Tree diversity effect on dominant height in temperate forest

Patrick Vallet, Thomas Pérot
Irstea Nogent-sur-Vernisson

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Overyielding in mixed forest

- Context
  - For many species associations, a mixture effect on productivity
  - Mixture effect often studied on basal area
- Is height growth influenced by tree mixture?
  - Is overyielding found on basal area correspond to:
    - A real-overyielding?
    - A different allocation of produced matter
- Study at the species level
  - Species dominant height growth

Analysis method using NFI data

GENERAL PRINCIPLE

- Step 1:
  - Selection of a “pure stand dataset” in NFI data
  - Selection of a “mixed stand dataset” in NFI data

- Step 2:
  - Development of specific dominant height growth model in pure stand

$$Hdom = f(age, climatic \ \& \ edaphic \ variables)$$

- Step 3:
  - Model applied in mixed stand dataset → Expected dominant height (control)
  - Calculation of mixture effects

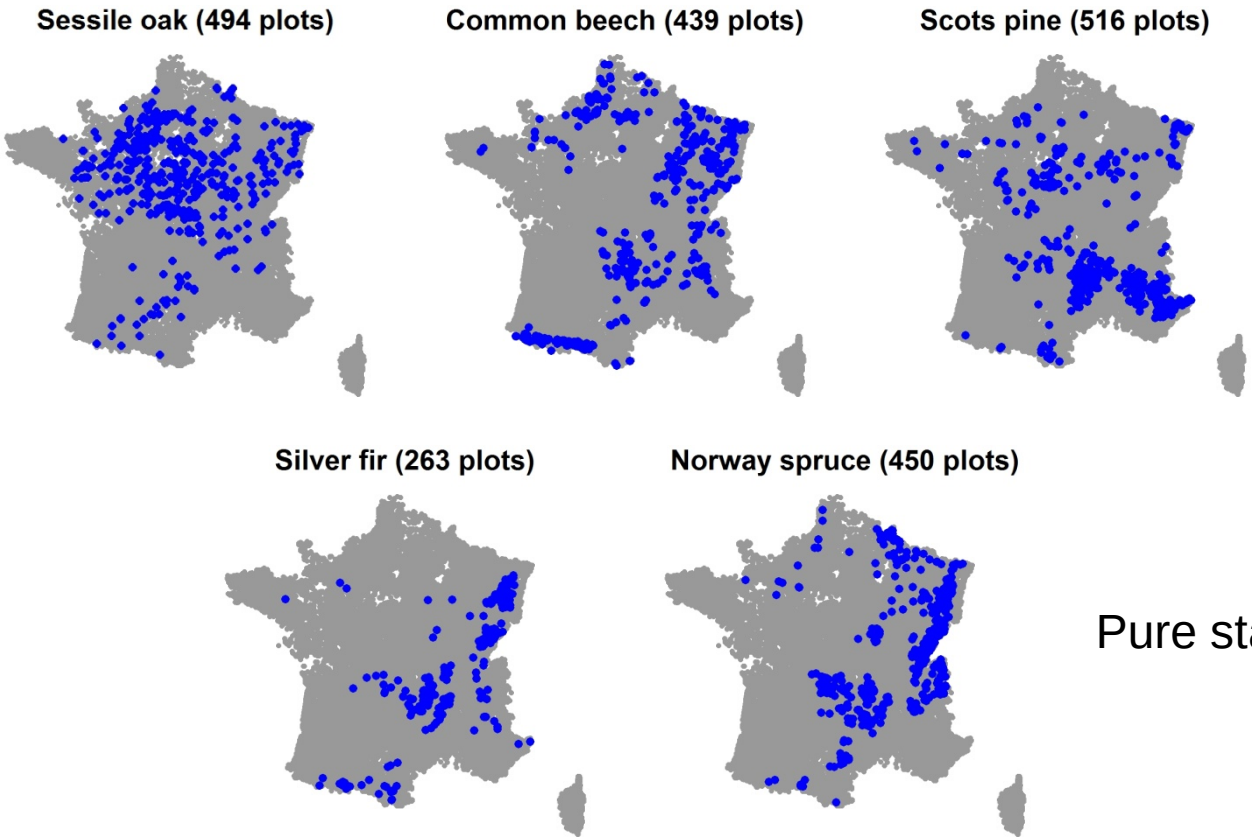
$$\text{Mixture effect} = \frac{Hdom_{observed} - Hdom_{expected}}{Hdom_{expected}}$$

