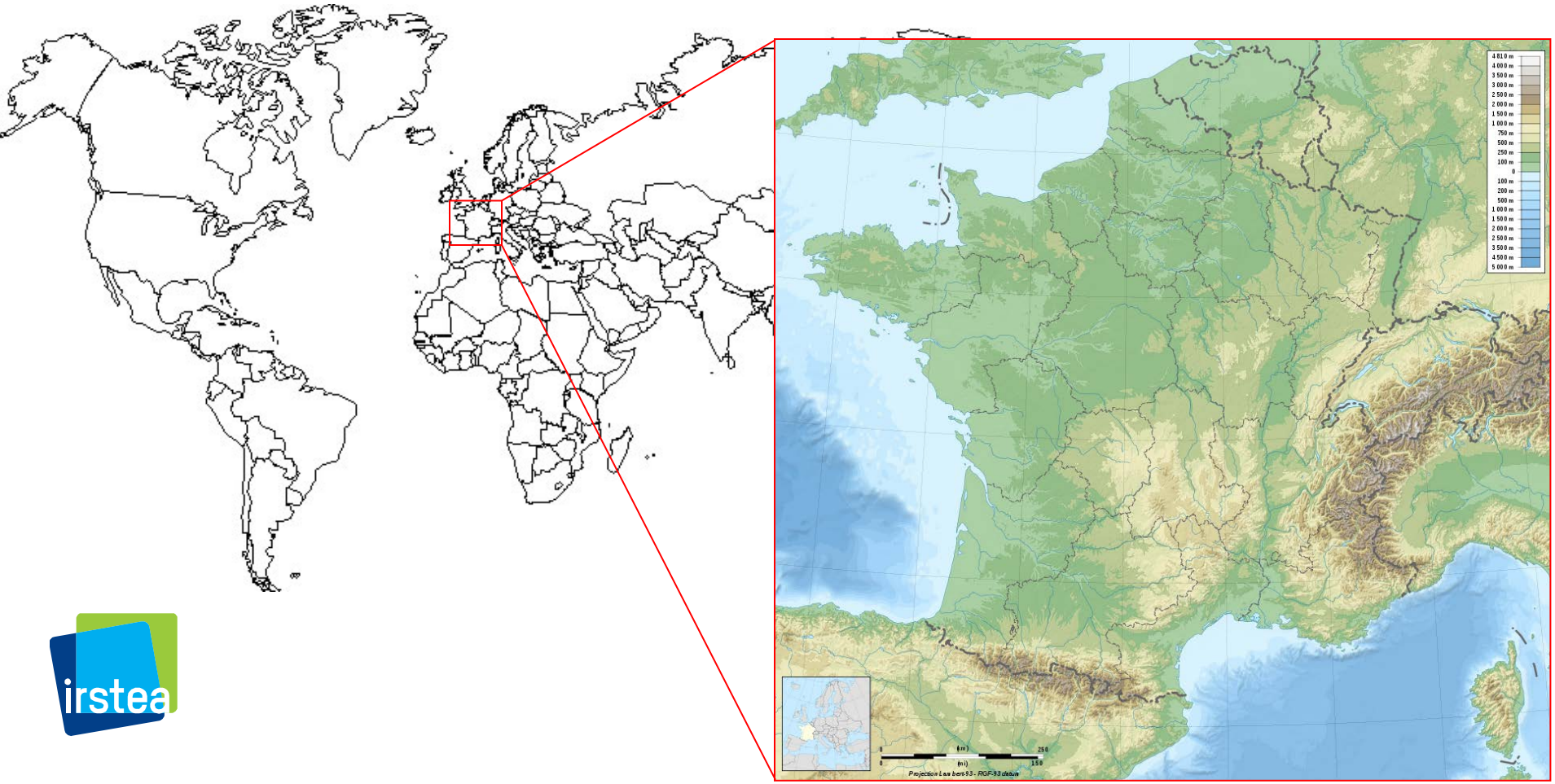
Methods

General Framework

Modeling	Productivity of sp. *i* in pure stands
Comparison	Productivity of sp. *i* in mixed stand vs. predicted productivity of sp. *i* in pure stand
Analyze	Influence of abiotic context

