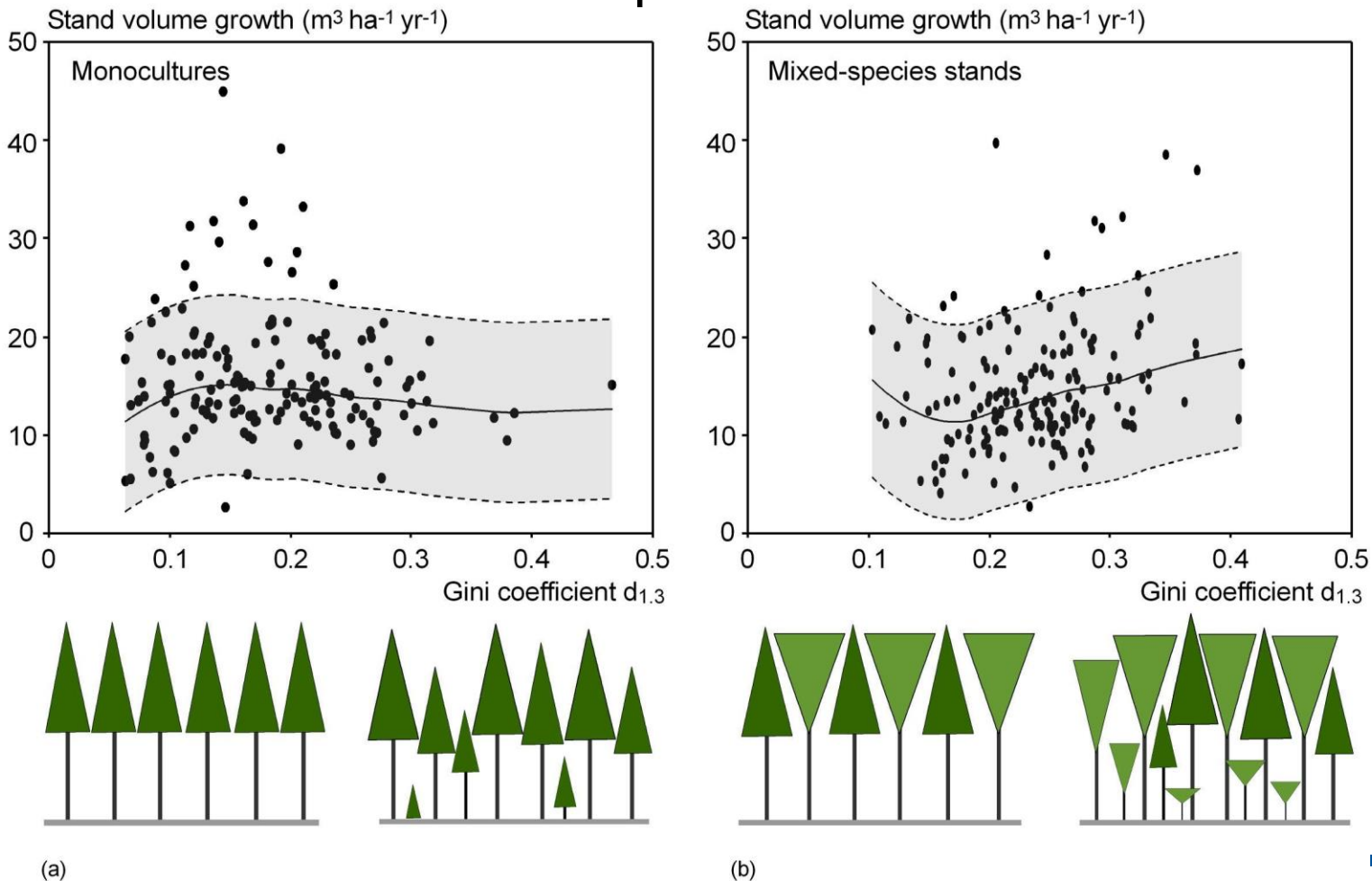
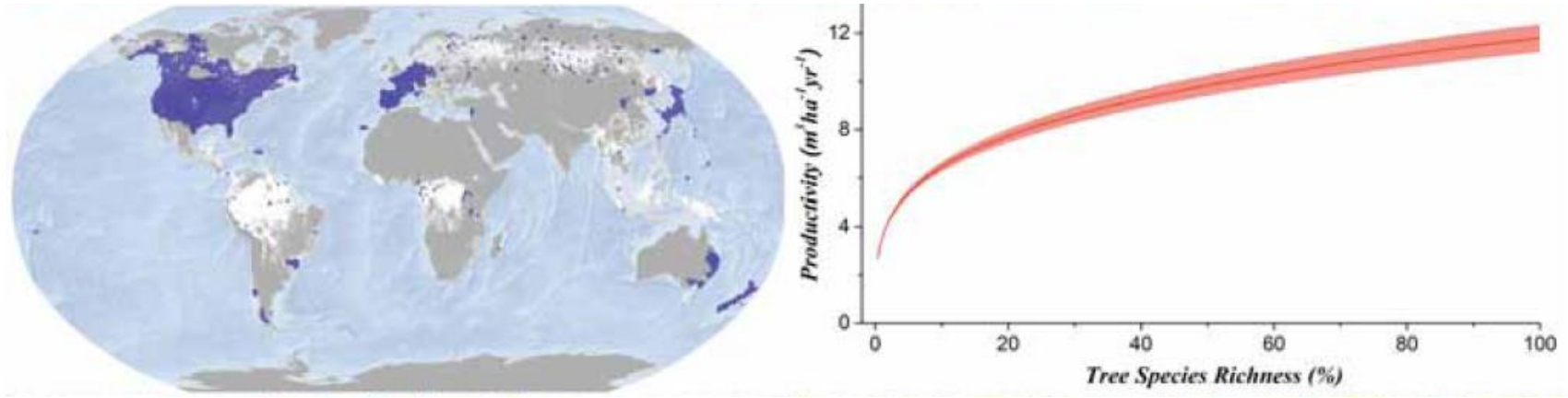
Structural heterogeneity, species richness, productivity. Evaluation based on ~ 300 long-term experiments



Mixing effects on forest productivity worldwide. Evaluation based on NFI data from 44 countries ~ 800,000 plots



Liang, J. et al. (2016) Positive Biodiversity-Productivity Relationship Predominant in Global Forests, Science, 354 (6309), aaf8957

Growth and yield in mixtures versus monocultures and practical management aspects

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Technical University of Munich
http://waldwachstum.wzw.tum.de/index.php?id=presentations

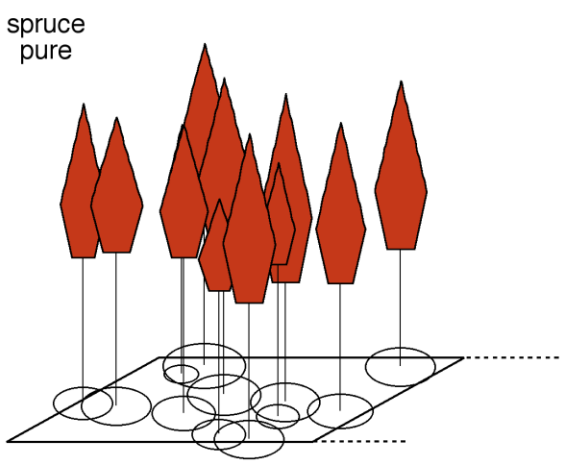
1 Growth and yield depending on the species assemblage

2 Main causes of mixing effects and the relevance of site conditions

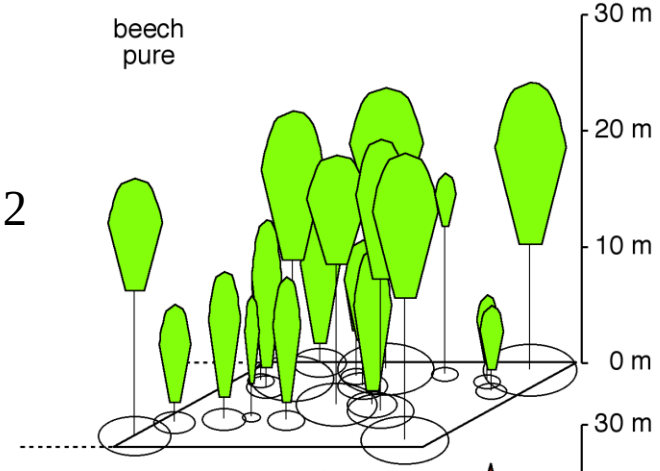
3 Silvicultural design and regulation of mixed-species stands

Experimental setup for scrutiny of mixing effects Zwiesel 111/3,4,5 Bavarian Forest

