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TECHNISCHE UNIVERSITÄT MÜNCHEN

Tracing tree species mixing effects from the stand to the tree level

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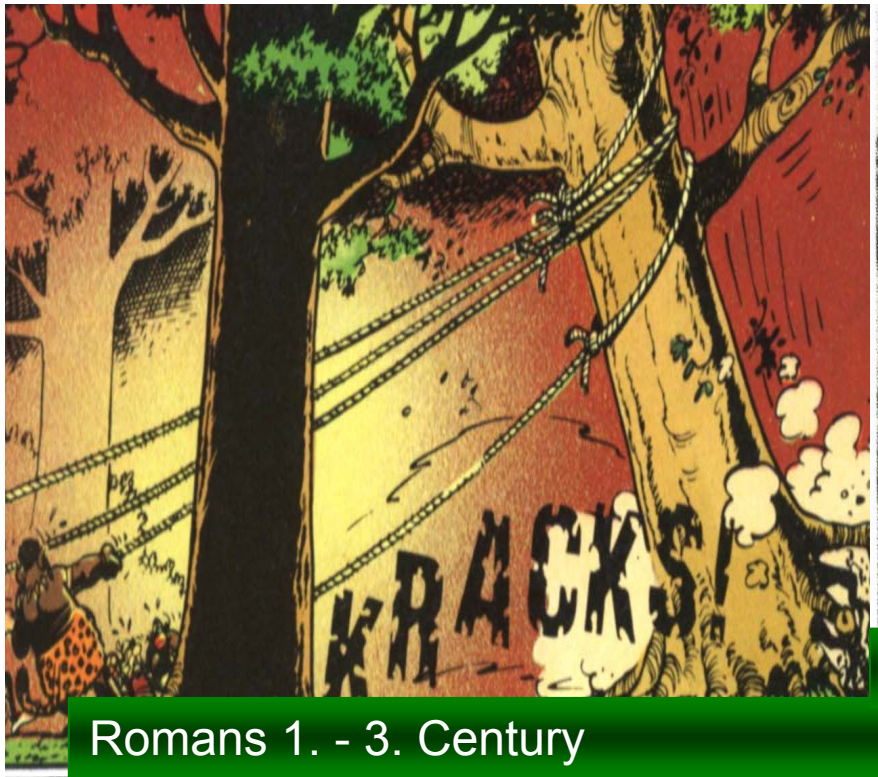
http://www.forestgrowth.wzw.tum.de/presentations.html

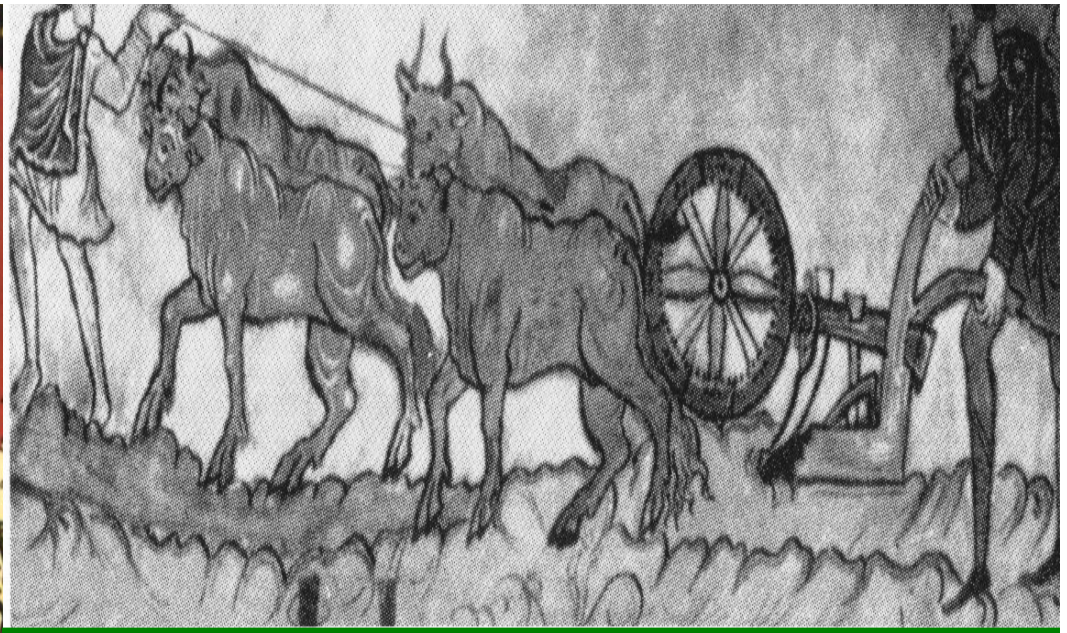
Lecture given on April 30th, 2015, CEF conference University of Québec a Rimouski, UQAR, Canada

Mixed spruce-fir-beech mountain forest in montane and subalpine zones (600-1,400 m a.s.l.)