Data

French National Forest Inventory

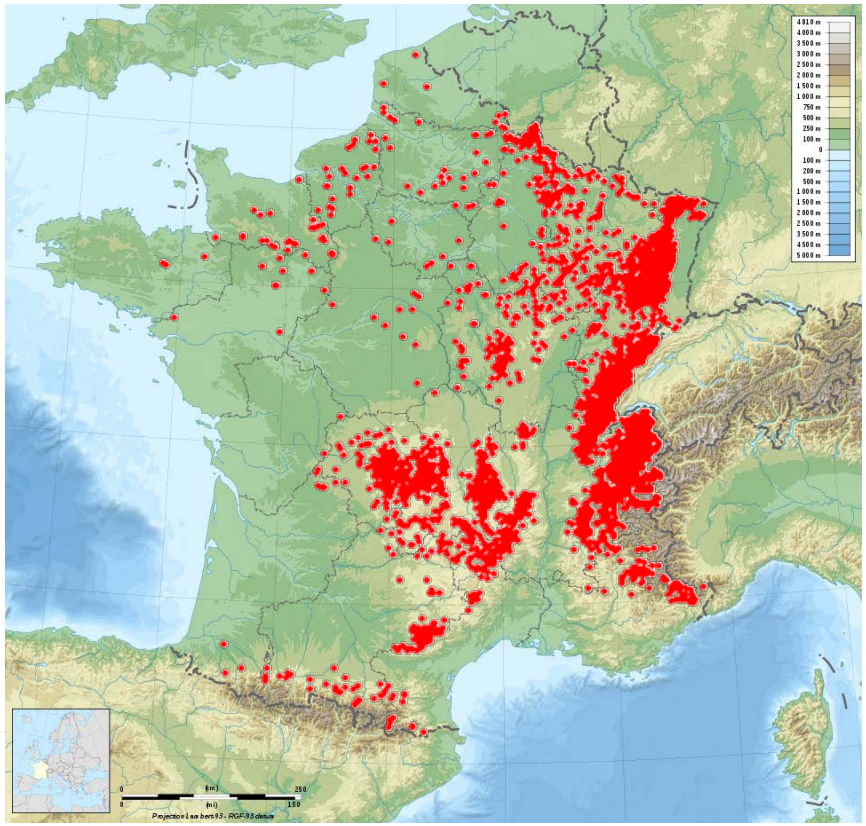


Data

Studied species

- 5 Species
  - Norway spruce *Picea abies*
  - Common beech *Fagus sylvatica*
  - Silver fir *Abies alba*
  - Sessile oak *Quercus Petraea*
  - Scots pine *Pinus sylvestris*
- 3 mountain species couples
  - Norway spruce – common beech
  - Norway spruce – silver fir
  - Common beech – silver fir
- 2 plain species couples
  - Sessile oak – Scots pine
  - Common beech – sessile oak