  - Analyses of the mixture effects

Species studied

PURE STANDS

- Dominant height growth model developed for 5 target species



Pure stand plots location

Species studied

MIXED STANDS

- Selection in the same geographical area (SylvoEcoRégions)
  - A SER is selected in mixed stand database
    only if at least 5 pure plots were used for pure stand model calibration

Species studied

MIXED STANDS

- Mixture effect of a companion species on the target species

	Abies alba Mill.	Acer pseudoplatanus L.	Betula pendula Roth	Carpinus betulus L.	Castanea sativa Mill.	Fagus sylvatica L.	Fraxinus Excelsior L.	Picea abies (L.) Karst.	Pinus nigra Arn. laricio	Pinus nigra Arn. nigra	Pinus sylvestris L.	Prunus avium L.	Pseudotsuga menziesii (Mirb.) Franco	Quercus robur L.	Quercus petraea (Matt.) Liebl.	Quercus pubescens Willd.
Sessile oak	-	-	12	21	12	233	25	-	-	-	42	-	-	123	-	-
Common beech	79	19	-	29	-	-	55	35	-	-	35	10	-	94	216	-
Scots pine	-	-	-	-	-	31	-	16	12	27	-	-	-	26	32	12
Silver fir	-	-	-	-	-	64	-	89	-	-	10	-	-	-	10	-
Norway spruce	109	-	-	-	-	43	-	-	-	-	23	-	15	-	-	-

Number of plots in mixed stands

Species studied

MIXED STANDS

- Seven mixture associations

Species association		Number of plots
Sessile oak	Common beech	195
Sessile oak	Scots pine	26
Common beech	Silver fir	63
Common beech	Norway spruce	35
Common beech	Scots pine	27
Scots pine	Norway spruce	14
Silver fir	Norway spruce	87

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Development of dominant height growth model

PURE STAND

- No height increment data in French NFI : only transversal data
  - → Use of a standard growth curve
  - → Need to include biophysical factors to take into account site fertility

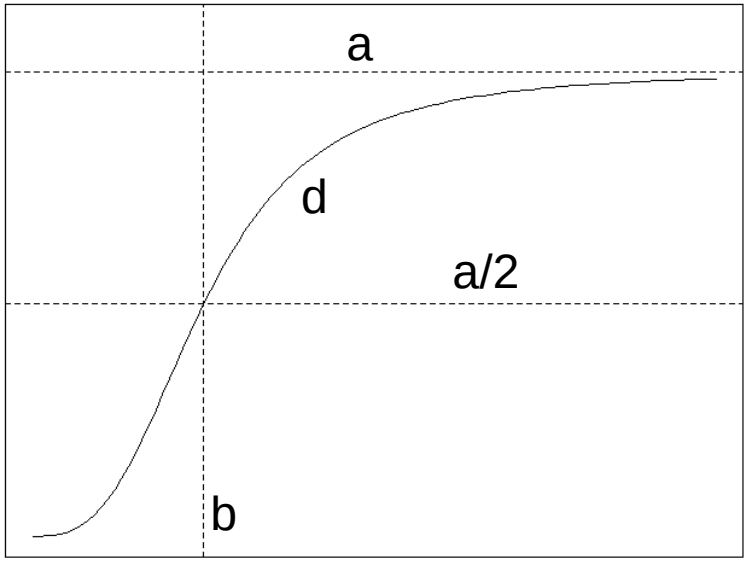
- Hossfeld II model type
  - Standard curve in literature
  - Parcimonious: 3 parameters
  - Flexible: can be adapted to many situations