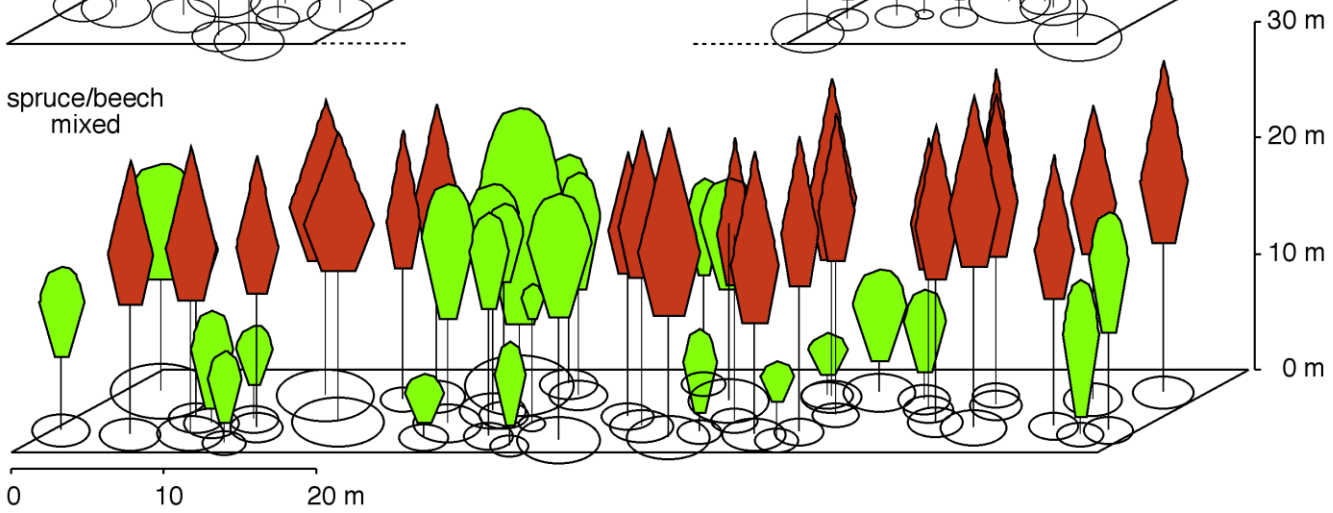
p_1



p_2

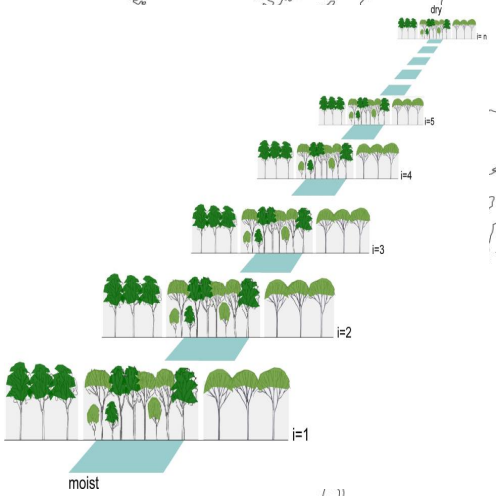


$p_{1,2}$
m_1
m_2



$p_{1,2}$ compared with $p_1 \times m_1 + p_2 \times m_2$

Establishment 32 triplets of Scots pine and European beech along a productivity gradient through Europe (EuMIXFOR FP 1206)



Swe 1
Swe 2
Lit 2
Lit 1
Pol 2
Pol 1
Net 1
Ger 7
Bel 2
Bel 1
Pol 3
Ukr 1
Pol 5
Pol 4
Cze 2
Cze 1
Fran 1
Ger 1-6
Slo 1
Aus 1
Ita 1
Ita 2
BHe 1
Ser 1
Sp 1
Sp 2
Bul 1

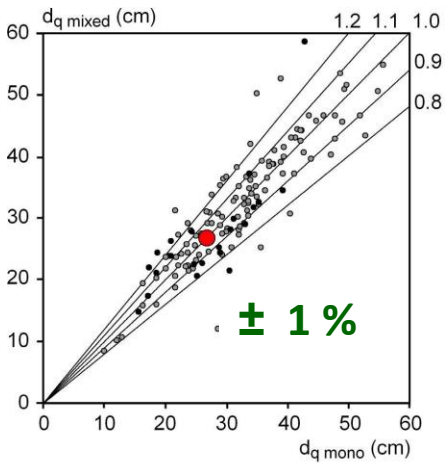
mean mixing effects in mature stands
PAIV: +15 %, SDI: + 20 %, V: +15 %

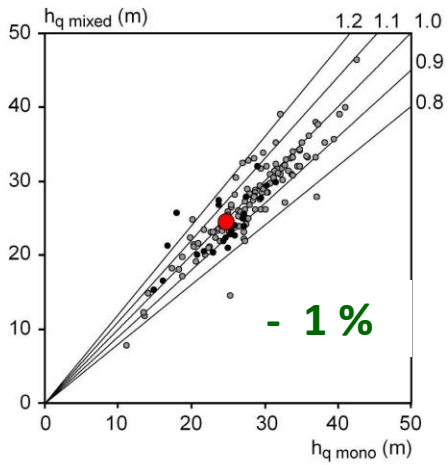
Mean overyielding various with tree species combination

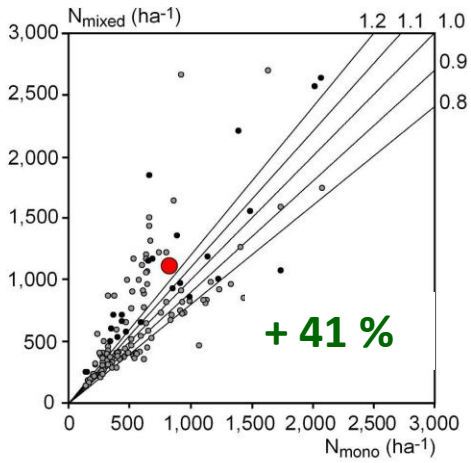
Species combination	N. sp/ E. be	S. pi/ E. be	s. oak/ E. be	E. be/ D-fir	S. pi/ N. sp	E. la/ N. sp	N. sp/ s. fir	mean
overyielding (± SE) in %	21 (± 3)	30 (± 9)	20 (± 3)	11 (± 8)	21 (± 11)	25 (± 6)	13 (± 6)	
corr. factor	1.10	1.20	1.10	1.10	1.20	1.20	1.10	1.10

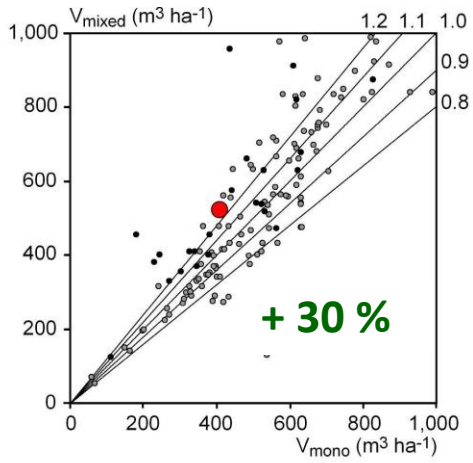
Pretzsch (2016) Ertragstafel-Korrekturfaktoren für Umwelt- und Mischunsgeffekte, AFZ Der Wald, 14/2016: 47-50

Mixing increases tree number and standing volume rather than mean tree diameter or height