Norway spruce area

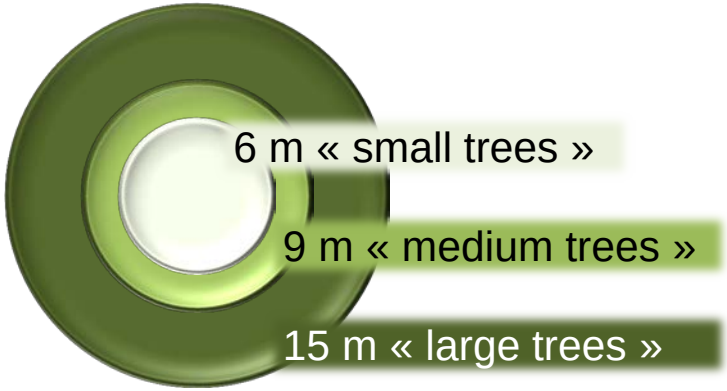


French NFI plots with at least 1 Norway spruce

Data

French National Forest Inventory

~ 6000 – 7000 plots/year



Compare pure vs. mixed stands

→

Plot selection

Data

French National Forest Inventory : data selection

Plots

Composition

Pure : 100%
Mixed : 80%

Structure

1 vertical layer
~ evenaged

Perturbation

No recent thinnings

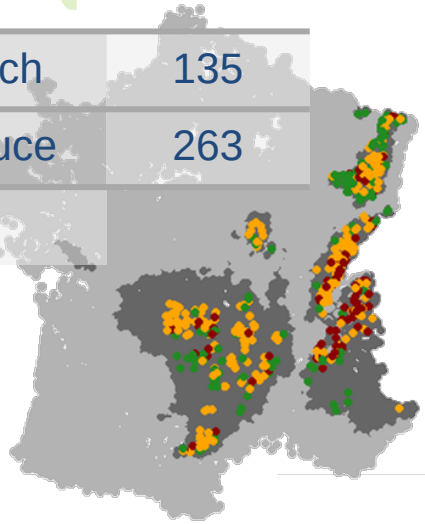
Geography

Same ecological units

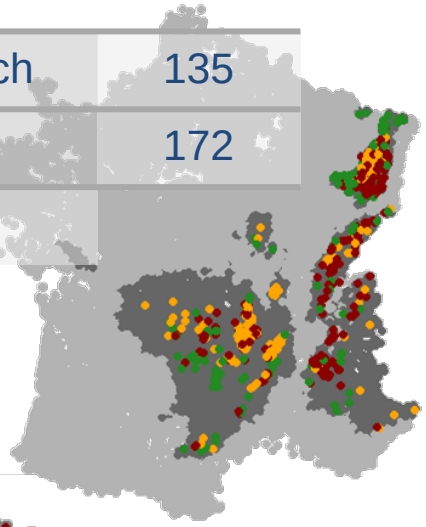
Data

French National Forest Inventory : data selection

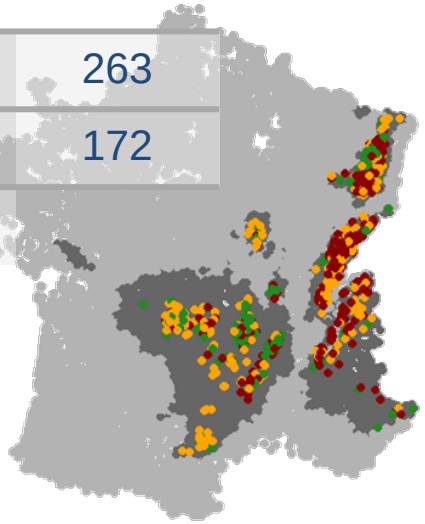
Beech	135
Spruce	263
117	



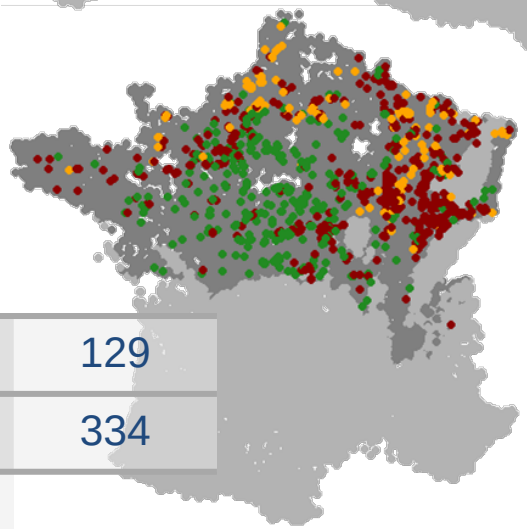
Beech	135
Fir	172
246	



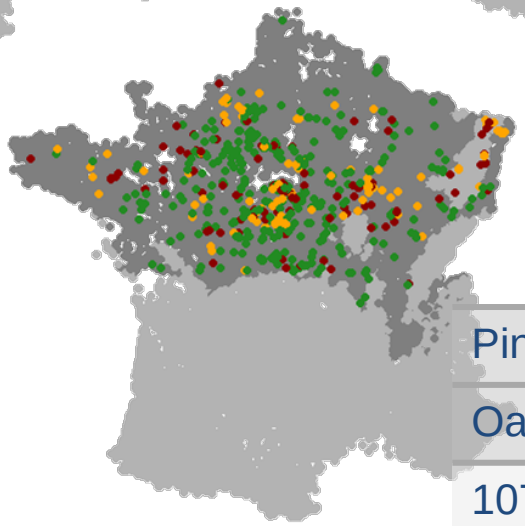
Spruce	263
Fir	172
292	



Beech	129
Oak	334
469	



Pine	100
Oak	334
107	



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Modeling

Basal area growth in pure stands

- Potential – reducers models

$$\text{Productivity sp.}i \sim f_1(\text{Abiotic factors}) \times f_2(\text{Density}) \times f_3(\text{Development stage})$$

