Productivity of mixed-species plantations

Hervé Jactel

INRAE

A growing need for forest biomass

1. Raw material for industry, construction...

2. Climate change mitigation

3. Ecosystem services provided by the forest

Tension on the forest resource

The supply of woody biomass is likely to decrease:

- productivity limits despite advances in genetics and silviculture
- negative impacts of climate change
- competition for available land

Hence the need to increase production density:

- proposal to diversify forests to increase their productivity in the long term

EUROPEAN COMMISSION

New EU Forest Strategy for 2030

In addition, certain management practices that support biodiversity and resilience, are essential in this context, such as the creation or maintenance at stand and landscape level of genetically and functionally diverse, mixed- species forests, especially with more broadleaves and deciduous trees and with species with different biotic and abiotic sensitivities and recovery mechanisms following disturbances, instead of monocultural plantations.

Forest productivity increases with tree species richness

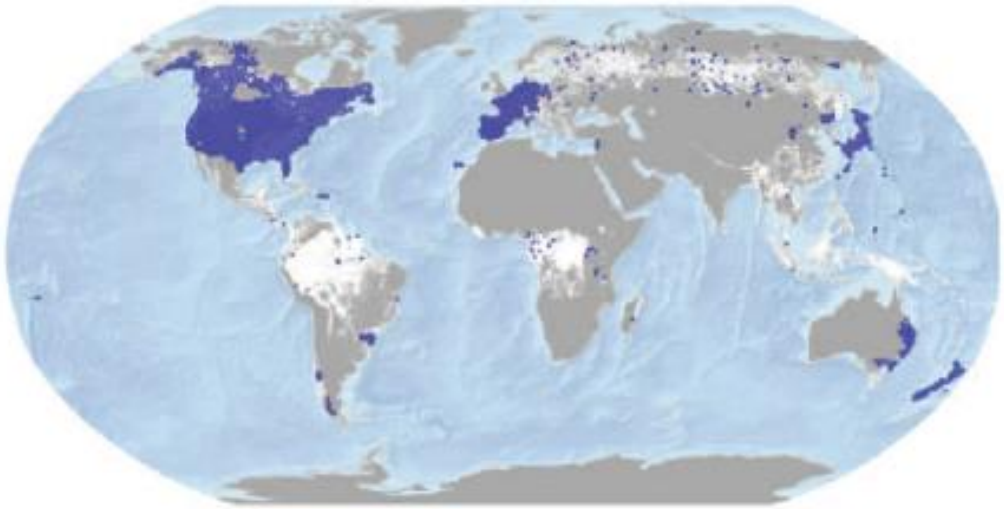
196 14 OCTOBER 2016 • VOL 354 ISSUE 6309 sciencemag.org SCIENCE

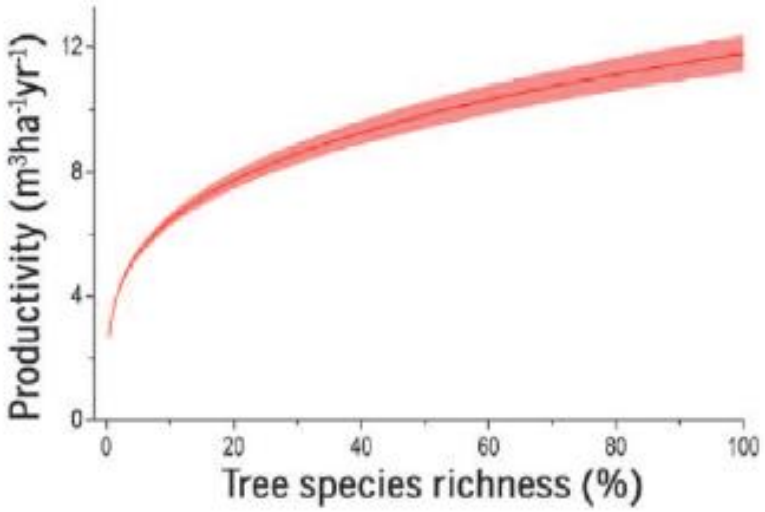
RESEARCH ARTICLE

FOREST ECOLOGY

Positive biodiversity-productivity relationship predominant in global forests

Jingjing Liang,[1]* Thomas W. Crowther,[2,3]† Nicolas Picard,[4] Susan Wiser,[5] Mo Zhou,[1]