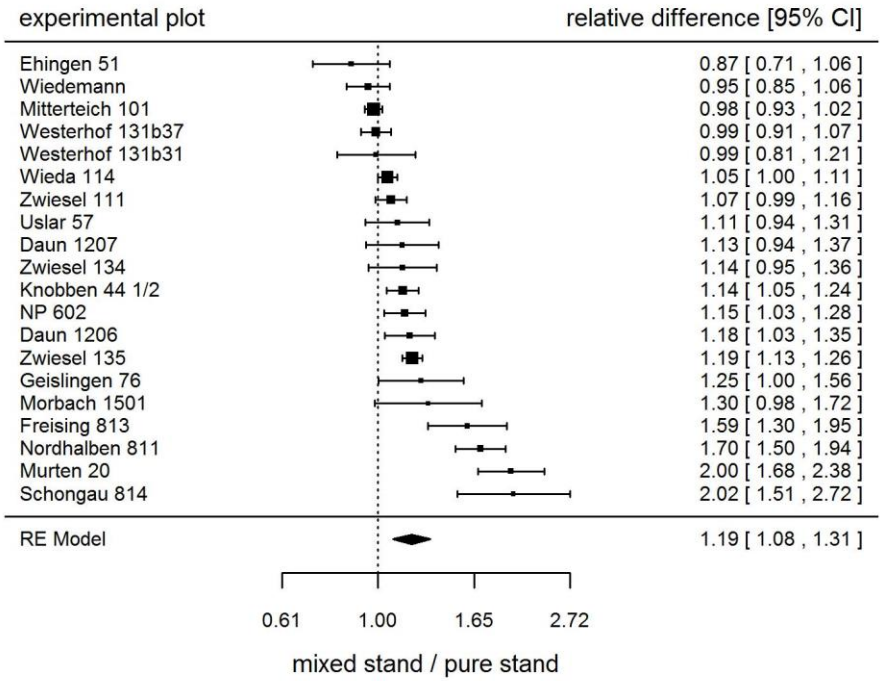




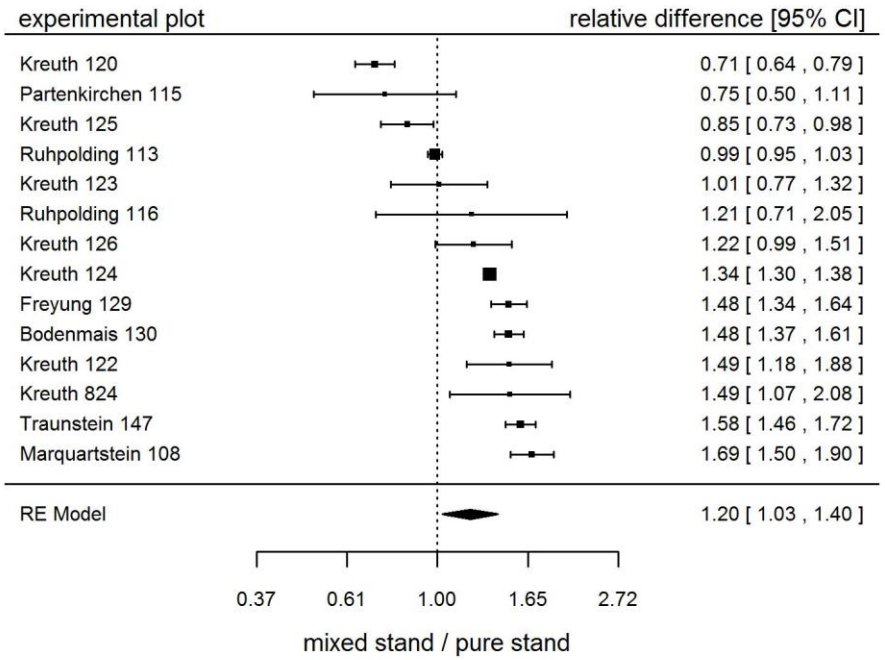
Pretzsch, Forrester, Bauhus (2017) Mixed-speceis forests, Springer

Meta-analysis on overyielding of mixed stands of Norway spruce, European beech, silver fir in Europe based on long-term experiments

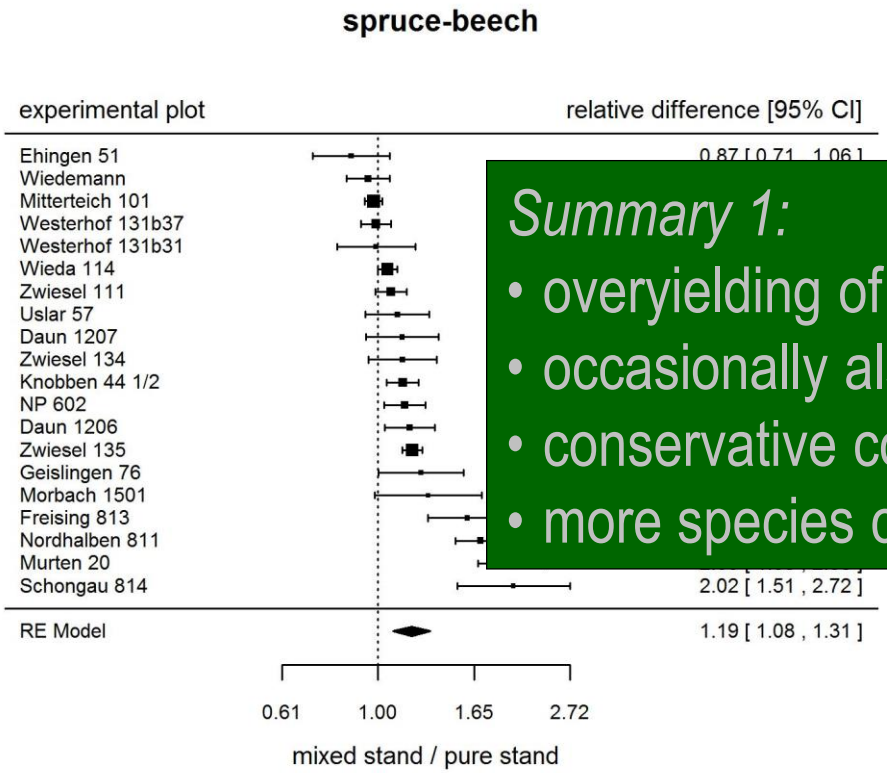
spruce-beech

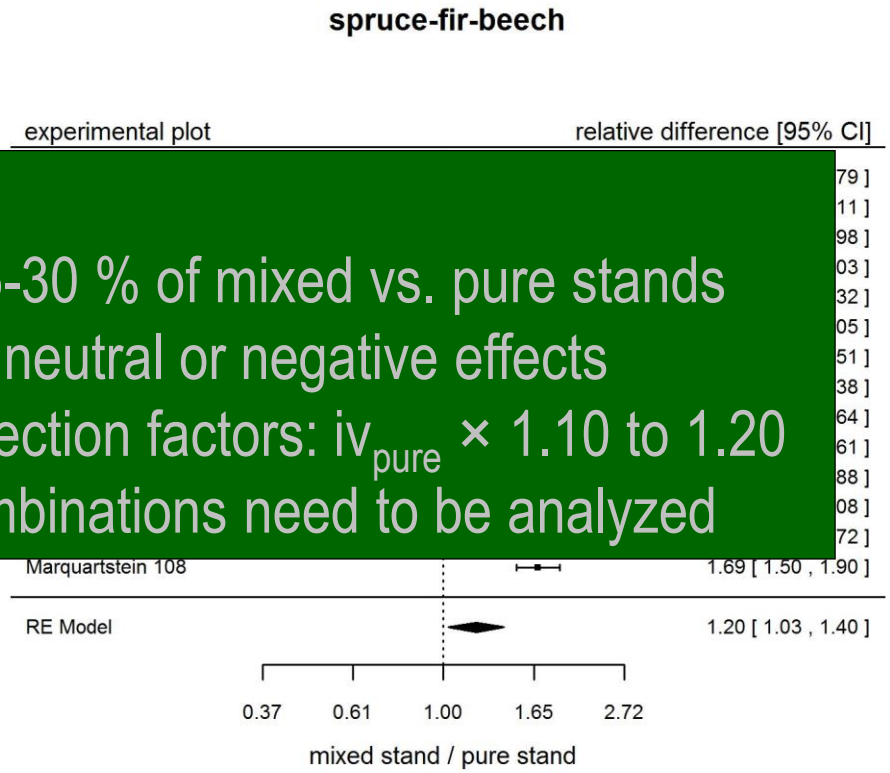


spruce-fir-beech



Meta-analysis on overyielding of mixed stands of Norway spruce, European beech, silver fir in Europe based on long-term experiments



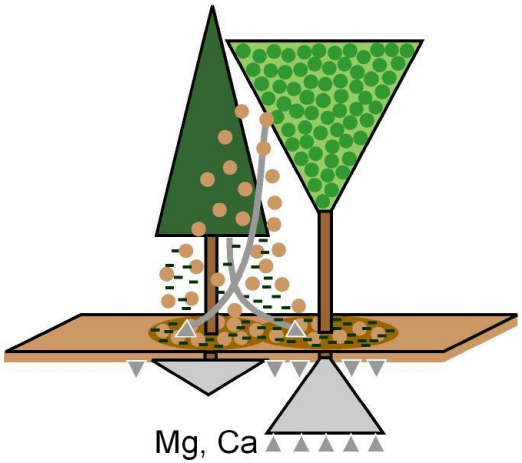


Summary 1:

- overyielding of 15-30 % of mixed vs. pure stands
- occasionally also neutral or negative effects
- conservative correction factors: iv_{pure} × 1.10 to 1.20
- more species combinations need to be analyzed