$$\text{hdom} \sim a \times \frac{1}{1+\left(\frac{b}{\text{age}}\right)^{d}}$$

Asymptotic value

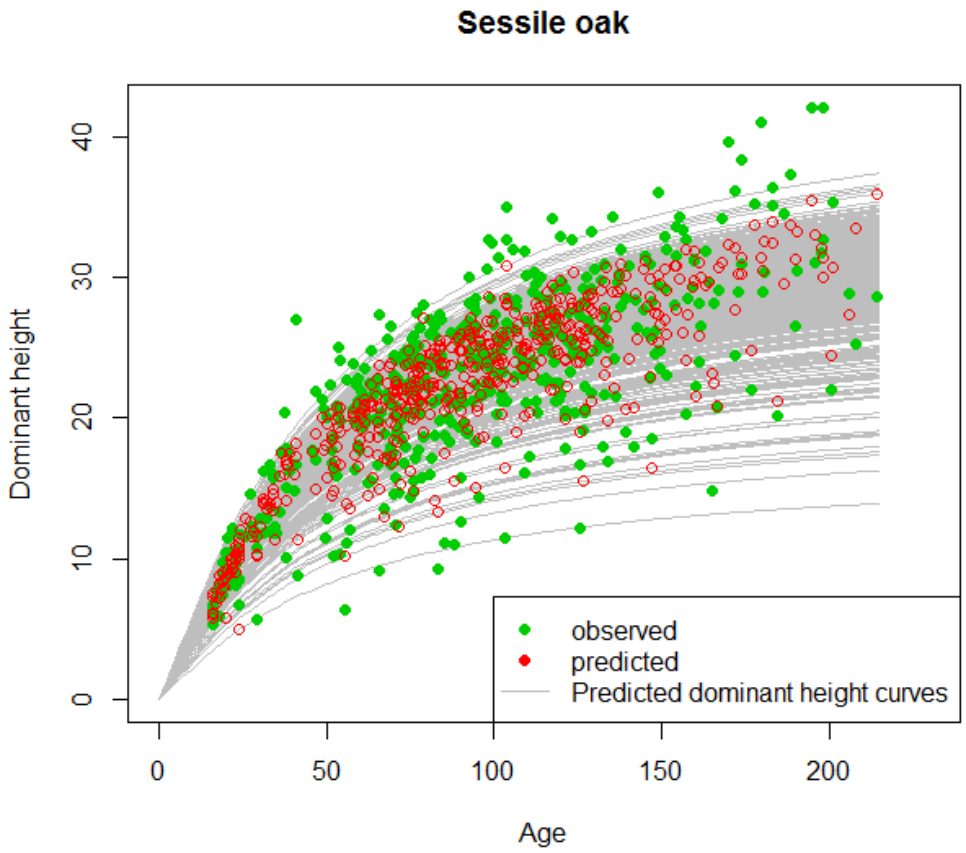
$$a = a_{0,i} + \sum_{k=1}^{n} a_{k,i} \times X_k$$

X_k are environmental factors



Example for sessile oak

PURE STAND



Environmental factors induced variations

Biophysical factors in the height models

	Factors		Parameter	Sessile oak	European beech	Scots pine	Silver fir	Norway Spruce
	Intercept		a_0	**36.87 *****	**33.81 *****	**23.57 *****	**23.28 *****	6.29
Climate and water availability	Elevation	(km)			**-8.69 *****	**-9.06 *****	**-8.17 *****	**7.99 *****
	Elevation ^{2}	(km^2)				**3.62 *****		**-7.59 *****
	March min. temperature	(°C)		**1.17 *****				
	Slope	(%)		**-0.10 *****		**-0.0317 ****		
	Soil depth	(cm)				**0.0496 *****		
	Soil water holding capacity	(mm)		**0.27 ****	**0.0490 *****		**0.0317 *****	**0.0303 *****
	July water balance	(mm)				**0.076 *****		
	July water balance ^{2}	(mm^2)			**-0.00055 *****			
	July water deficit	(mm)						**-0.049 *****
Soil characteristics	Nitrogen index (Ellenberg)	-	a_k		**0.86 ****	**1.01 *****	**1.17 *****	**0.89 *****
	pH ^{2}	-				**-0.098 *****		
	Limestone bedrock	(boolean)		**-6.82 *****				
	Siliceous bedrock	(Boolean)						**3.36 *****
Light access	Light index (Ellenberg)	-		**-3.06 *****	**-0.82 ***			**9.17 ****
	Light index (Ellenberg) ^{2}	-						**-1.02 *****
	Density index	-		**14.94 *****		**4.90 *****	**18.26 *****	**2.96 ****
	Density index ^{2}	-		**-7.06 *****			**-6.97 ***	
Geo. residual effects	Geographical Unit (Oceanic North-West)	(boolean)		**-2.91 ****				
	Geographical Unit (Massif Central mountains)	(boolean)			**-1.85 ****			
	Geographical Unit (Alps mountains)	(boolean)					**-3.74 ****	
	Age for ½ asymptotic value		**b**	**51.56 *****	**37.91 *****	**24.62 *****	**36.21 *****	**32.86 *****
	Shape factor		**c**	**1.14 *****	**1.87 *****	**1.86 *****	**2.04 *****	**1.96 *****