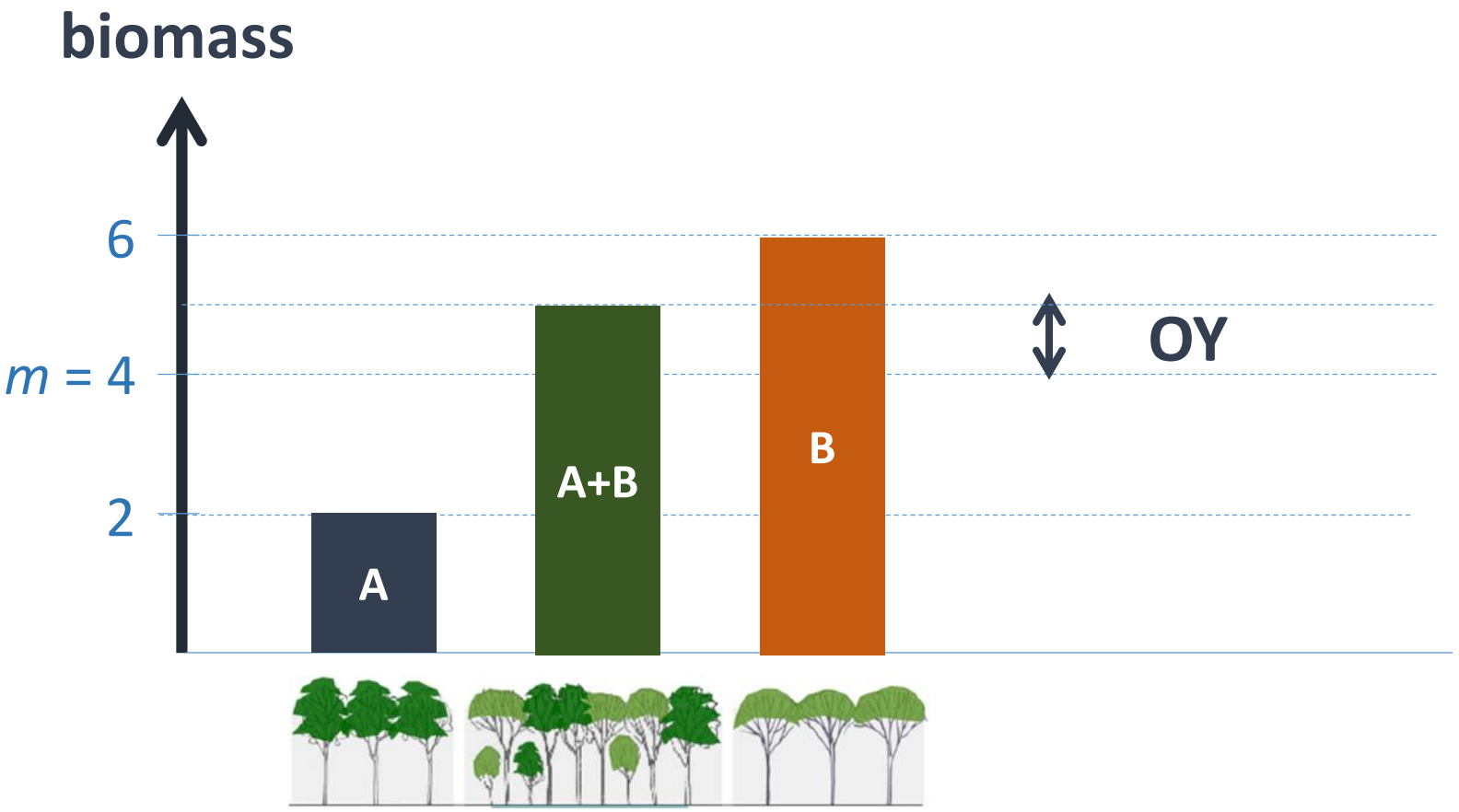


Global effect of tree species diversity on forest productivity. Ground-sourced data from 777,126 global forest biodiversity permanent sample plots (dark blue dots, left), which cover a substantial portion of the global forest extent (white), reveal a consistent positive and concave-down biodiversity-productivity relationship across forests worldwide (red line with pink bands representing 95% confidence interval, right).