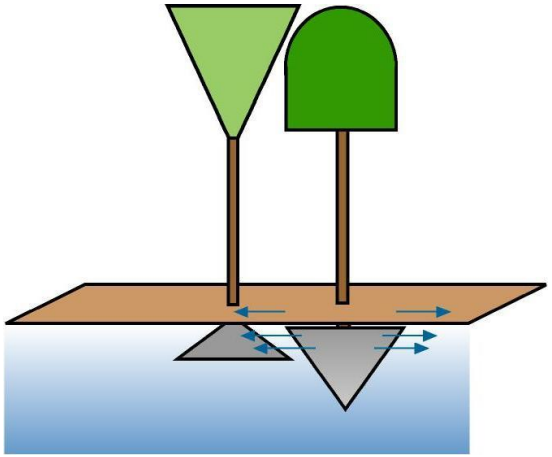
Facilitation by better mineral nutrients and water exploitation

nutrients upward transport



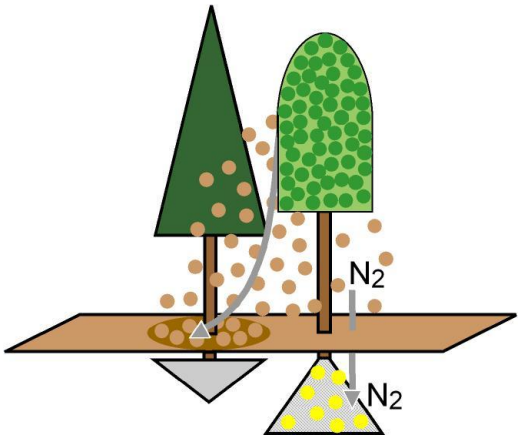
e.g. Rothe, Binkley (2001)

hydraulic redistribution



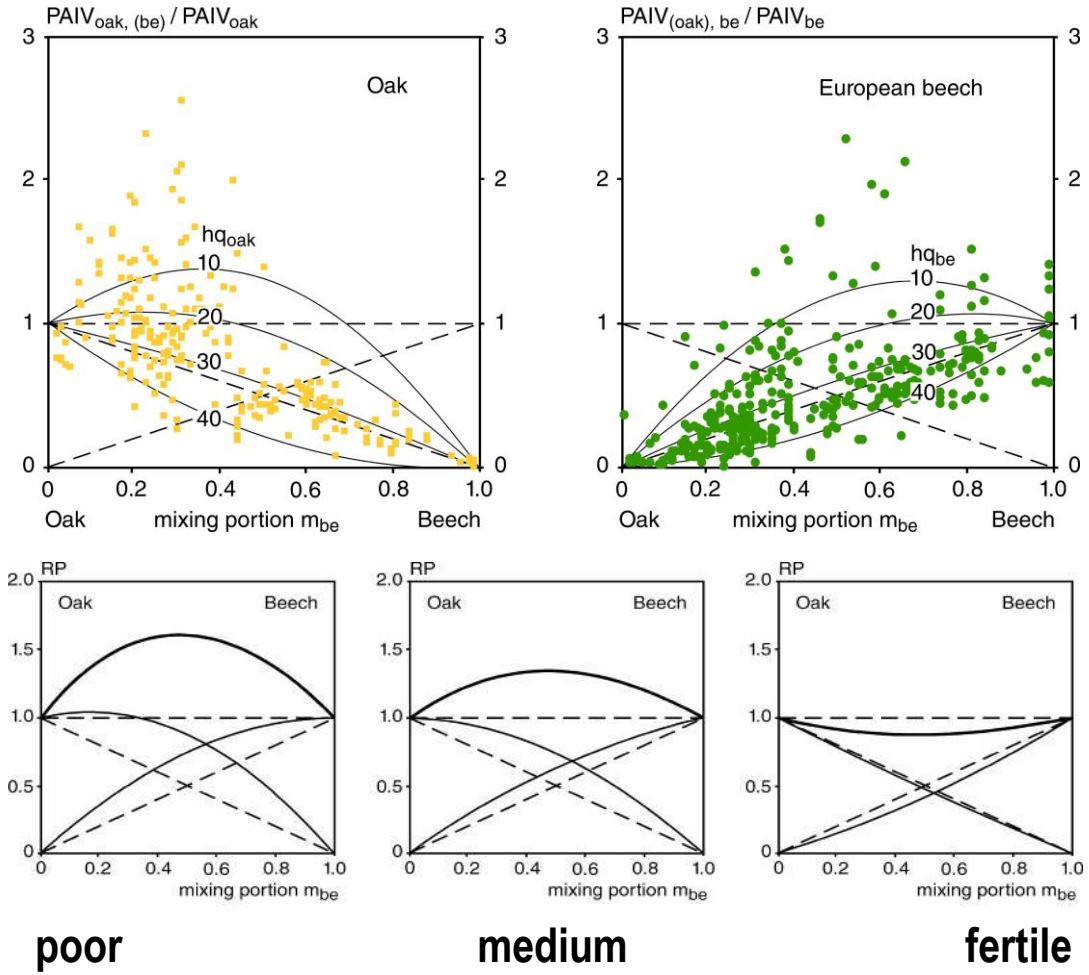
e.g. Prieto et al. 2012

atmospheric N_2 fixation



e..g. Forrester et al. 2007, 2007

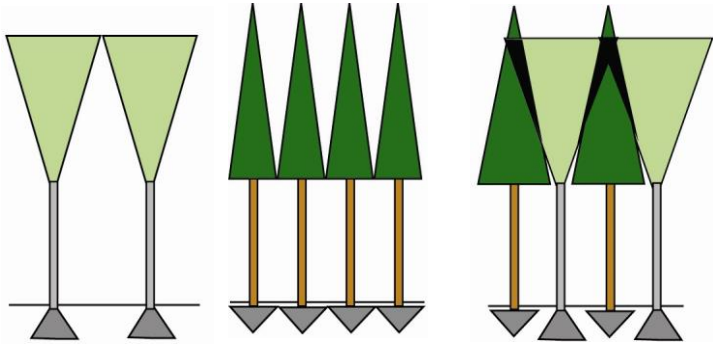
Study in sessile oak-European beech
Overyielding increases with water and nutrient scarcity



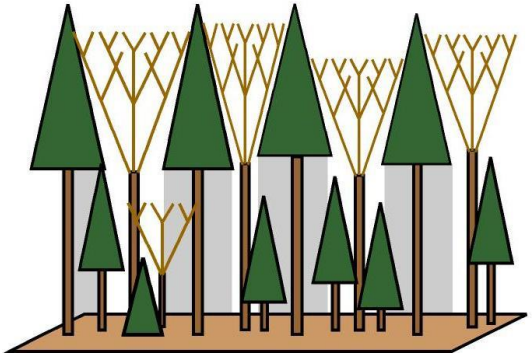
Pretzsch et al. (2013) Productivity of mixed versus pure stands of oak (*Quercus petraea* (Matt.) Liebl. and *Quercus robur* L.) and European beech (*Fagus sylvatica* L.) along an ecological gradient, EJFOR, 132 (2):263-280

Reduction of competition for light by morphological, temporal and spatial complementarity

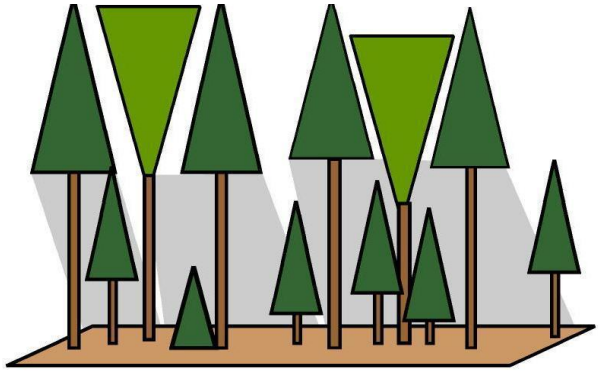
morphological complementarity



temporal complementarity

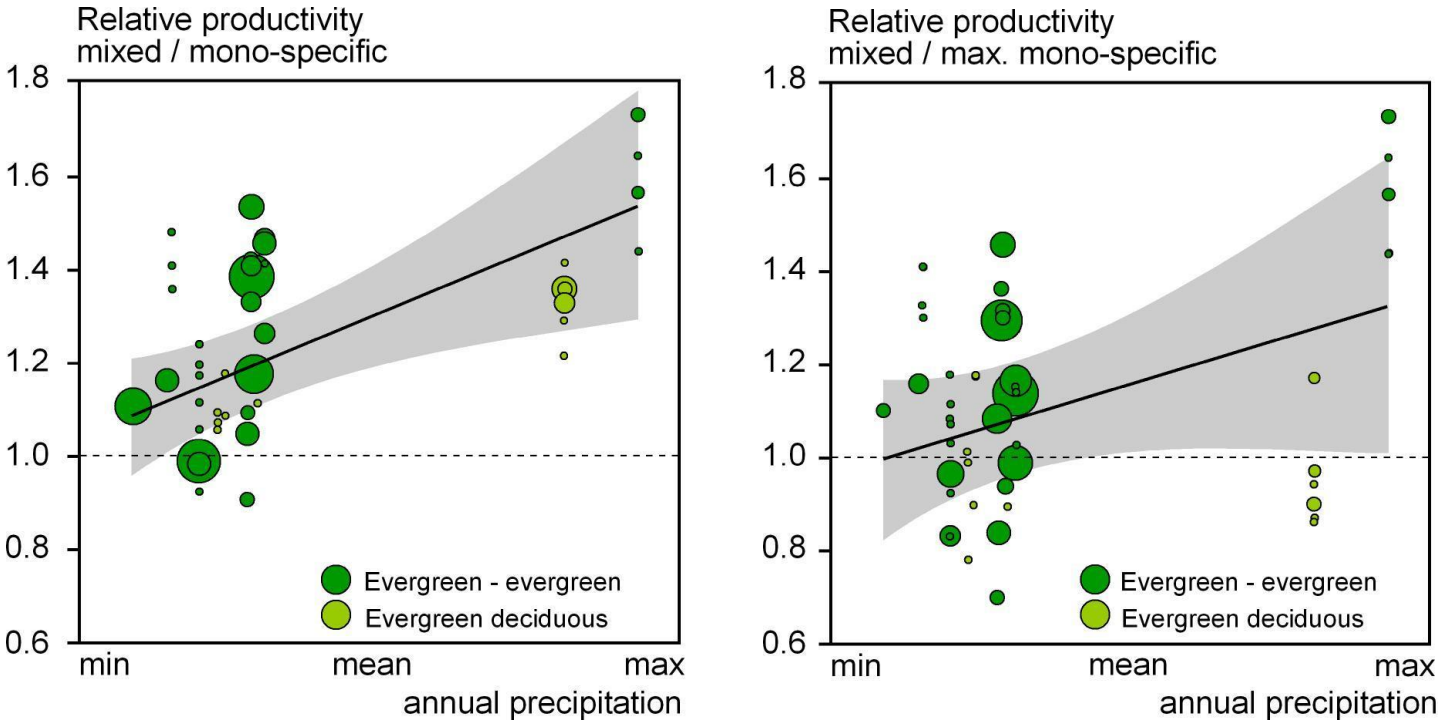


spatial complementarity



Pretzsch, H, Forrster, D, Bauhus, J (2017) Mixed-species Forests. Ecology and Management, Springer, Berlin, 653 p