Mixed European beech forest in Central European lowlands



Romans 1. - 3. Century



Clearings in medieval times 12. – 13. Century

Industrialisation 18. – 19. Century

World War I. und II. 20. Century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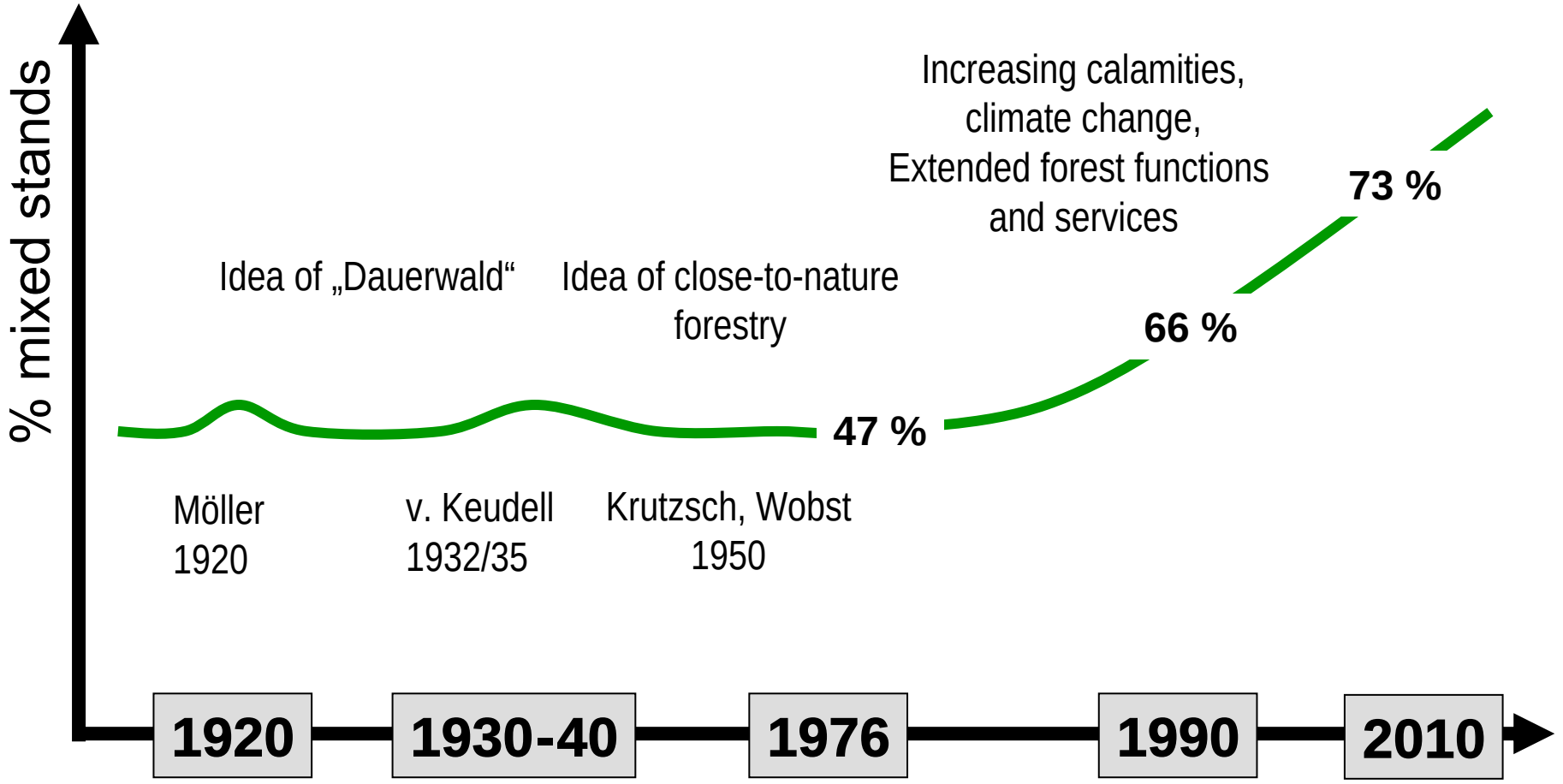
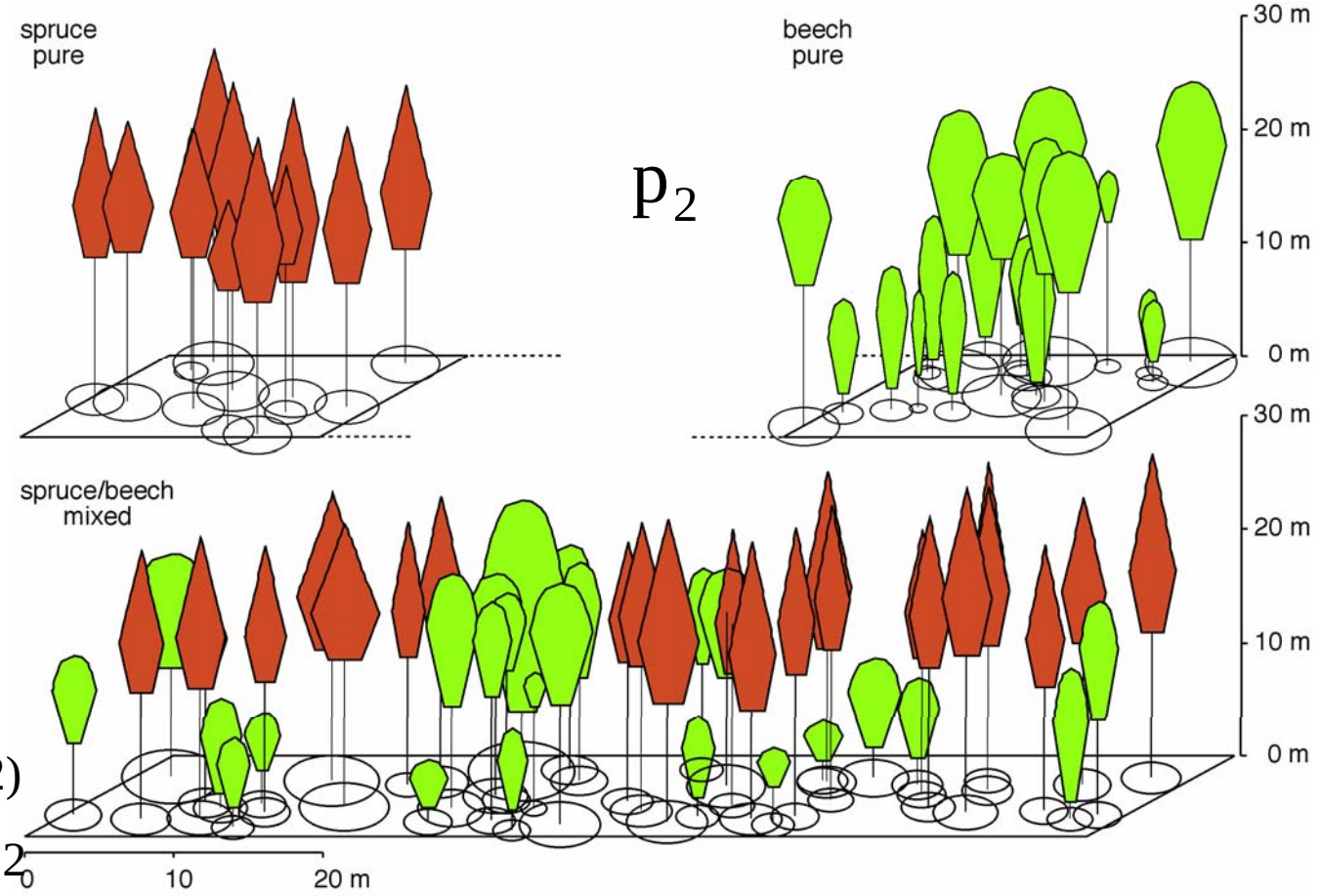
Back to complex mixed-species forests. From the idea to realization in Bavaria