Mixed-species forests produce more than the average productivity of their component species monocultures

The concept d'overyielding (OY)

$$OY = M_{A+B} - (P_A \times M_A + P_B \times M_B)$$



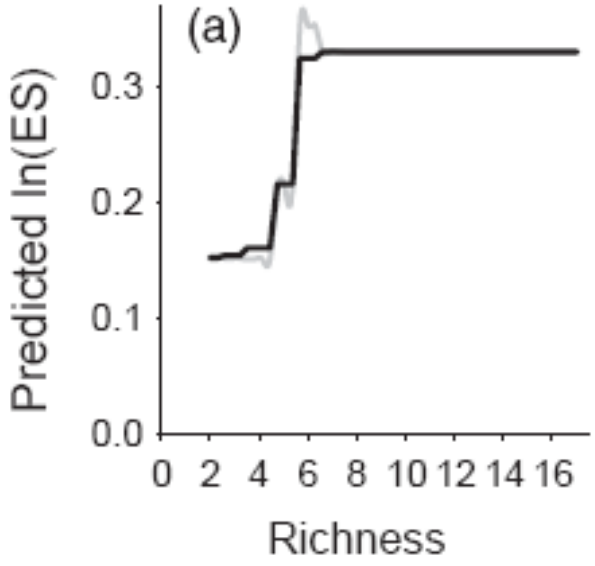
Mixed-species forests produce more than the average productivity of their component species monocultures

Journal of Ecology 2012, **100**, 742–749 doi: 10.1111/j.1365-2745.2011.01944.x

Forest productivity increases with evenness, species richness and trait variation: a global meta-analysis

Yu Zhang[1], Han Y. H. Chen[1]* and Peter B. Reich[2,3]

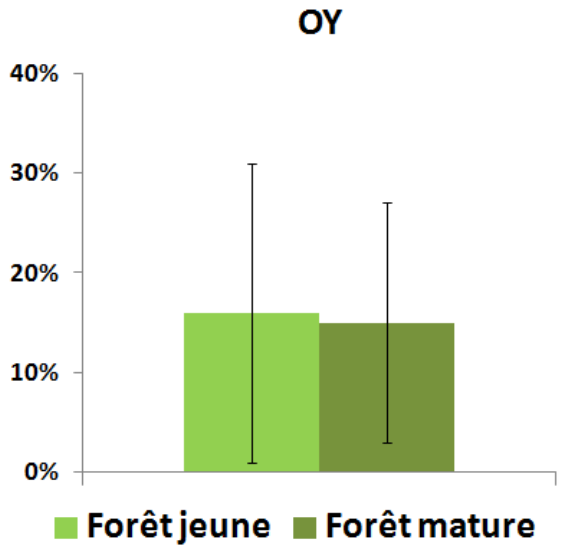
23.7% higher productivity in polycultures



Mixed-species forests produce more than the average productivity of their component species monocultures

Positive biodiversity – productivity relationships in forests: climate matters

H. Jactel[1], E. S. Gritti[2], L. Drössler[3], D. I. Forrester[4], W. L. Mason[5], X. Morin[6], H. Pretzsch[7] and B. Castagneyrol[1]



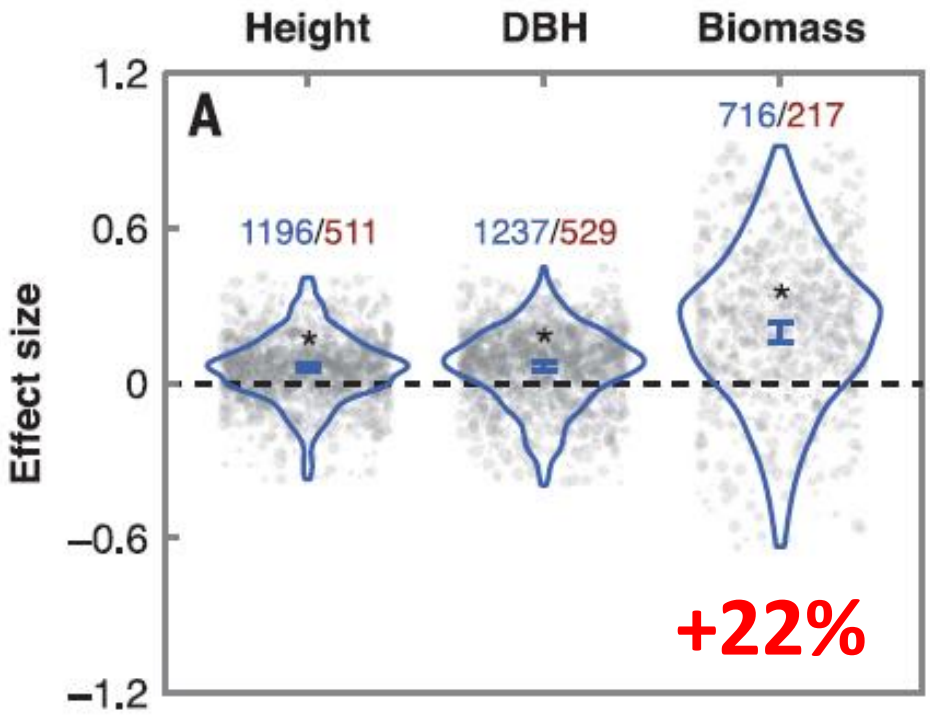
126 comparisons pure vs. mixed forests in 60 sites