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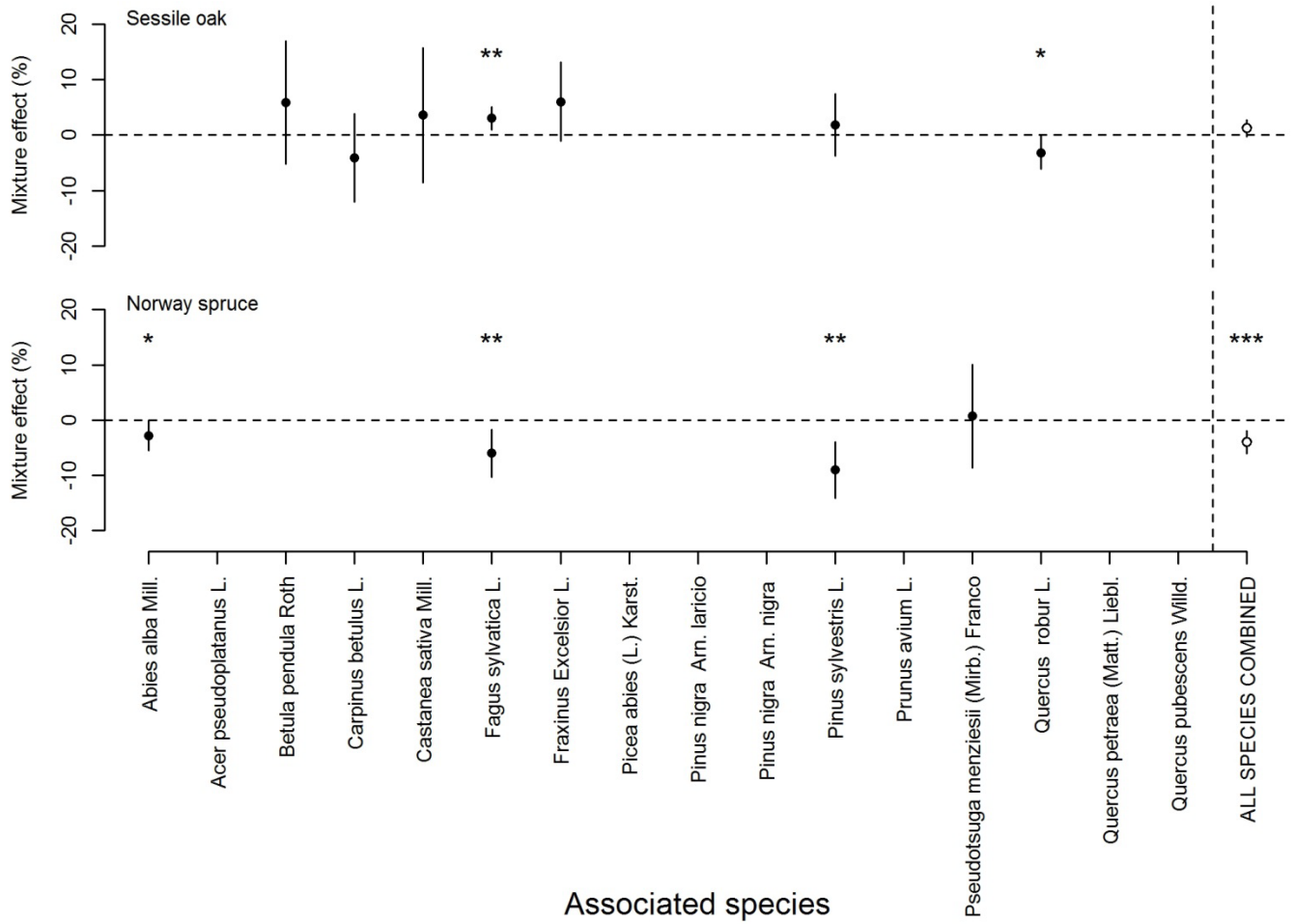
Mean mixture effects on target species