Mixing proportions (>10 % stand area) according to inventories GRI 1971, BWI I 1987, BWI 2 2002, BWI 3 2014 in Bavaria

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



p_1

p_2

$p_{1,2}$

m_1

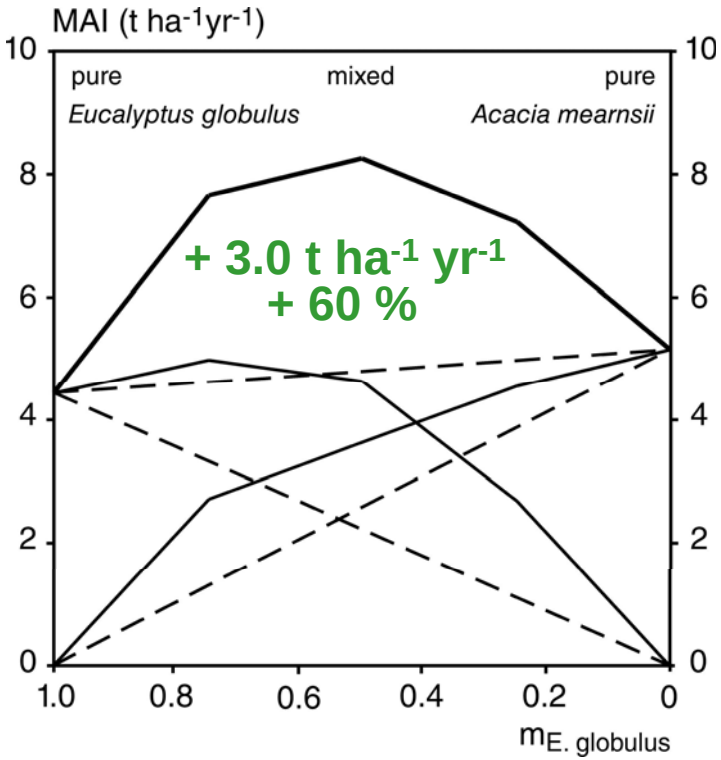
m_2

$pp_{1,(2)}$

$pp_{(1),2}$

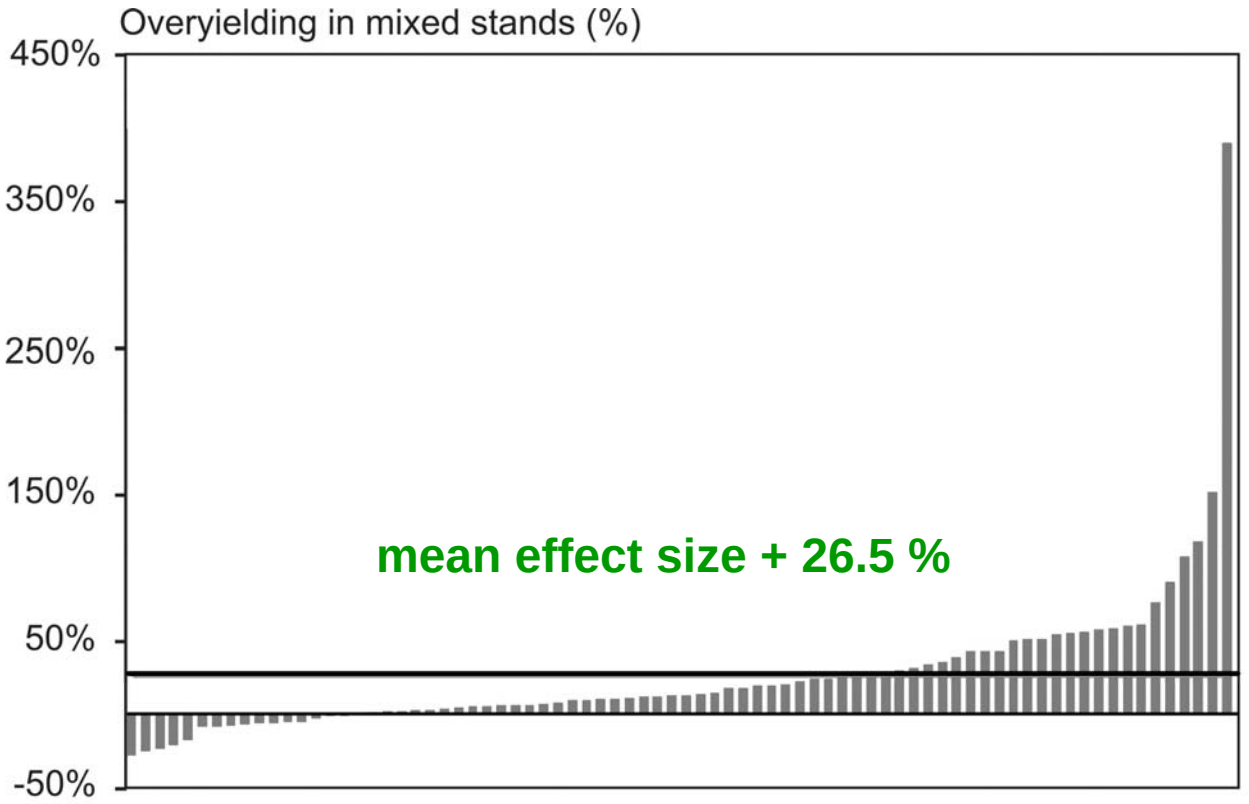
$$p_{1,2} = pp_{1,(2)} + pp_{(1),2}$$

Overyielding in mixed versus pure stands of *Eucalyptus globulus* Labill and *Acacia mearnsii* De Wild.



Forrester et al. (2006) Mixed-species plantations of *Eucalyptus* …, Forest Ecology and Management 233:211-230