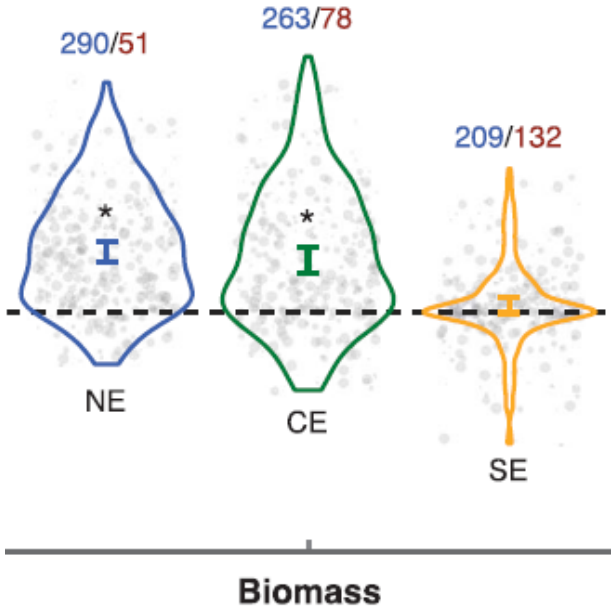
Overyielding = 15%

Mixed-species forests produce more than the average productivity of their component species monocultures

Multispecies forest plantations outyield monocultures across a broad range of conditions

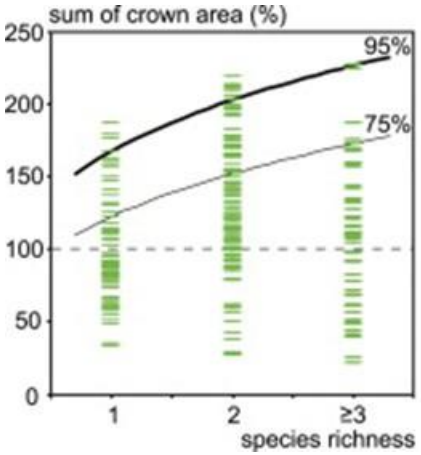
Feng *et al.*, *Science* **376**, 865–868 (2022)