MIXED STANDS – EXAMPLE FOR OAK AND SPRUCE

- Effects can be negative, null or positive



Mean mixture effects by species associations

MIXED STANDS

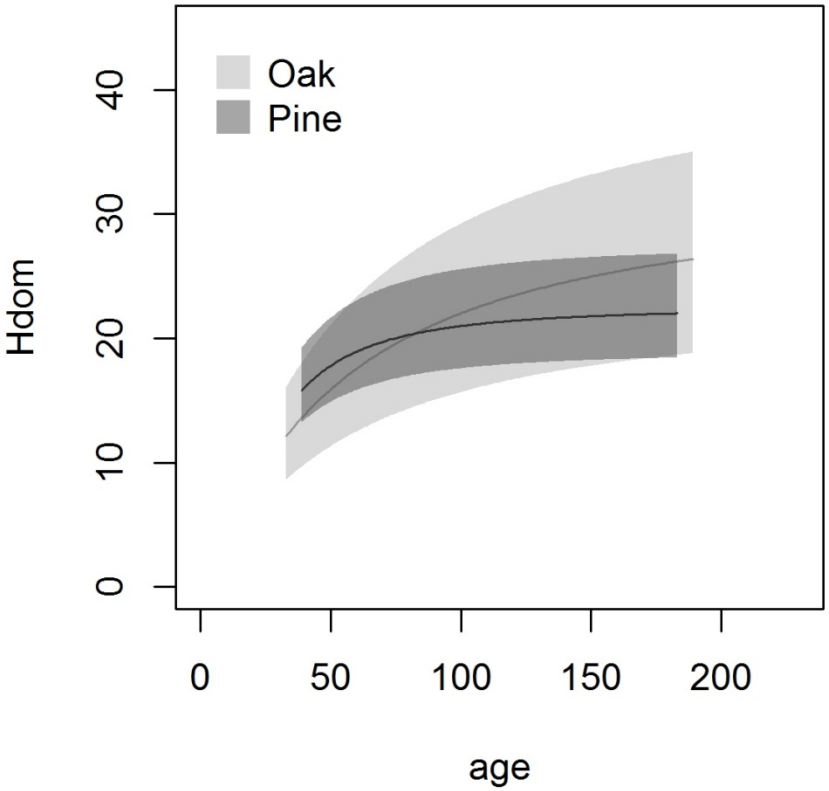
- Effects can be negative, null or positive

Species association		Number of plots	Effect of species 2 on species 1	Effect of species 1 on species 2
Species 1	Species 2			
Sessile oak	Common beech	195	+2.0%	**- 5.4%**
Sessile oak	Scots pine	26	+1.3%	+6.3%
Common beech	Silver fir	63	**+ 4.8%**	+3.2%
Common beech	Norway spruce	35	**+ 7.7%**	**- 7.8%**
Common beech	Scots pine	27	+2.8%	**+ 16.7%**
Scots pine	Norway spruce	14	**+ 11.6%**	-6.5%
Silver fir	Norway spruce	87	**+ 3.3%**	**- 3.9%**