Stand basal area
m^2/ha/5 years

Growth potential

m^2/ha/5 years

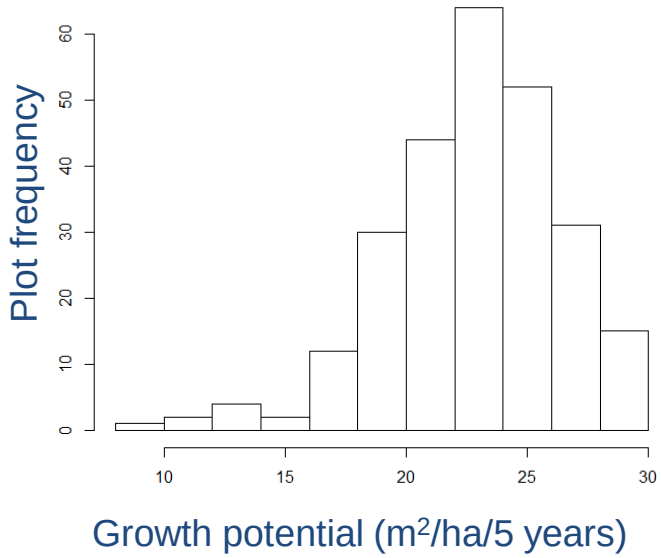
Reducers

[0:1]

Stress gradient

IN PURE AND MIXED STANDS

- When RDI = 1 and Dg = 7.5 cm, f1 is maximal
  - f1 potential is a site index



Stress gradient

Growth potential : f_1

BASAL AREA GROWTH IN PURE STANDS

- Linear combination of abiotic factors
- Different factors for each species

- For Spruce:

f_1 (Abiotic factors)

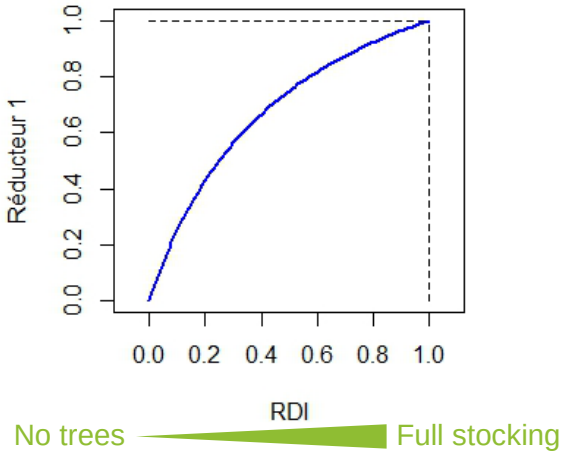
Factor	Effect
Min January temperatures	⇗
Humus (mull type)	⇗
Rocky outcrops	⇘
Slope	⇘

Growth reducers: f_2 and f_3

BASAL AREA GROWTH IN PURE STANDS

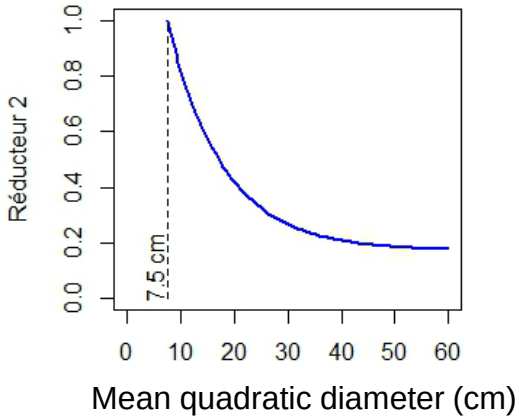
- Density reducer

f_2(Density)



- Development stage reducer

f_3(Development stage)



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Comparison

Pure stand versus Mixed stand productivity

Diversity relative effect on sp. *i*

$$= \frac{\text{Observed productivity in mixed stands} - \text{Expected productivity}}{\text{Expected productivity}}$$