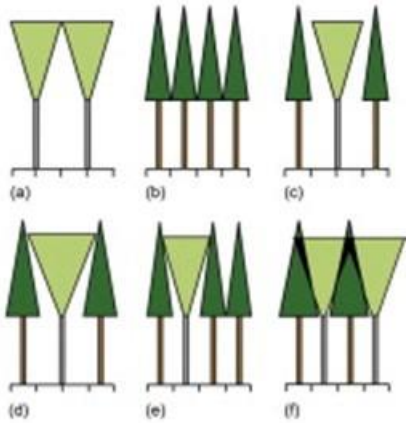




3 main mechanisms explain the pattern

Mechanism # 1: tree packing





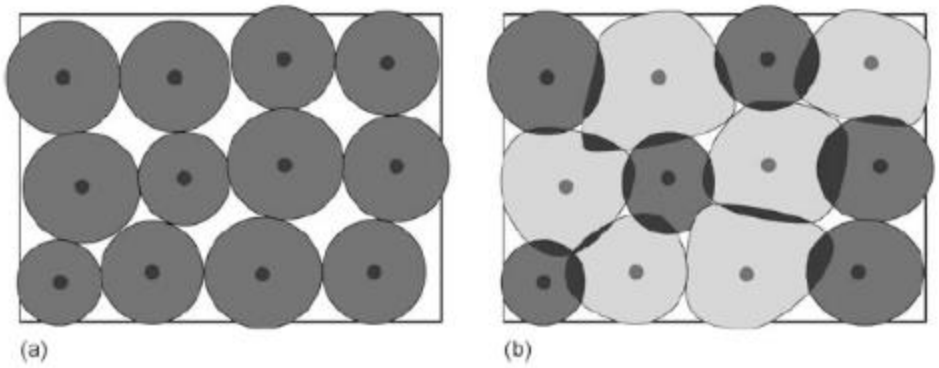
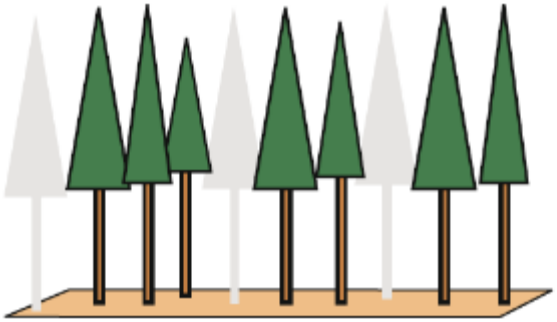
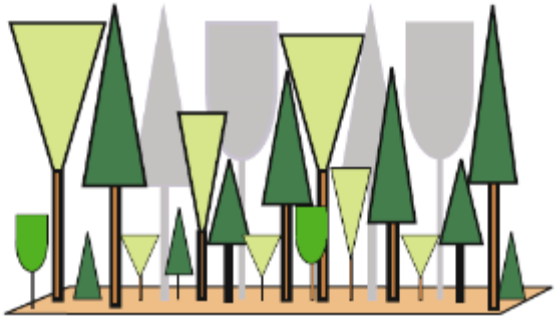


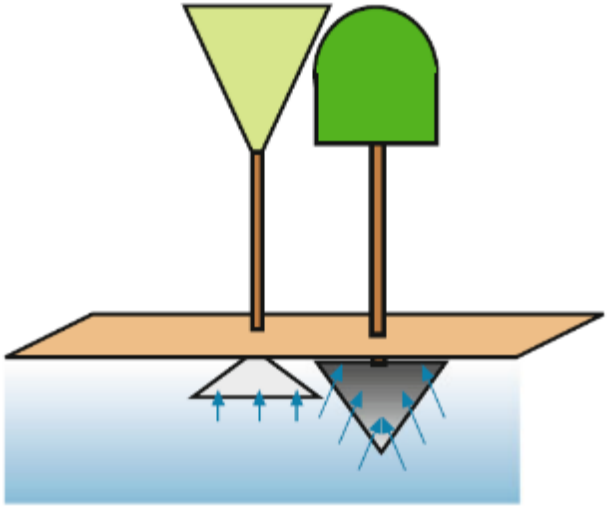
Fig. 6.32 Schematic representation of canopy pattern in monospecific versus mixed stands. (**a**) Rather circular crowns in monospecific stand with about 5–10% uncovered space in between, a crown cover of 90–95%, and sum of crown areas below 100%. (**b**) More irregular crown shapes in mixed stand with scarce uncovered space in between, crown cover close to 100%, and multiple crown overlap resulting in a sum of crown areas of greater than 100%

