Overyielding in mixed forests decreases with site productivity

P. Vallet¹, M. Toïgo¹, T. Pérot¹, J.-D. Bontemps², C. Piedallu², B. Courbaud³

1 – Forest Ecosystems Research Unit, Irstea, France
2 – LERFoB, AgroParisTech-INRA, France
3 – Mountain Ecosystems Research Unit, Irstea, France

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)

Herbaceous species (Experimentation)

Forest (Simulation)

Tilman et al. 2001

Morin et al. 2011
Diversity – productivity relationship

PRODUCTIVITY: AN INDICATOR OF SPECIES INTERACTIONS

- Competition
- Niche complementarity
- Facilitation
- Competition

Productivity sp. $i$

Proportion sp. $i$

Relative mixture effect

Pure stand

Mixed stand

Harper 1977

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)

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**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

Overyielding in mixed forests decreases with site productivity

Maude Toigo¹, Patrick Vallet¹*, Thomas Perot¹, Jean-Daniel Bontemps²,³, Christian Piedallu²,³ and Benoit Courbaud⁴
## Methods

### General Framework

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling</td>
<td>Productivity of sp. $i$ in pure stands</td>
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<td>Comparison</td>
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<td>Analyze</td>
<td>Influence of abiotic context</td>
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</table>
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
Data
French National Forest Inventory

~ 6000 – 7000 plots/year

Compare pure vs. mixed stands

Plot selection
**Data**

**FRENCH NATIONAL FOREST INVENTORY : data selection**

- **Composition**
  - Pure: 100%
  - Mixed: 80%

- **Perturbation**
  - No recent thinnings

- **Structure**
  - 1 vertical layer ~ evenaged

- **Geography**
  - Same ecological units
**Data**

**FRENCH NATIONAL FOREST INVENTORY : data selection**

<table>
<thead>
<tr>
<th>Tree Type</th>
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<tbody>
<tr>
<td>Beech</td>
<td>135</td>
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<td>334</td>
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**GENERAL FRAMEWORK**

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General Framework

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Influence of abiotic context
Modeling

**BASAL AREA GROWTH IN PURE STANDS**

- Potential – reducers models

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

- 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 chart]
Growth potential : $f_1$

**Basal area growth in pure stands**

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

- For Spruce:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min January temperatures</td>
<td>![↑]</td>
</tr>
<tr>
<td>Humus (mull type)</td>
<td>![↑]</td>
</tr>
<tr>
<td>Rocky outcrops</td>
<td>![↑]</td>
</tr>
<tr>
<td>Slope</td>
<td>![↑]</td>
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</table>
Growth reducers: $f_2$ and $f_3$

**Basal area growth in pure stands**

- **Density reducer**
  \[ f_2 \left( \text{Density} \right) \]

- **Development stage reducer**
  \[ f_3 \left( \text{Development stage} \right) \]
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Analyze
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Comparison

**PURE STAND VERSUS MIXED STAND PRODUCTIVITY**

Diversity relative effect on sp. $i$ =

\[
\text{Observed productivity in mixed stands} - \text{Expected productivity}
\]

Expected productivity
Methods

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**Analyze**

**MIXTURE EFFECT**

- **Average mixture effect**
  - Function of species proportion

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

\[
\text{Relative effect of diversity on sp. } i \approx a \times (1 - \text{sp. } i \text{ prop })
\]

\[
\text{Relative effect of diversity on sp. } i \approx (a_0 + a_1 X) \times (1 - \text{sp. } i \text{ prop })
\]
Results

Mean mixture effect – for a 50% proportion

Stand level

Species level
Results

PRODUCTIVITY GRADIENT EFFECT – FOR A 50% PROPORTION

Species level

Site productivity

Relative diversity effect

-0.5
0
0.5
1

Species:
- beech
- spruce
- fir
- pine
- oak

Comparing site productivity:
- low
- high

Analyze
Results

PRODUCTIVITY GRADIENT EFFECT – FOR A 50% PROPORTION

Spruce with Beech

Spruce with Fir

Basal area increment (m²/ha/Syr)

Spruce proportion

Rich sites (quantile 95%)
Medium sites (quantile 50%)
Poor sites (quantile 5%)
Results summary

Species growth is limited by:

- Non-resource factors (temperature)
- Resource factors (water)

Maestre et al. 2009
Thank you for your attention!