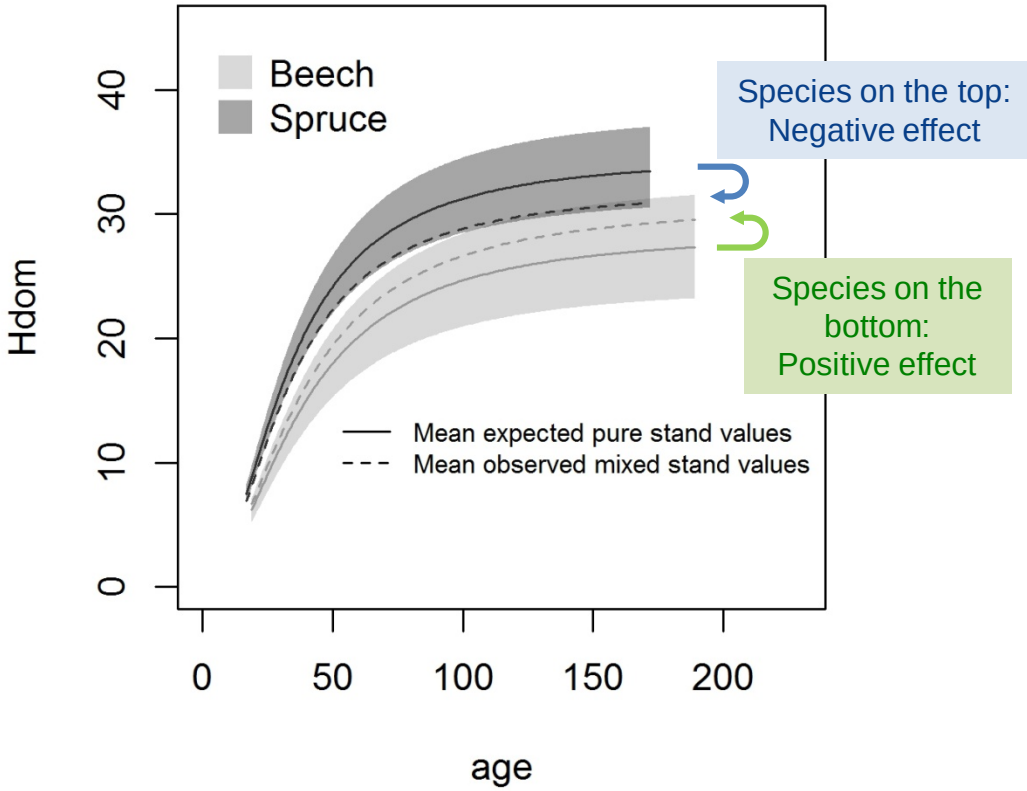
Significant positive value

Significant negative value

Mixture effect depends on height difference between species



Oak – pine case:
Close H_{dom} dynamics → no mixture effect



Beech – Spruce case:
Differentiated H_{dom} dynamics → mixture effect

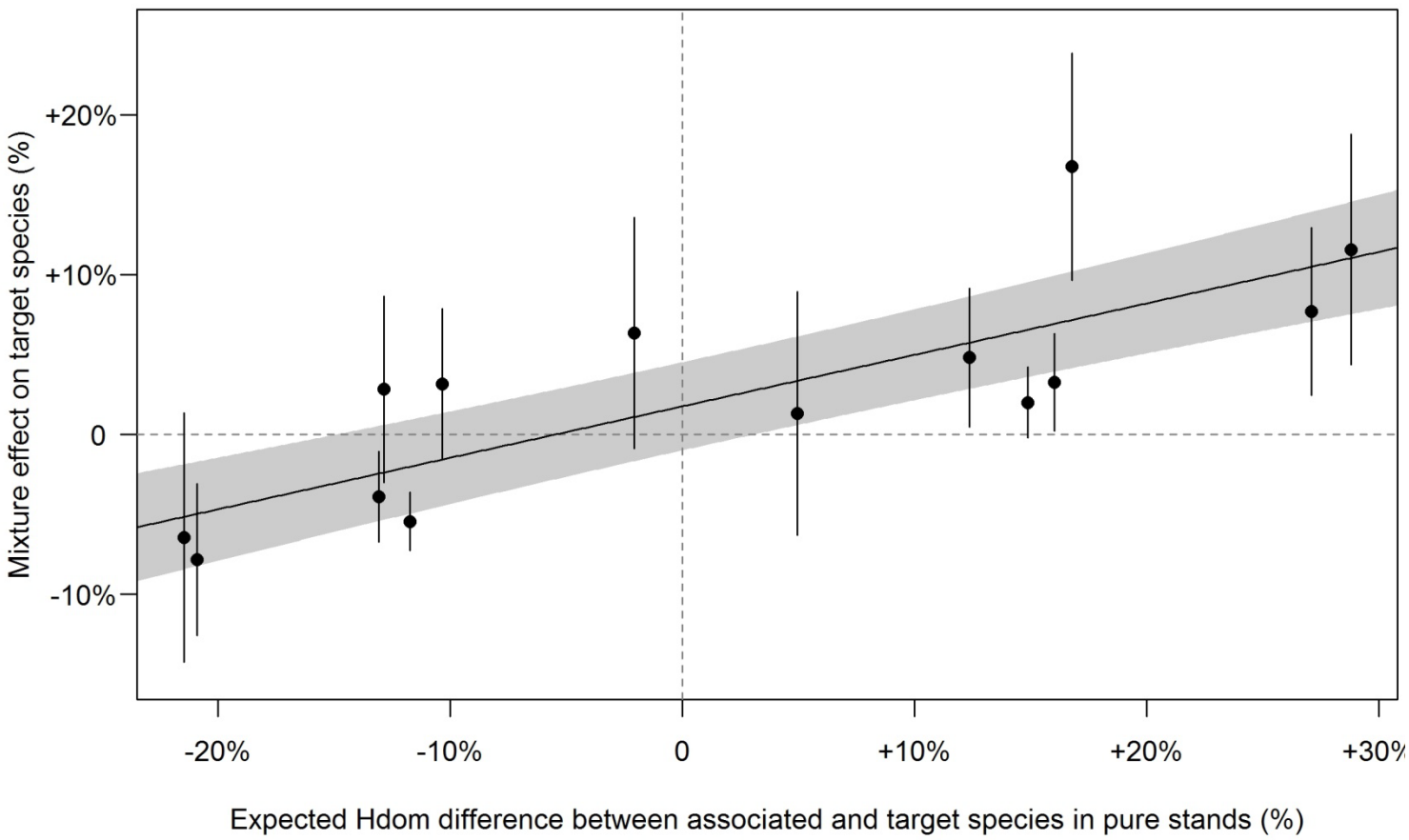
Each species reach the other one

Generalization of the result

ALL SPECIES ASSOCIATIONS TOGETHER

When the associated species is smaller, the mixture effect is negative

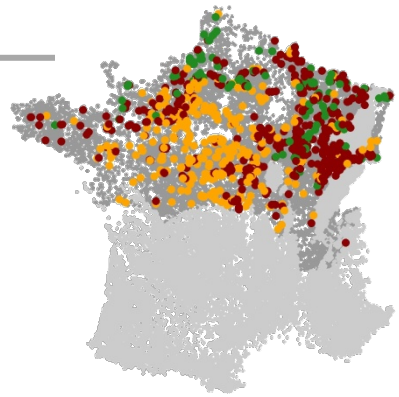
When the associated species is taller, the mixture effect is positive