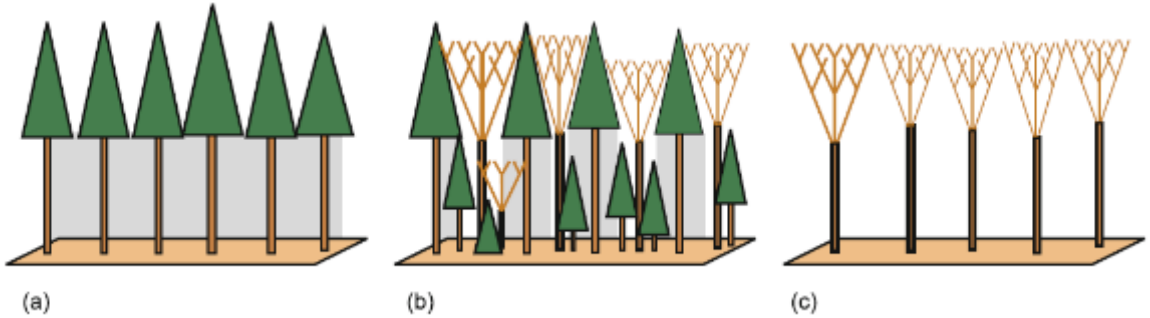
3 main mechanisms explain the pattern

Mechanism # 2: complementarity in resources use



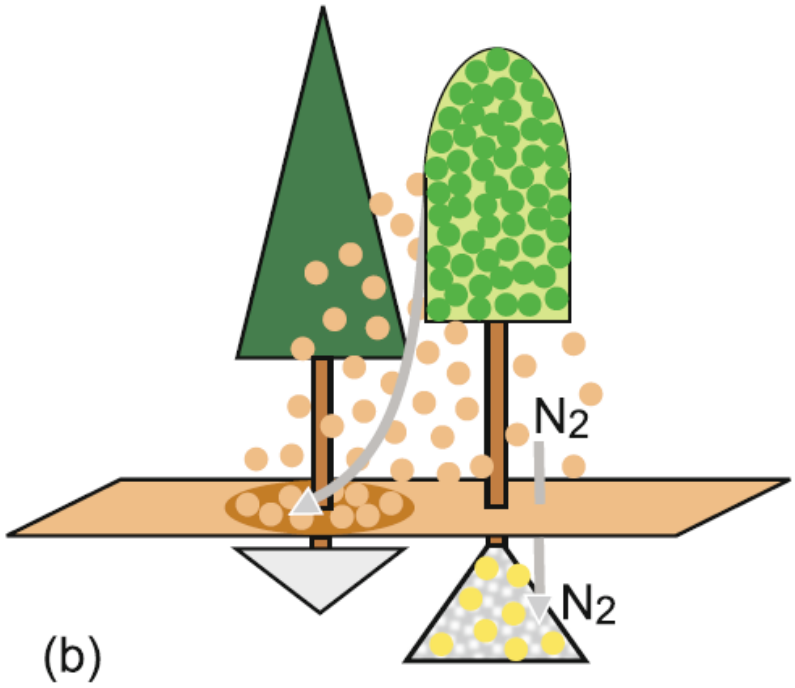


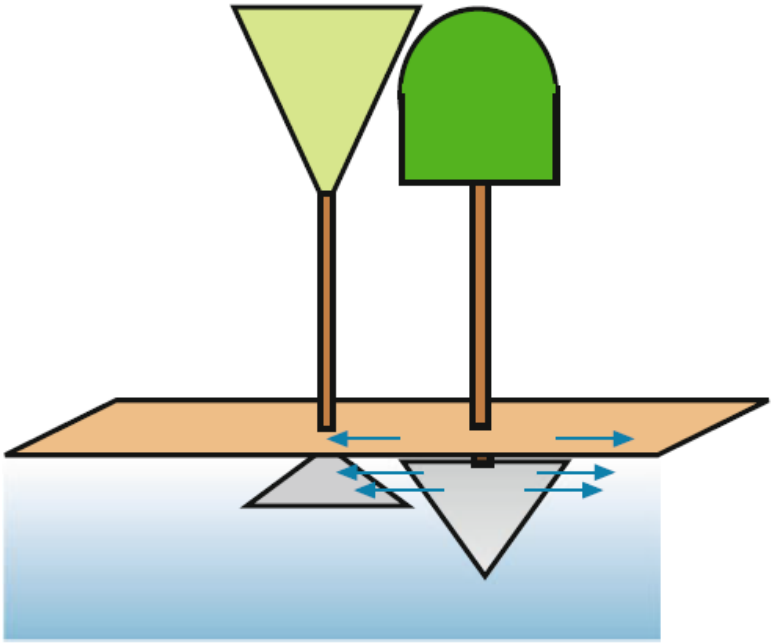




3 main mechanisms explain the pattern

Mechanism # 3: facilitation

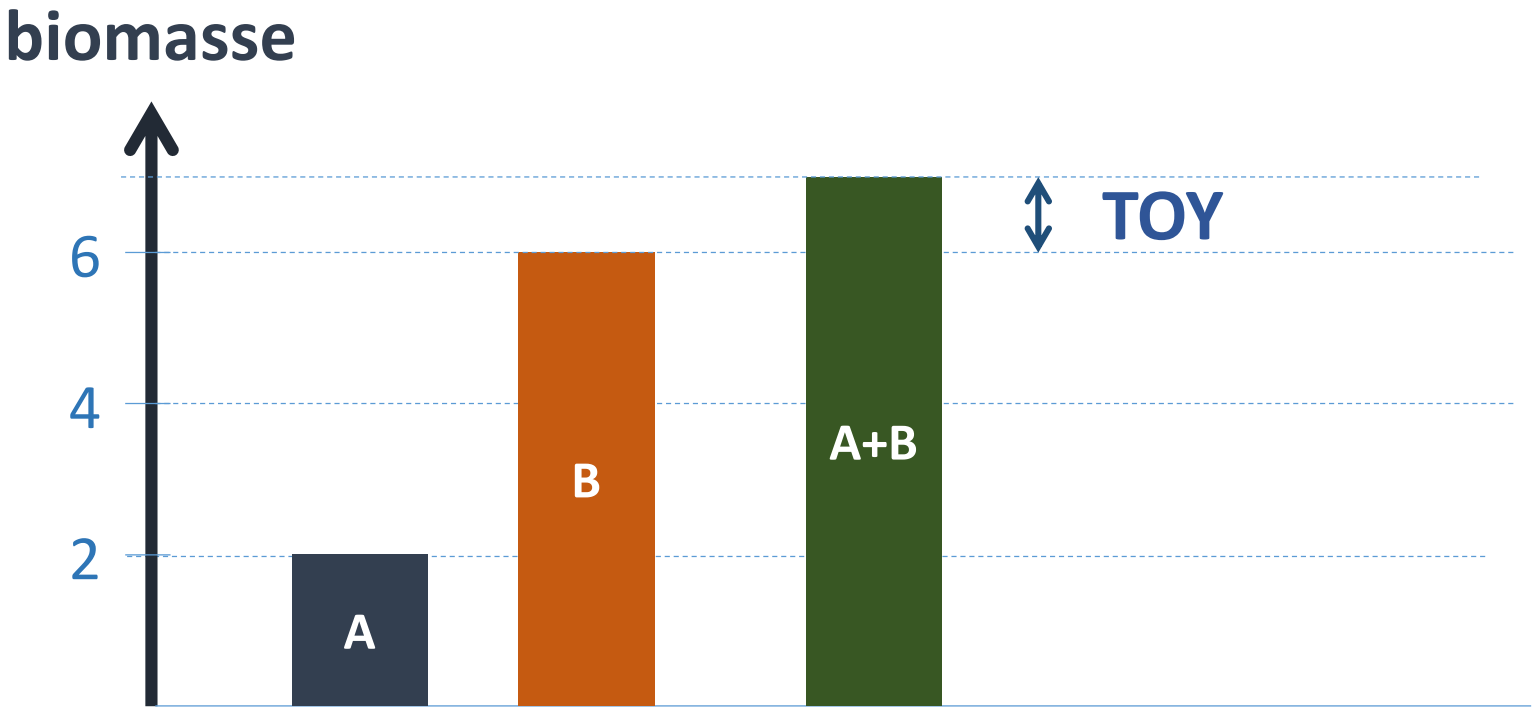