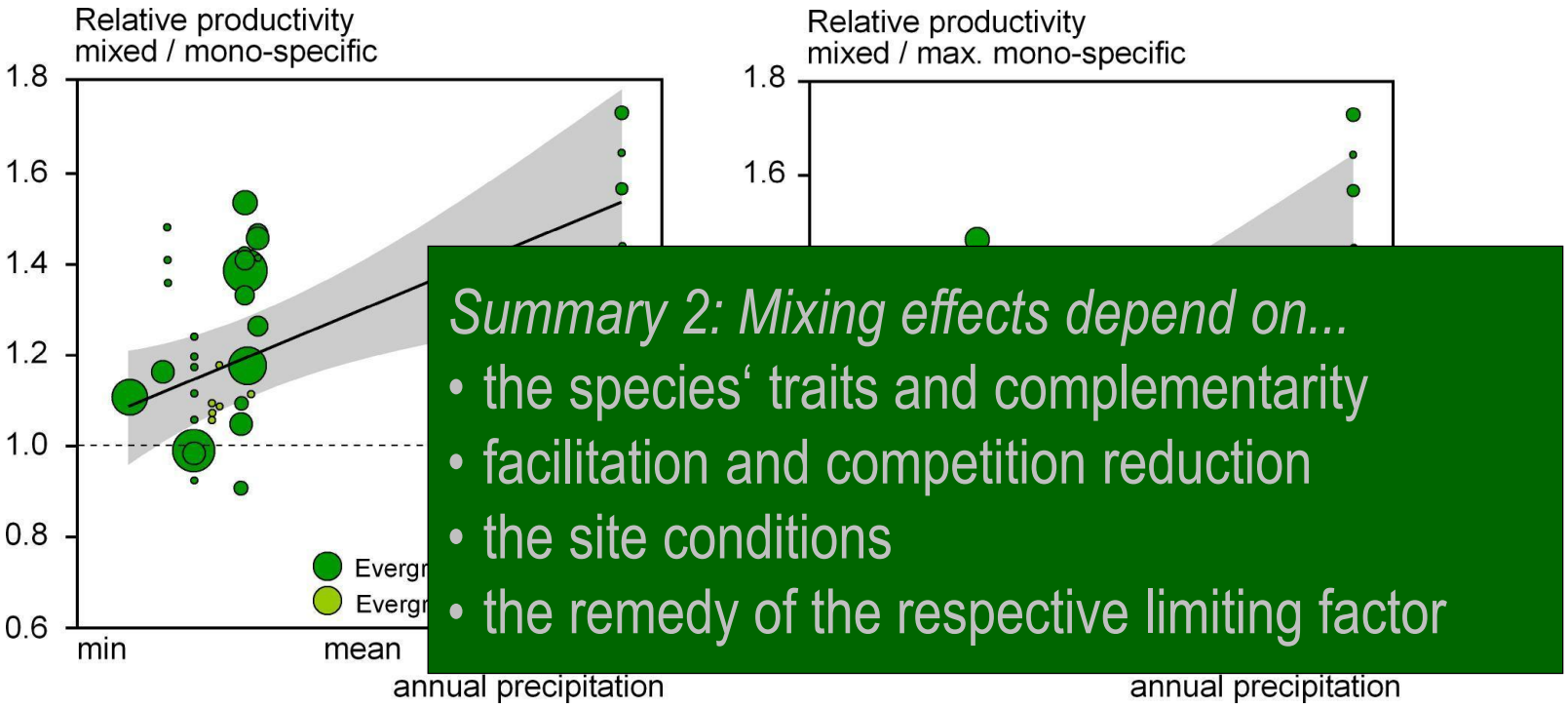
Increasing overyielding (15 %) and transgressive overvielding with water availability



no significant transgressive underyielding

Jactel, H. et al. (2018) Positive diversity-productivity relationships in forests: climate matters, Biology Letters 20170747, http://dx.doi.org/10.1098/rsbl.2017.0747

Increasing overyielding (15 %) and transgressive overvielding with water availability



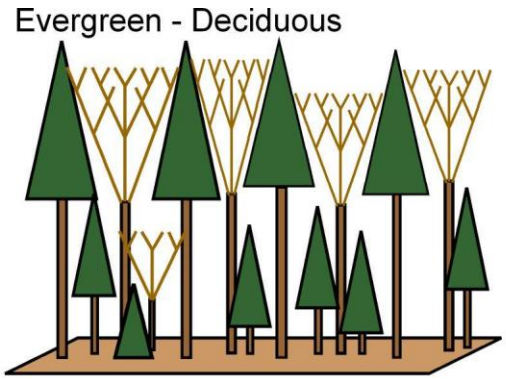
Summary 2: Mixing effects depend on...

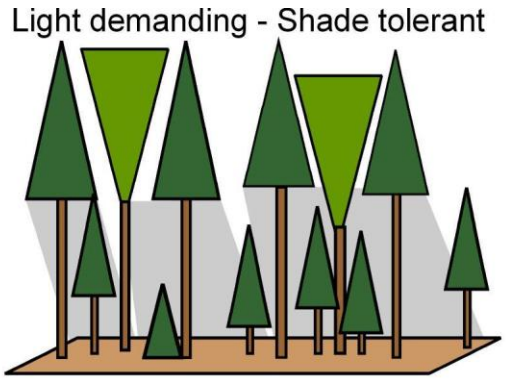
- the species‘ traits and complementarity
- facilitation and competition reduction
- the site conditions
- the remedy of the respective limiting factor

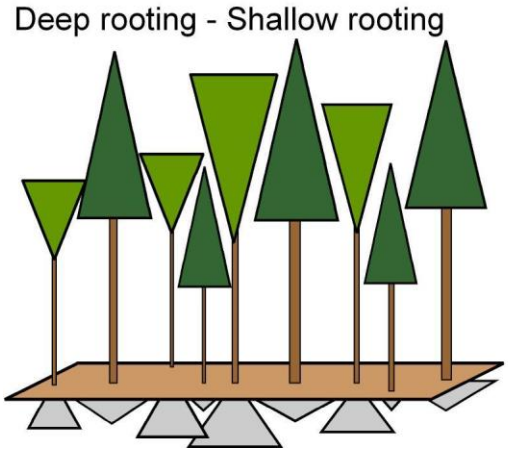
no significant transgressive underyielding

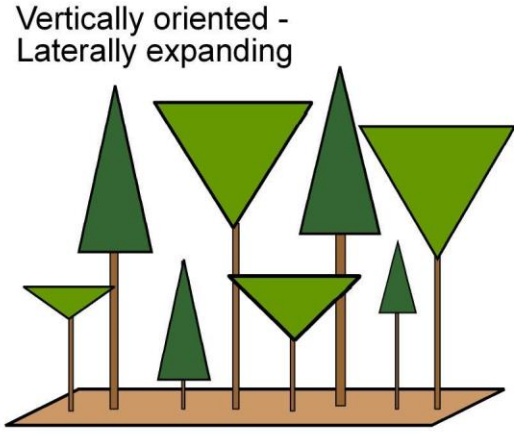
Jactel, H. et al. (2018) Positive diversity-productivity relationships in forests: climate matters, Biology Letters 20170747, http://dx.doi.org/10.1098/rsbl.2017.0747

Which species combinations enables complementarity and overyielding?