Methods

General Framework

Modeling	Productivity of sp. *i* in pure stands
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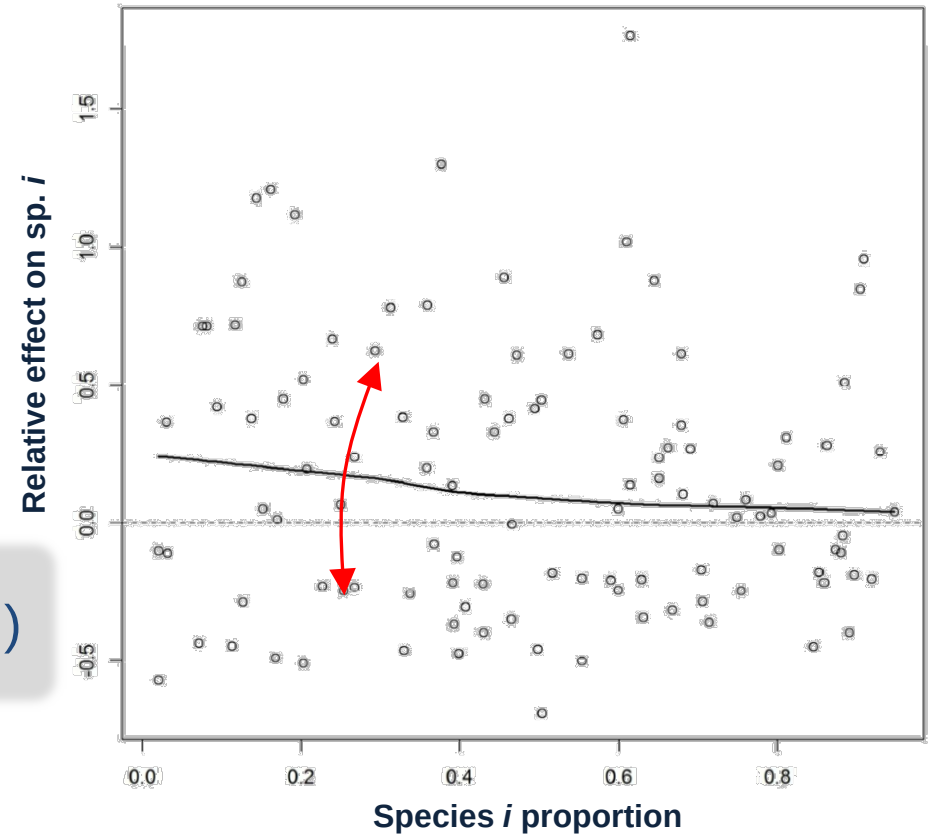
Analyze	**Influence of abiotic context**

Analyze

Mixture effect

- Average mixture effect
  - Function of species proportion



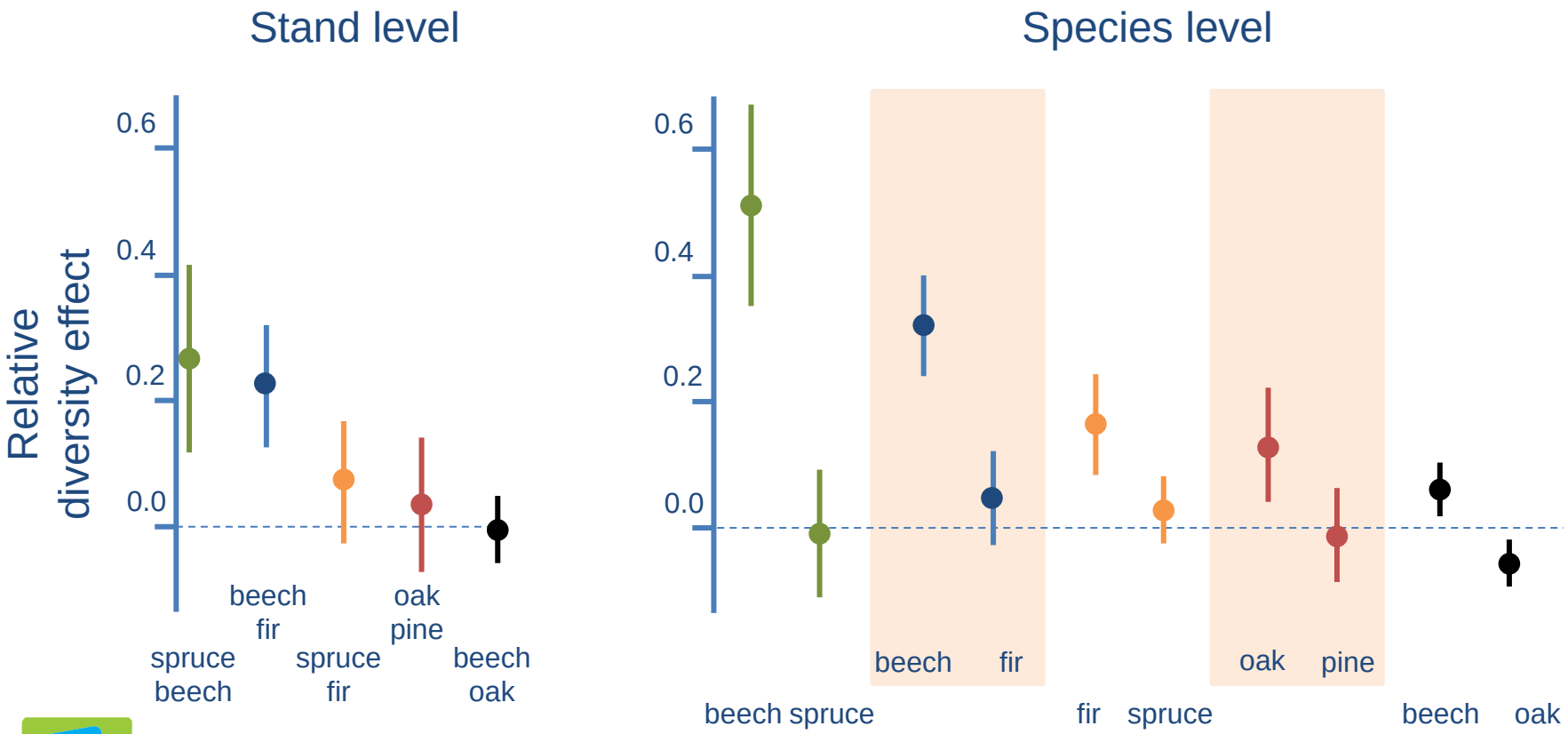
Relative effect of diversity on sp. *i* ~ $a \times (1 - \text{sp. } i \text{ prop})$