Some mixed species forests can be more productive than the most productive monoculture of their component species

Concept of transgressive overyielding (TOY)

$$TOY = M_{A+B} - MAX(M_A ; M_B)$$

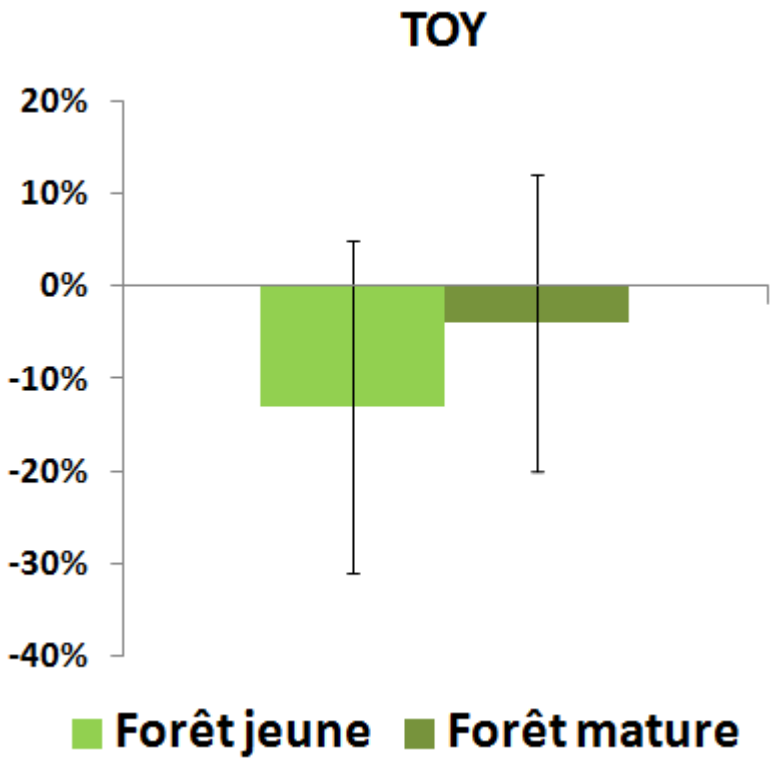


Some mixed species forests can be more productive than the most productive monoculture of their component species