Forrester, unpublished data from Cann River Exp., precip. 850 mm yr^{-1}, mean temp. 14.4 °C, Southeastern Australia

Meta-analysis on overyielding of mixed versus pure stands in boreal and temperate forests
29 publications, 78 case studies



Gritti, E. S. et al. 2015: Diversity-productivity relationships in Forests, a Meta-Analysis, in preparation for submission

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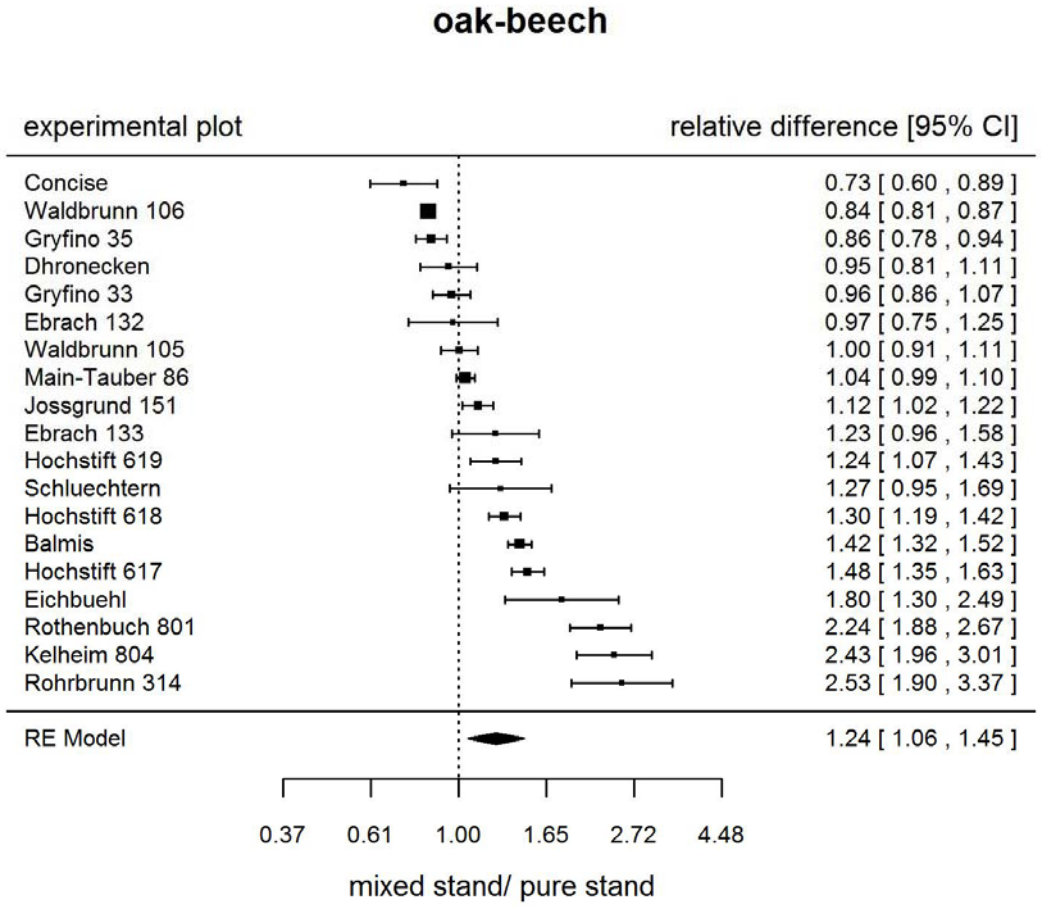
Meta-analysis on overyielding of mixed stands of sessile oak and European beech versus pure stands in Europe based on long-term experiments