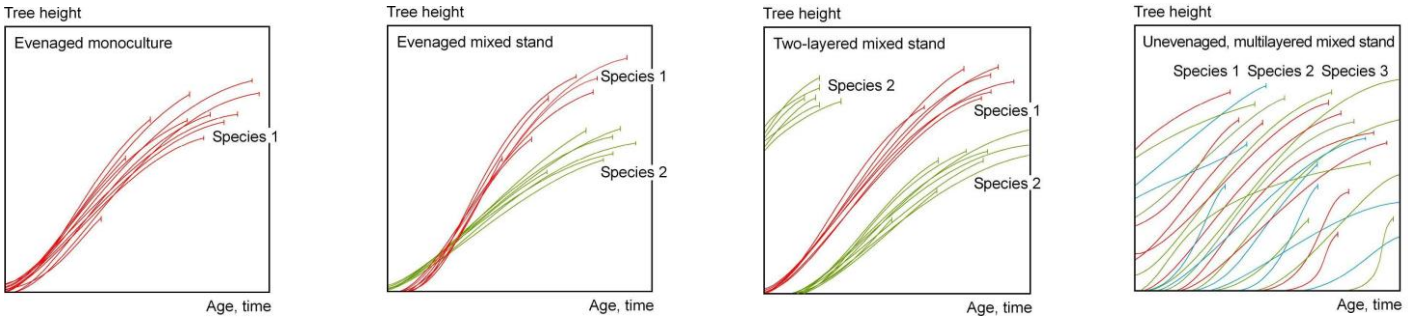


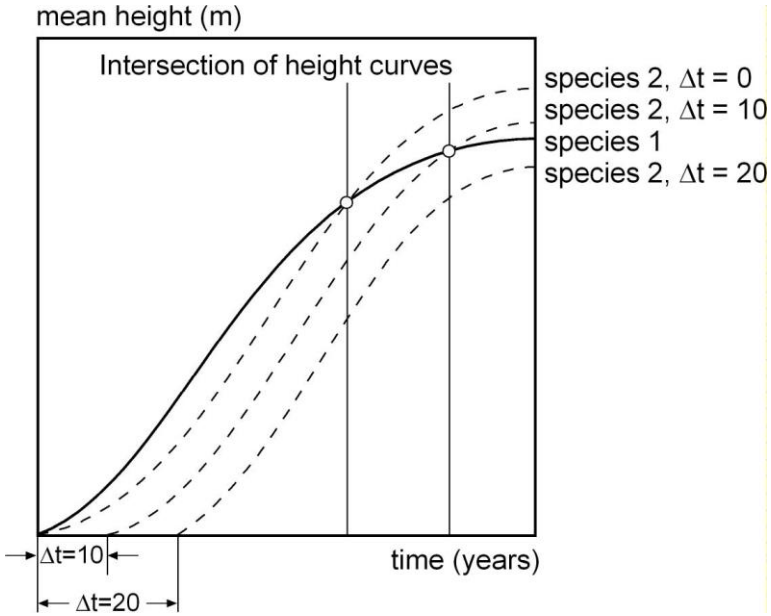


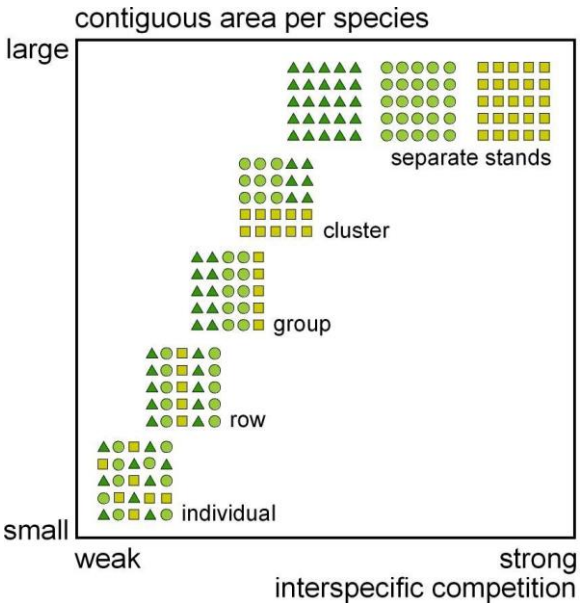




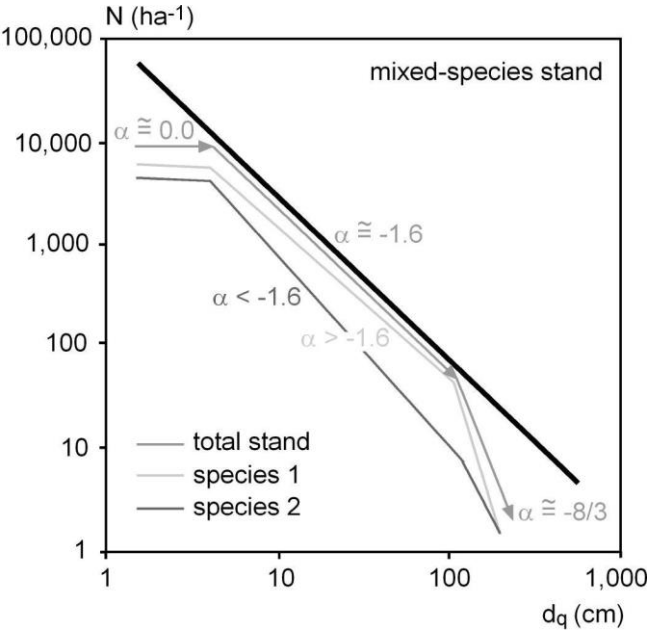
How to establish mixed stands considering the species-specific growth trajectories?

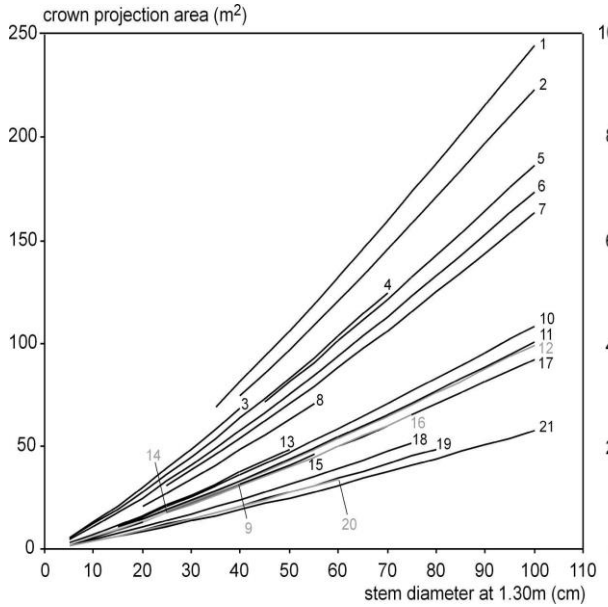


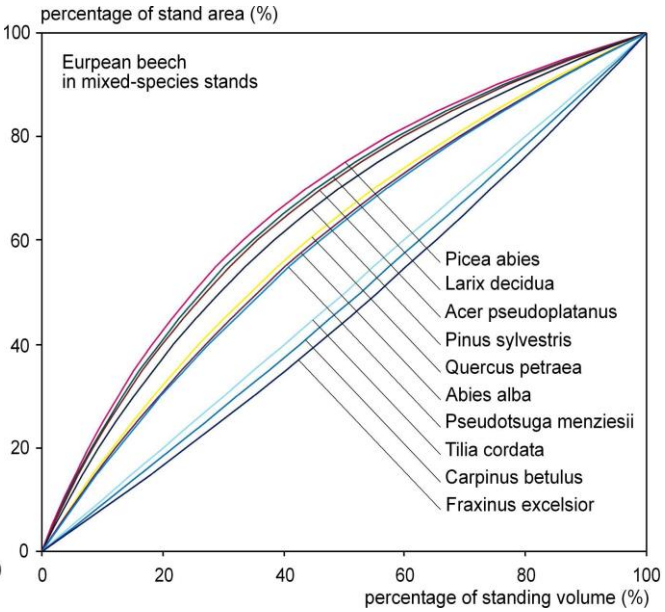




How to regulate stand density and mixing proportions?