- Variation of the slope with abiotic conditions (stress gradient)

Relative effect of diversity on sp. *i* ~ $(a_0 + a_1 X) \times (1 - \text{sp. } i \text{ prop})$

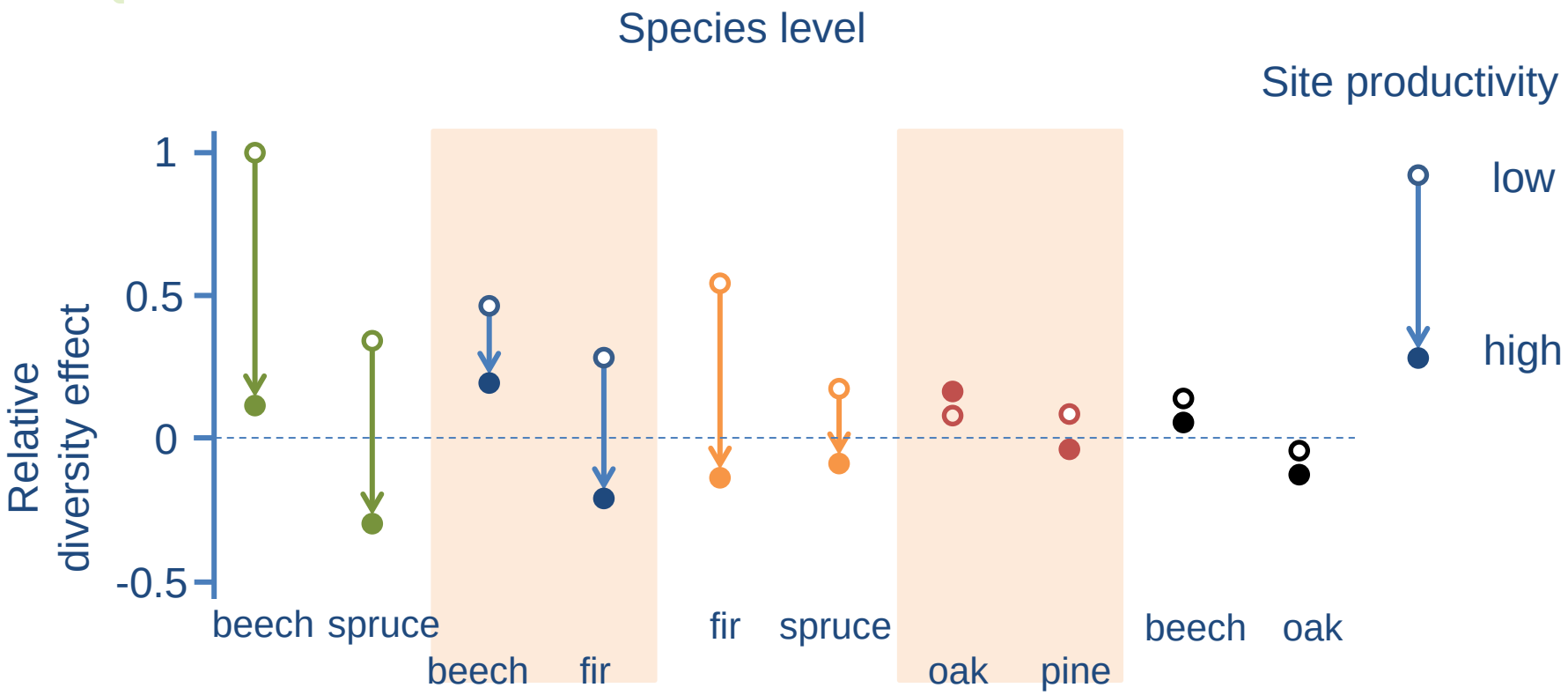
Results

Mean mixture effect – for a 50% proportion