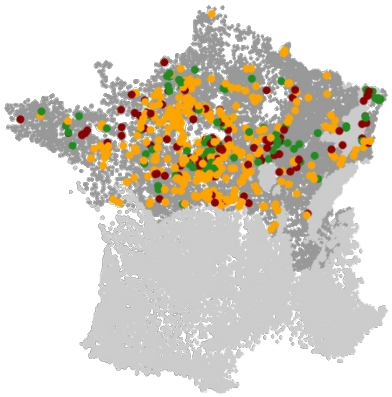
Comparison with results on basal area

MAUDE TOÏGO'S PHD : 5 COUPLES OF SPECIES

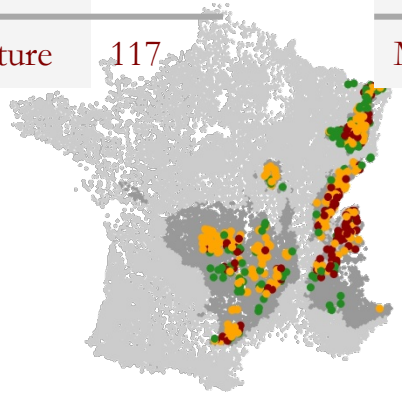
Beech	129
Sessile Oak	334
Mixture	469



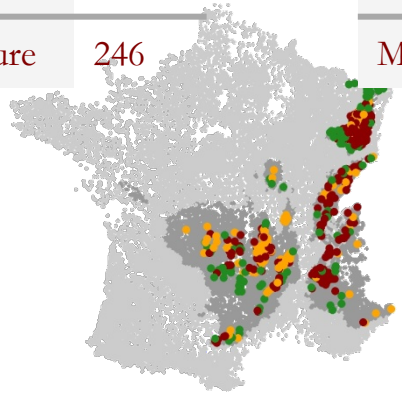
Scots pine	100
Sessile oak	334
Mixture	107