Positive biodiversity – productivity relationships in forests: climate matters

H. Jactel[1], E. S. Gritti[2], L. Drössler[3], D. I. Forrester[4], W. L. Mason[5], X. Morin[6], H. Pretzsch[7] and B. Castagneyrol[1]

Transgressive overyielding ≠ 0%



Examples of transgressive overyielding in mixed-species plantations in Europe

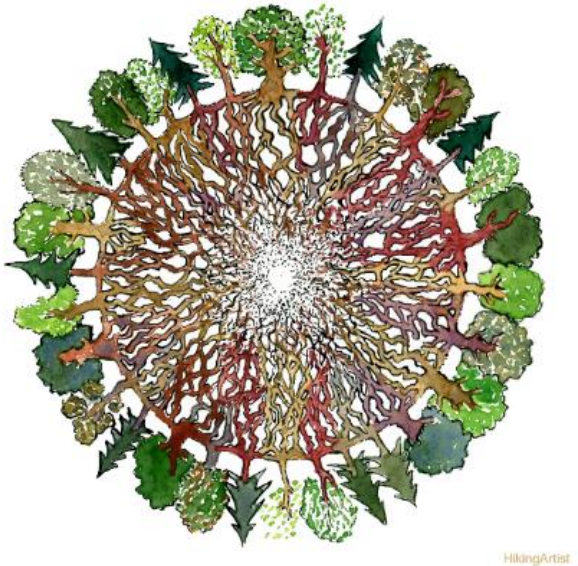
Picea abies + Fagus sylvatica (Pretszch et al. 2009)
Picea abies + Betula pendula (Jonsson et al. 2019)
Picea abies + Alnus glutinosa (Mason et al. 2014)
Picea sitchensis + Tsuga heterophylla (Mason et al., 2020)
Pinus sylvestris + Tsuga heterophylla (Mason et al., 2020)
Pinus sylvestris + Picea sitchensis (Mason et al., 2021)
Pinus sylvestris + Picea abies (Drössler et al., 2018; Jonsson et al., 2019)
Pinus sylvestris + Quercus robur/petraea (Steckel et al. 2019)
Pinus sylvestris + Fagus sylvatica (Condes et al. 2013)
Pinus sylvestris + Betula pendula (Jonsson et al. 2013)

Remaining questions to promote and develop mixed-species plantations

1. Choice of tree species to associate
2. Spatial planting pattern
3. Silvicultural guidelines
4. Integration in the bioeconomy

Interreg Sudoe COMFOR

FORMIX
A new network of experimental mixed plantations



A twofold concept:
1. Adopting common principles
2. Adjusting to local conditions

6 Common Principles

1. All **tree species** to plant must be **relevant to the local forestry sector**
2. **Two-species mixtures**, if possible associating broadleaves and conifers
3. Tree species planted as **monocultures as well**
4. Test of **different tree densities** to optimize productivity/revenues
5. Tree species intermingling pattern = **row-wise planting**
6. **Large experimental plots** to allow realistic cost benefit calculations

Adjustment to local conditions

Choice of adapted tree species to local soil and future climate, and relevant to local stakeholders/industries expectations

For the sake of resilience and multifunctionality, let's diversify planted forests!

Conservation Letters

Christian Messier[1,2] | Jürgen Bauhus[3] | Rita Sousa-Silva[3] | Harald Auge[4,5] | Lander Baeten[6] | Nadia Barsoum[7] | Helge Bruelheide[6,8] | Benjamin Caldwell[9] | Jeannine Cavender-Bares[10] | Els Dhiedt[6] | Nico Eisenhauer[6,11] | Gislene Ganade[12] | Dominique Gravel[13] | Joannès Guillemot[14,15] | Jefferson S. Hall[16] | Andrew Hector[17] | Bruno Hérault[18] | Hervé Jactel[19] | Julia Koricheva[20] | Holger Kreft[21,22] | Simone Mereu[23,24] | Bart Muys[25] | Charles A. Nock[26] | Alain Paquette[2] | John D. Parker[27] | Michael P. Perring[6,28,29] | Quentin Ponette[30] | Catherine Potvin[31] | Peter B. Reich[32,33] | Michael Scherer-Lorenzen[34] | Florian Schnabel[3,5] | Kris Verheyen[6] | Martin Weih[35] | Meike Wollni[36] | Delphine Clara Zemp[20,21,37]