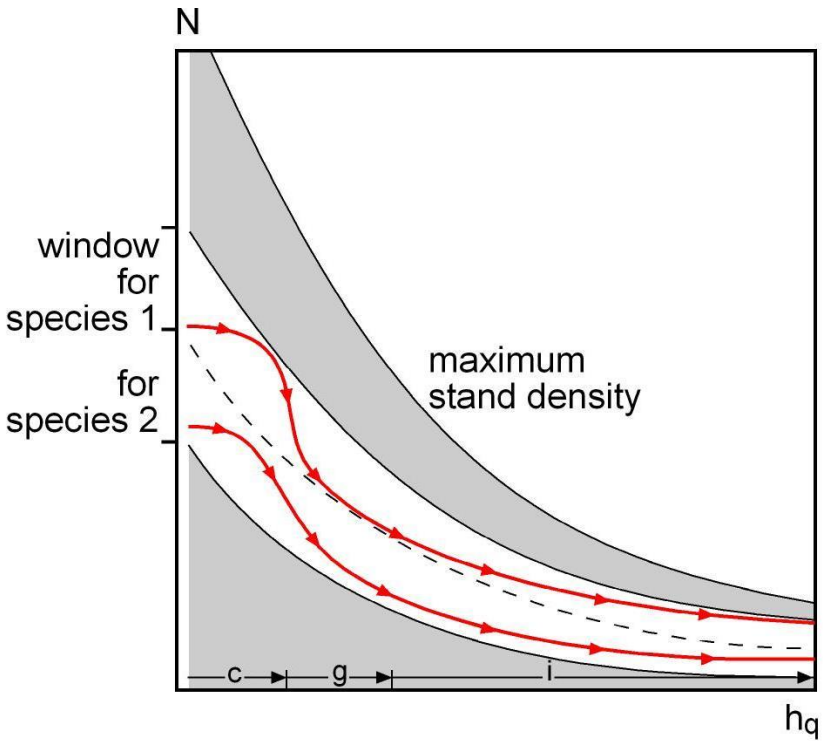


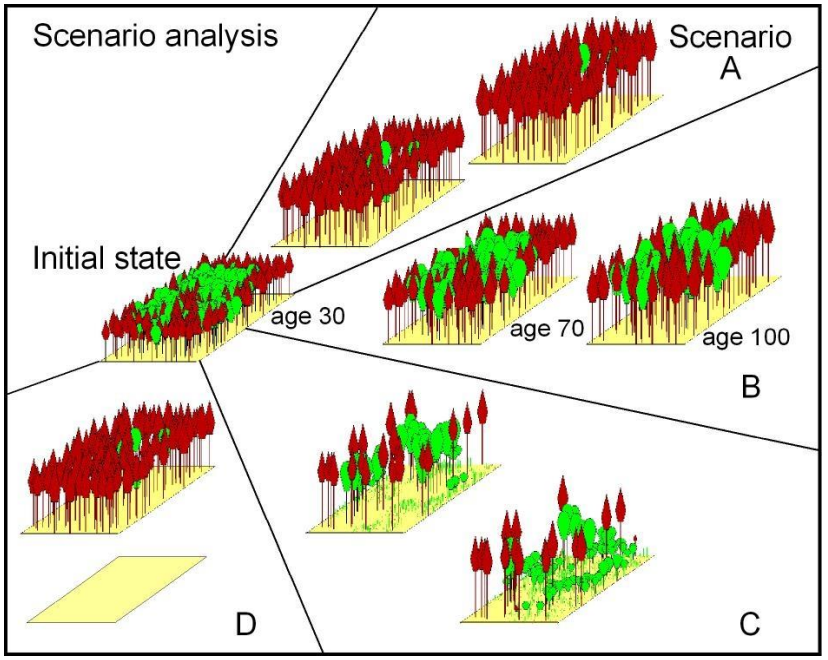




1) *Quercus nigra* L., 2) *Platanus x hispanica* Münchh., 3) *Carpinus betulus* L., 4) *Tilia cordata* Mill.,
5) *Khaya senegalensis* (Desr.) A.Juss., 6) *Fagus sylvatica* L., 7) *Aesculus hippocastanum* L.,
8) *Robinia pseudoacacia* L., 9) *Alnus glutinosa* [L.] Gaertn., 10) *Araucaria cunninghamii* Aiton ex. D.Don,
11) *Pseudotsuga menziesii* [Mirb.], 12) *Abies alba* Mill., 13) *Sorbus aucuparia* L., 14) *Betula pendula* Roth,
15) *Acer pseudoplatanus* L., 16) *Abies sachalinensis* Mast., 17) *Quercus petraea* [Matt.] Liebl.,
18) *Pinus sylvestris* L., 19) *Larix decidua* Mill., 20) *Fraxinus excelsior* L., 21) *Picea abies* [L.] Karst.

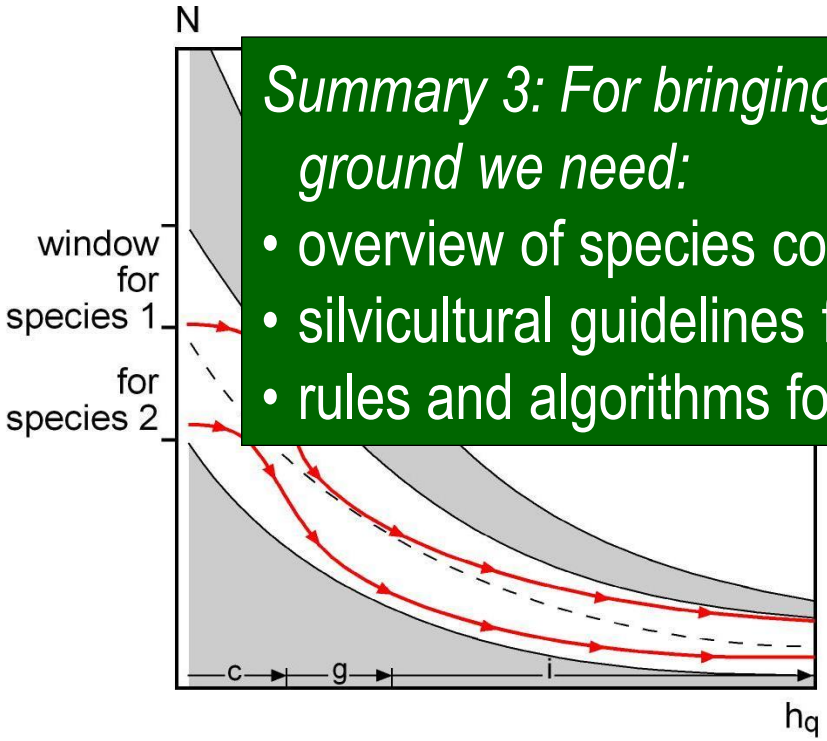
Silvicultural guidelines for bringing the mixing idea onto the ground

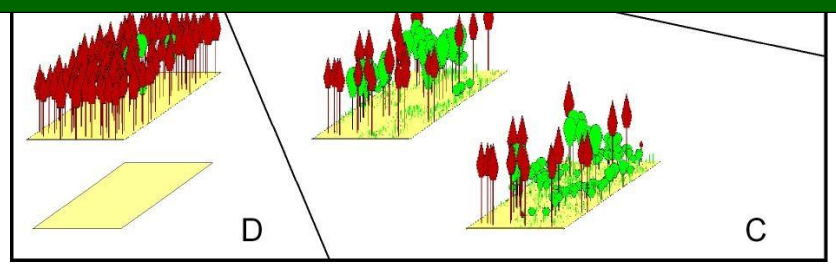




Pretzsch, H and Zenner E (2017) Toward managing mixed-species stands: from parametrization to prescription, Forest Ecosystems, DOI : 10.1186/s40663-017-0105-z

Silvicultural guidelines for bringing the mixing idea onto the ground





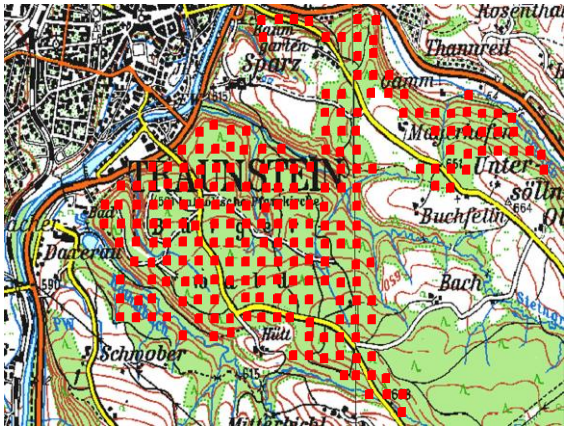
Summary 3: For bringing the mixed-species stand idea to the ground we need:

- overview of species complementarity
- silvicultural guidelines for design and regulation in practice
- rules and algorithms for regulating mixture in models

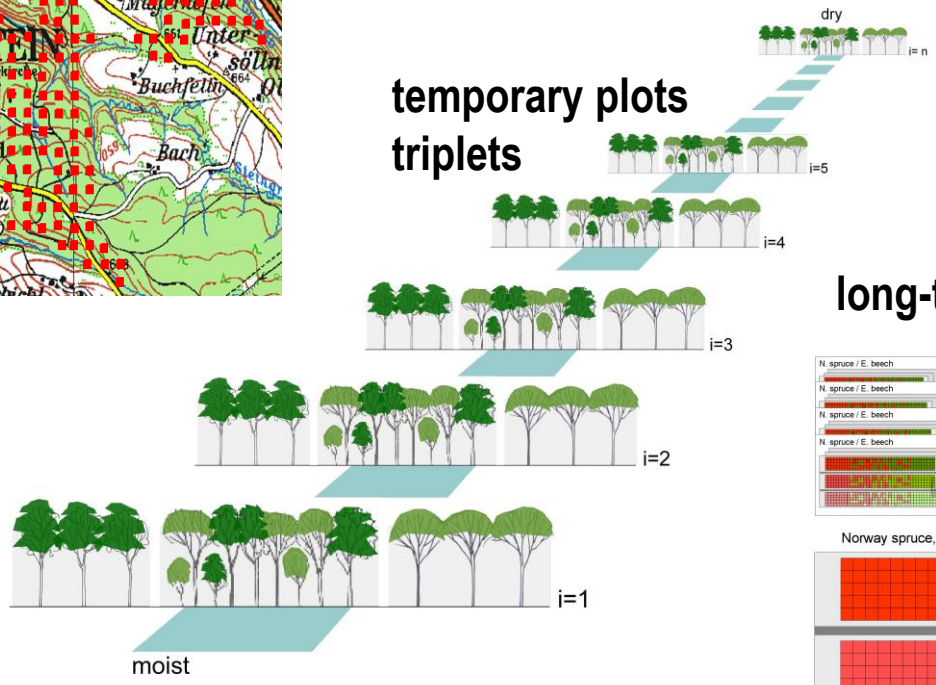
Pretzsch, H and Zenner E (2017) Toward managing mixed-species stands: from parametrization to prescription, Forest Ecosystems, DOI : 10.1186/s40663-017-0105-z