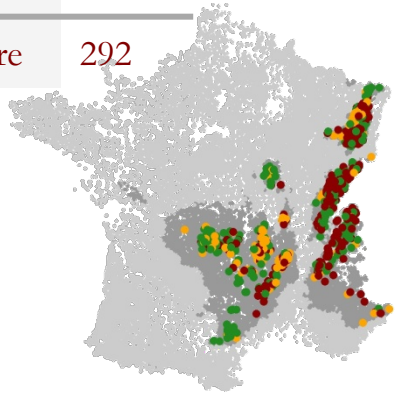
Beech	138
Spruce	257
Mixture	117



Beech	138
Silver fir	172
Mixture	246

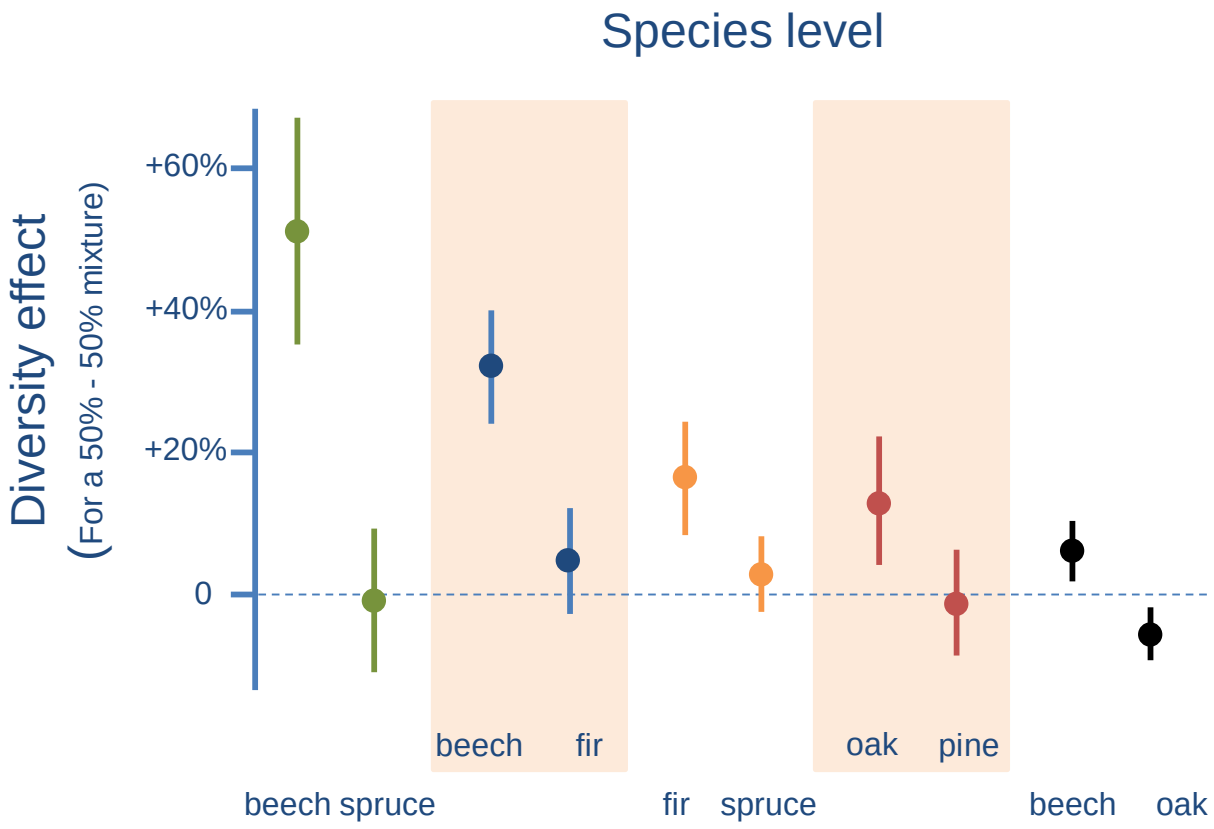


Spruce	257
Silver fir	172
Mixture	292



Mean mixture effect

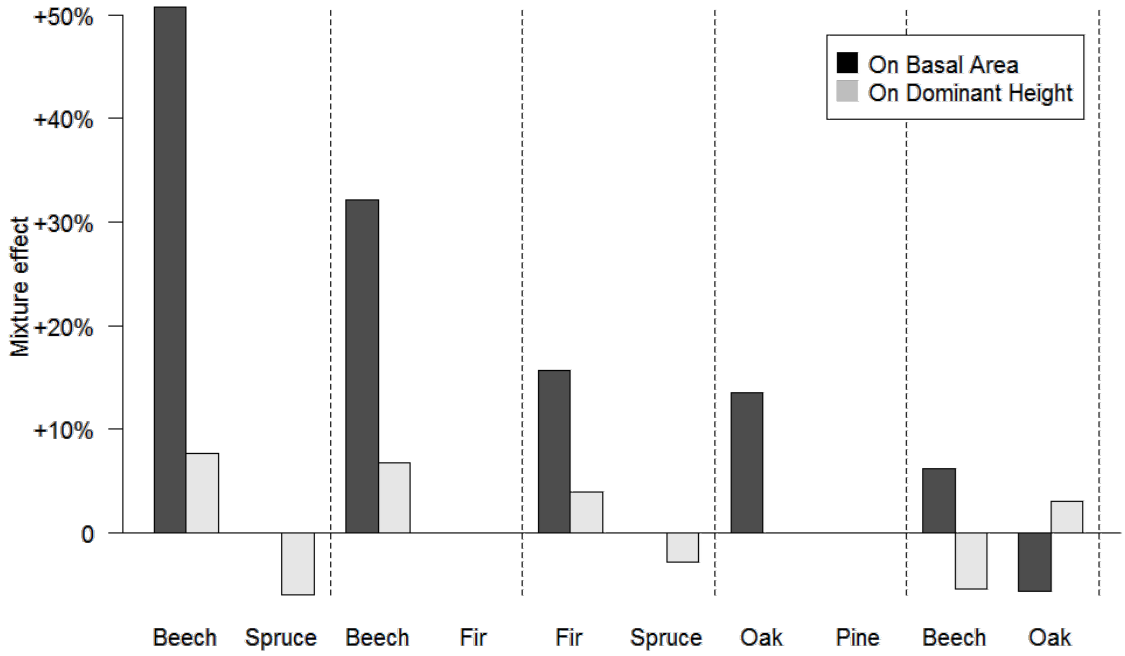
MIXTURE EFFECT ON BASAL AREA



Comparison of height and basal area mixture effects

- CAUTION: Only qualitative comparison

Volume ~ α x G x H



Mixture effect is not a compensation between the compartments but a real effect on volume

Conclusion

- Mixture effect on dominant height depends on height differences between species
  - Leveling process:
    - The taller species limits its height growth
    - The smaller species increases its height growth

- Lower magnitude compared to effects on basal area
  - From -7.8% to +16.7% for dominant height
  - Basal area effects from -5.8% to 50.8% (Toïgo et al. 2015), and usually in the same direction

→ Real overyielding, and not a compensation between radial and height productivity