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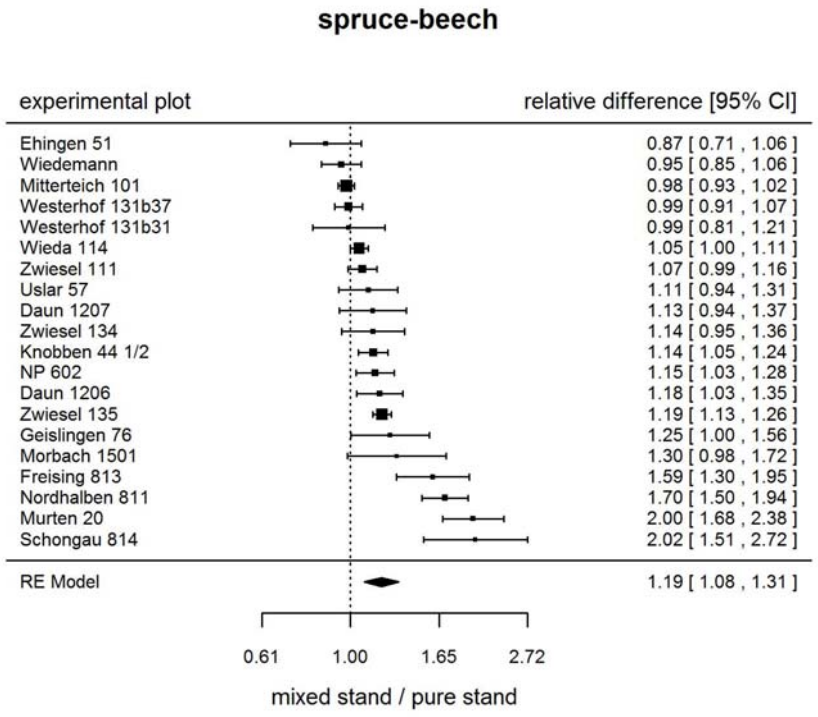
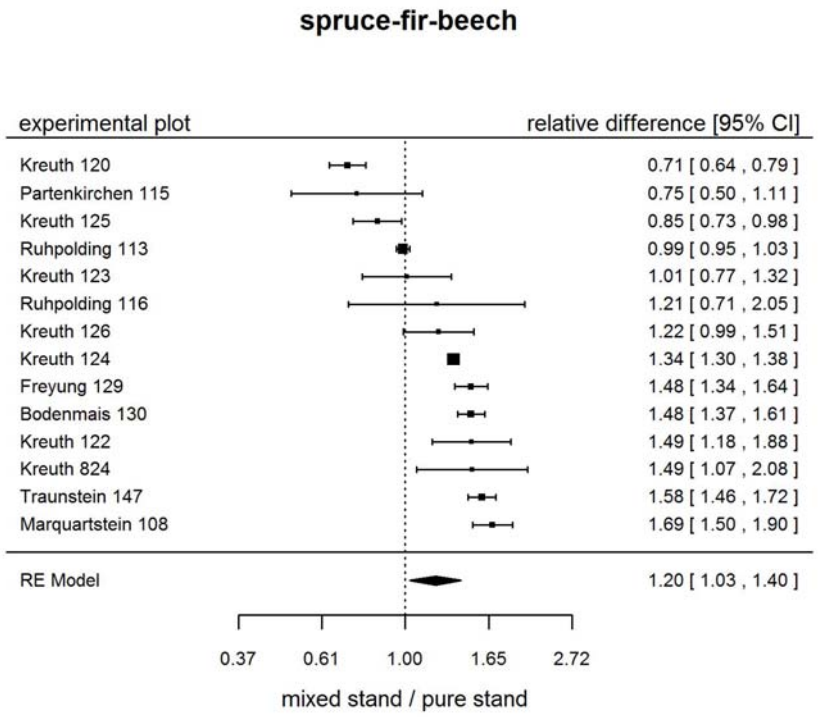
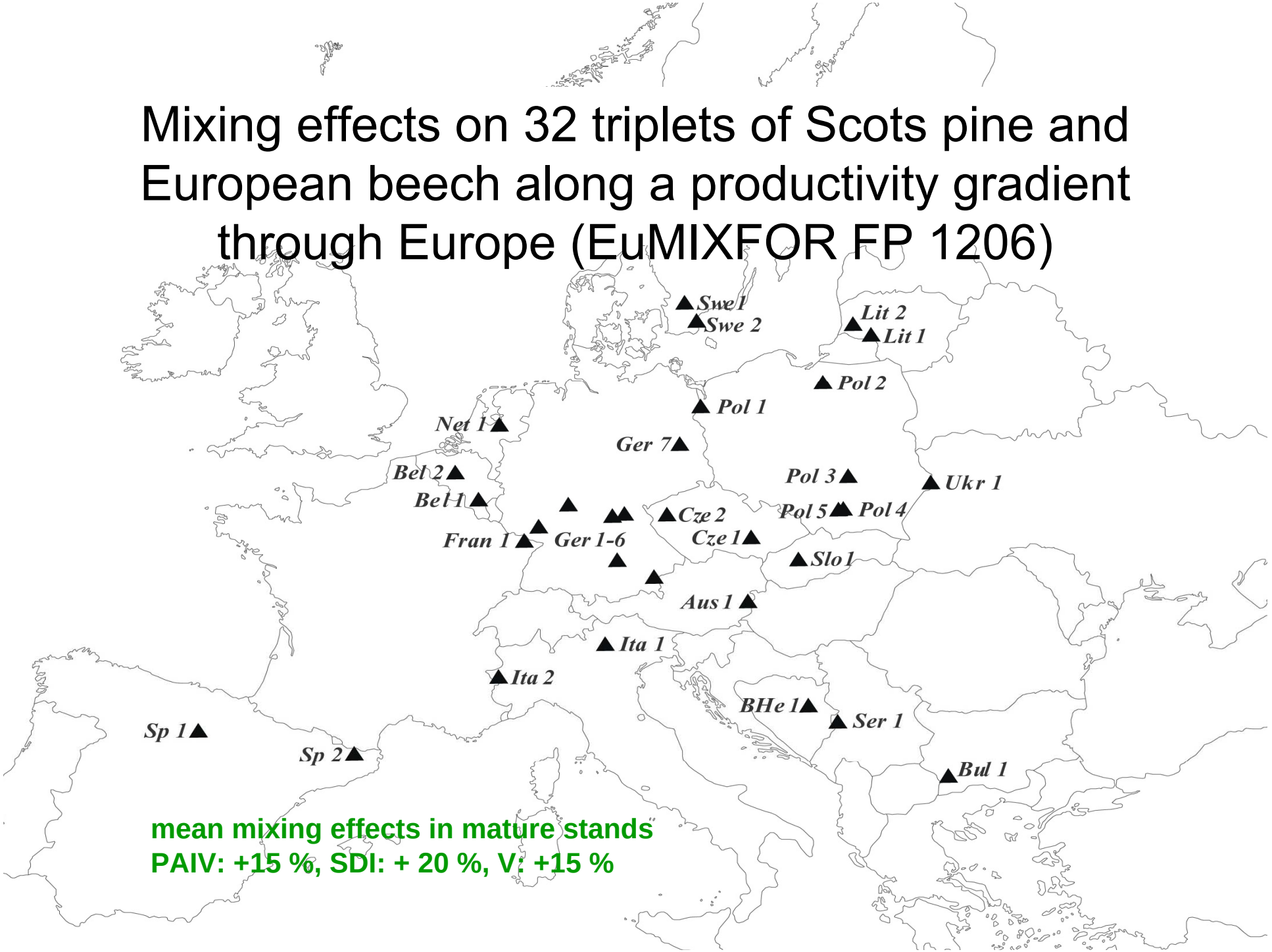
Meta-analysis on overyielding of mixed stands of Norway spruce, European beech, silver fir in Europe based on long-term experiments