Data base: From forest inventories to temporary plots and long-term experiments

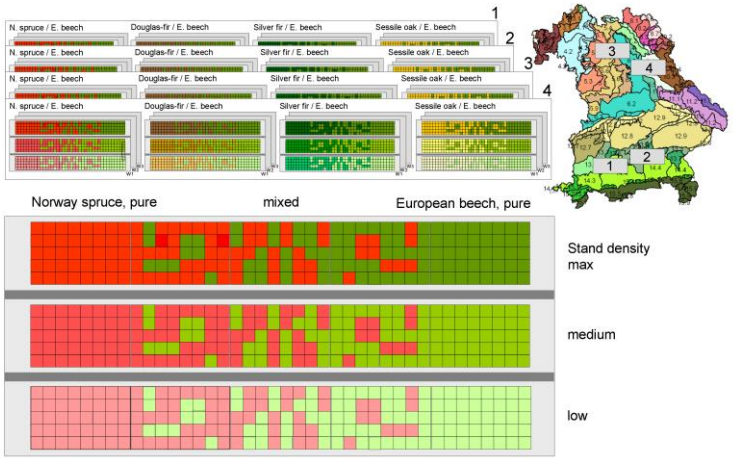
forest inventories



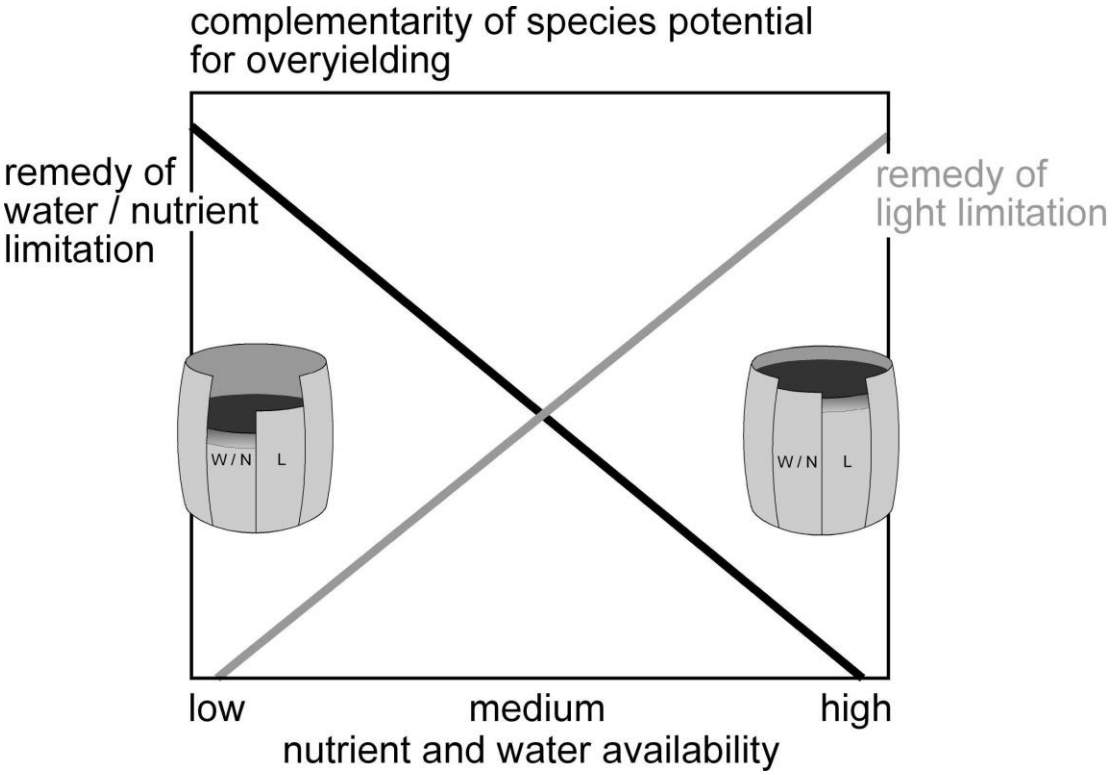
temporary plots triplets



long-term experiments

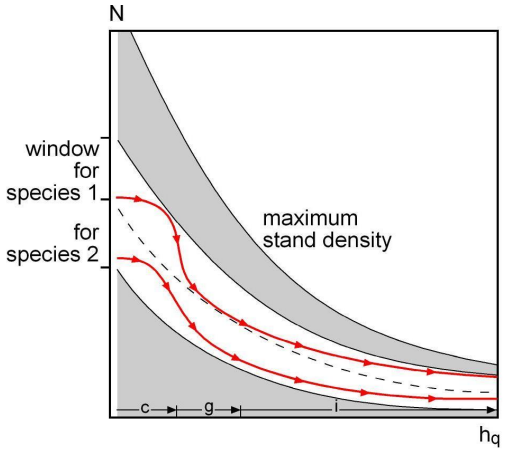


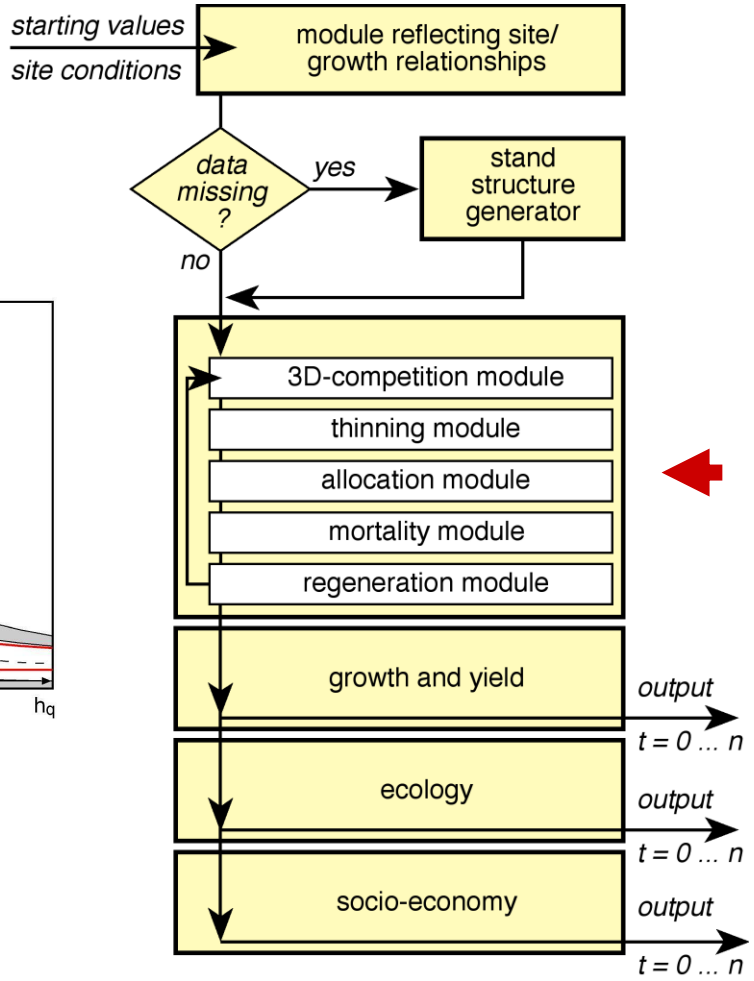
Further research into the dependency of mixing effects on site conditions



Forrester 2017, Pretzsch 2017

Further development of spatially explicit individual tree models for pure and mixed stands





Integration of mixing effects on growth, structure, mortality

Extension of the algorithms for silvicultural regulation

Criteria for sustainable forest management. Objective hierarchy for the management of municipal forest Traunstein

Criteria for sustainable forest management	Indicators	Weight (%)
Forest resources	timber resources, area of forest, extension of area	20
Health and vitality	stability, fitness, elasticity	17
Productive functions	growth, yield, net return	12
Biological diversity	habitat quality, richness flora/fauna, conservation	10
Protective functions	soil, water, climate, noise, protection	10
Socio-economic functions	employment, recreation, esthetics, proximity to nature	31

according to MCPFE, 2000

Thanks for funding by
EU REFORM (# 2816ERA02S),
CLIMO, CARE4C, BIODIVERSA
DFG
MStELF, MStU, BaySF

Thanks for provinding data to
partner institutions in Sweden, Denmark,
England, Poland, France, Germany
Austria, Switzerland, Italy, Spain, and others

http://waldwachstum.wzw.tum.de/index.php?id=presentations