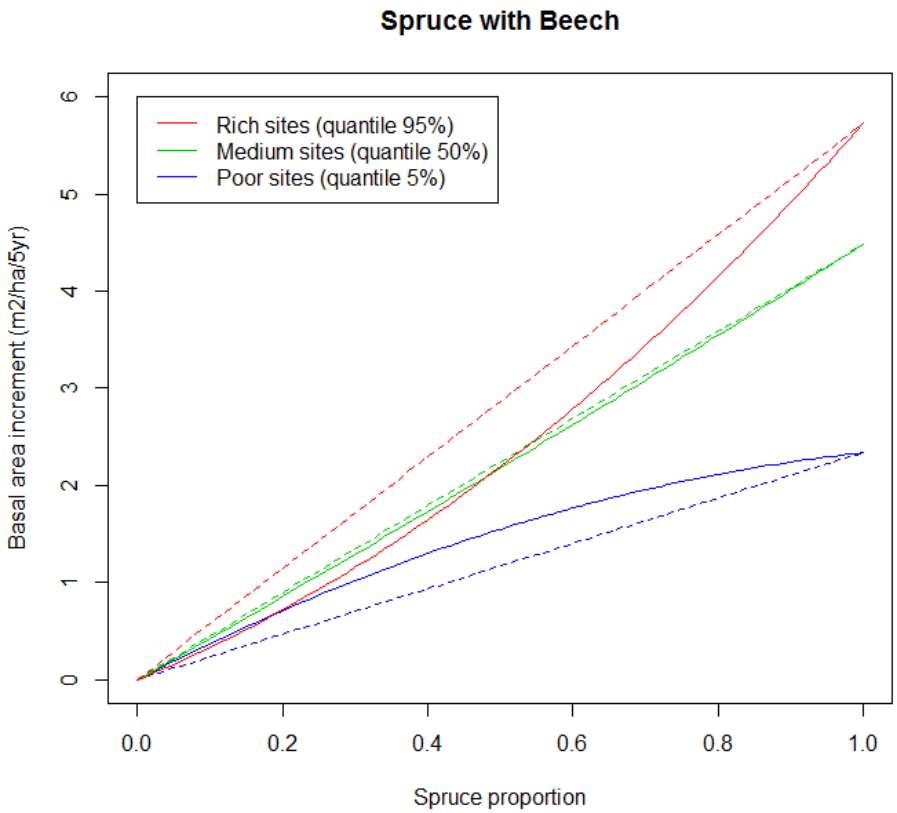
Results

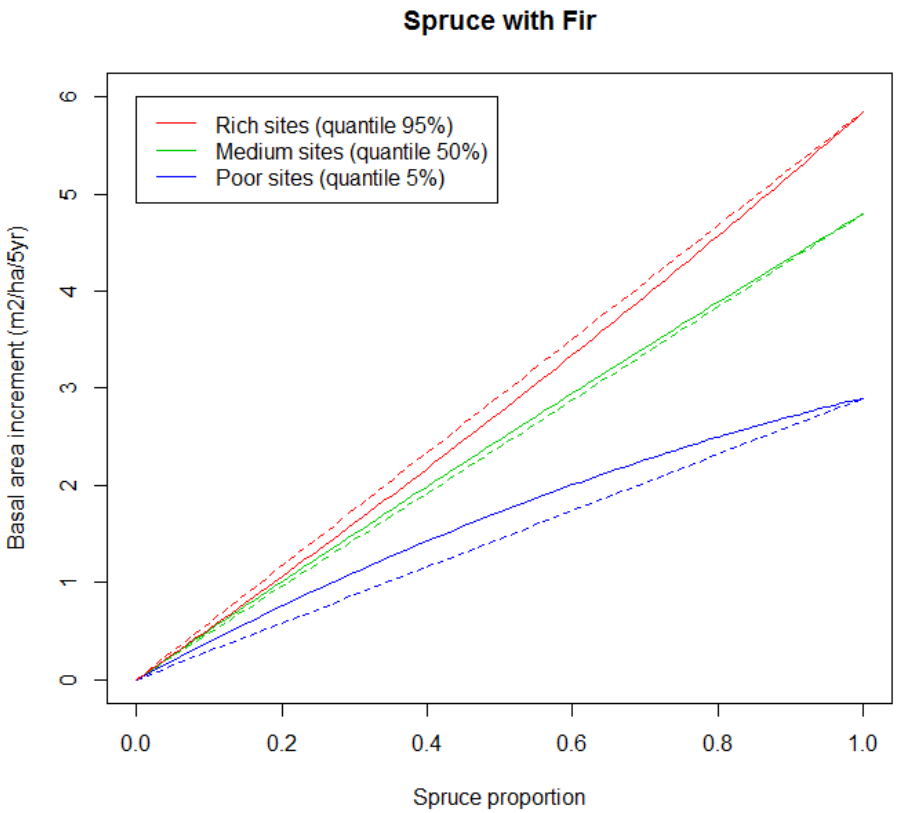
Productivity gradient effect – for a 50% proportion



Results

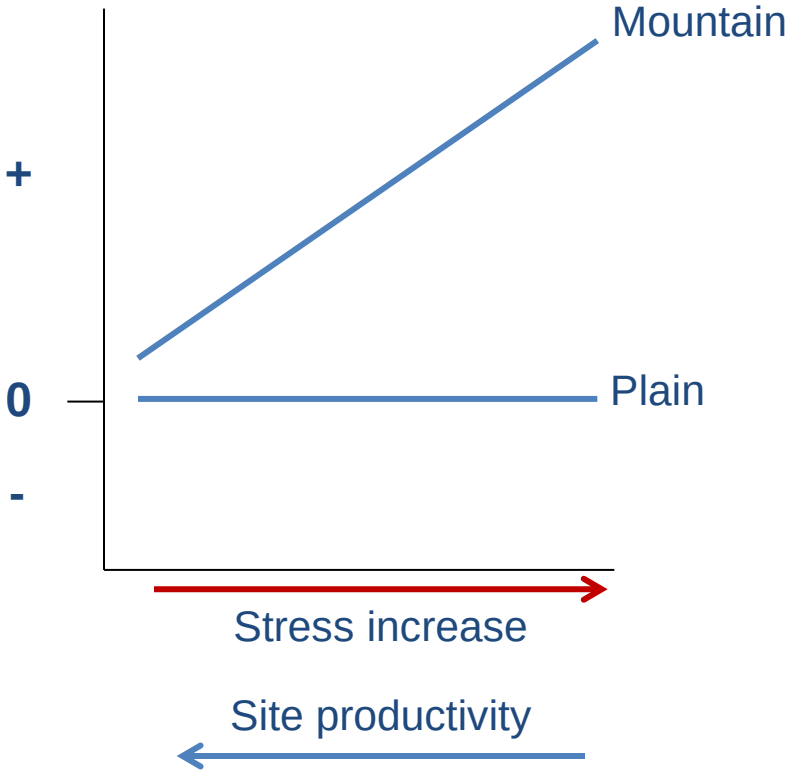
Productivity gradient effect – for a 50% proportion





Results summary

Net effects of interactions



Species growth is limited by:

Spruce
Fir
Beech

Non-ressource factors (temperature)

Beech
Oak
Pine

Ressource factors (water)

Maestre et al. 2009

Thank you for your attention !