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



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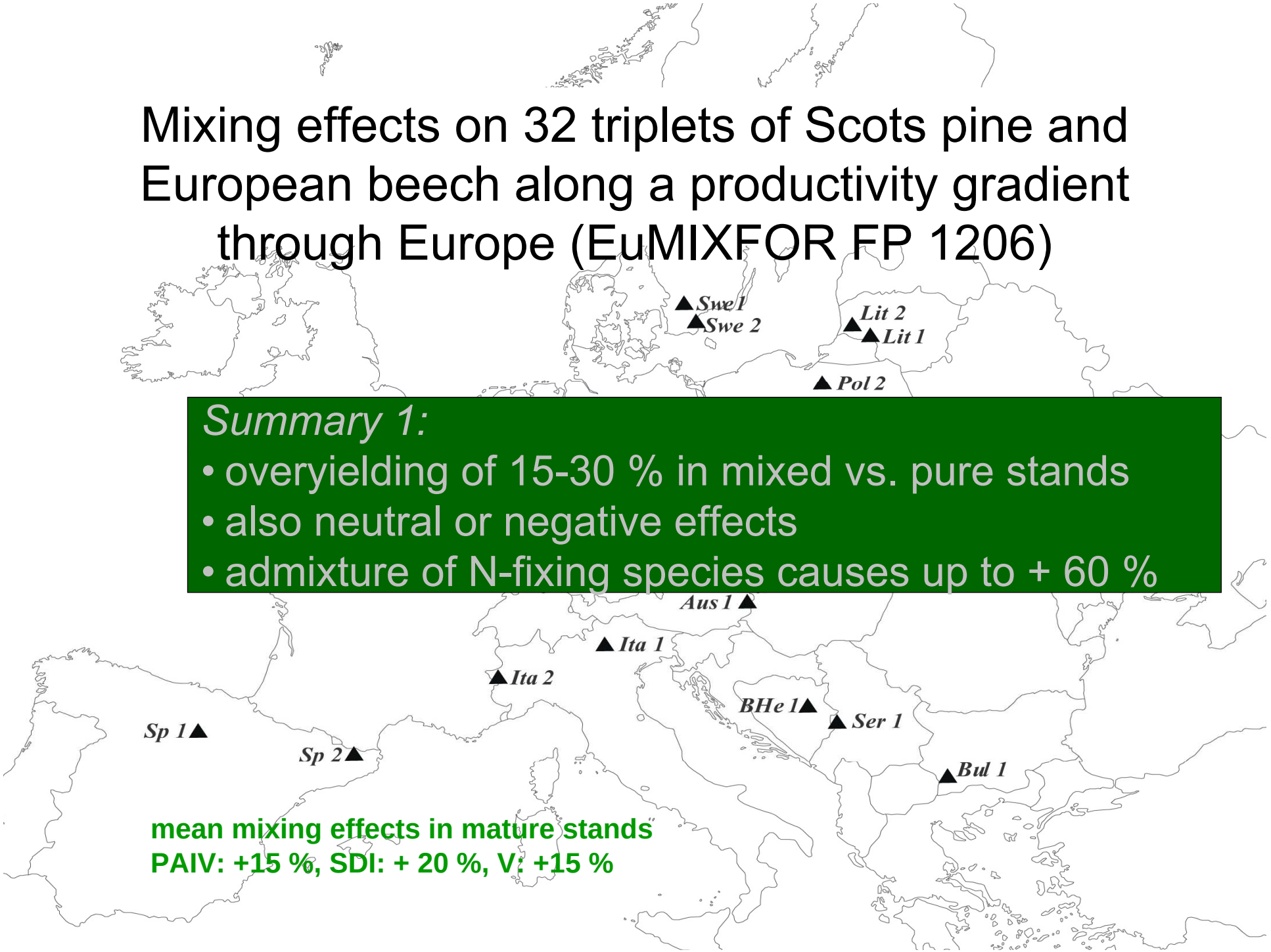

Summary 1:

- overyielding of 15-30 % in mixed vs. pure stands
- also neutral or negative effects
- admixture of N-fixing species causes up to + 60 %

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

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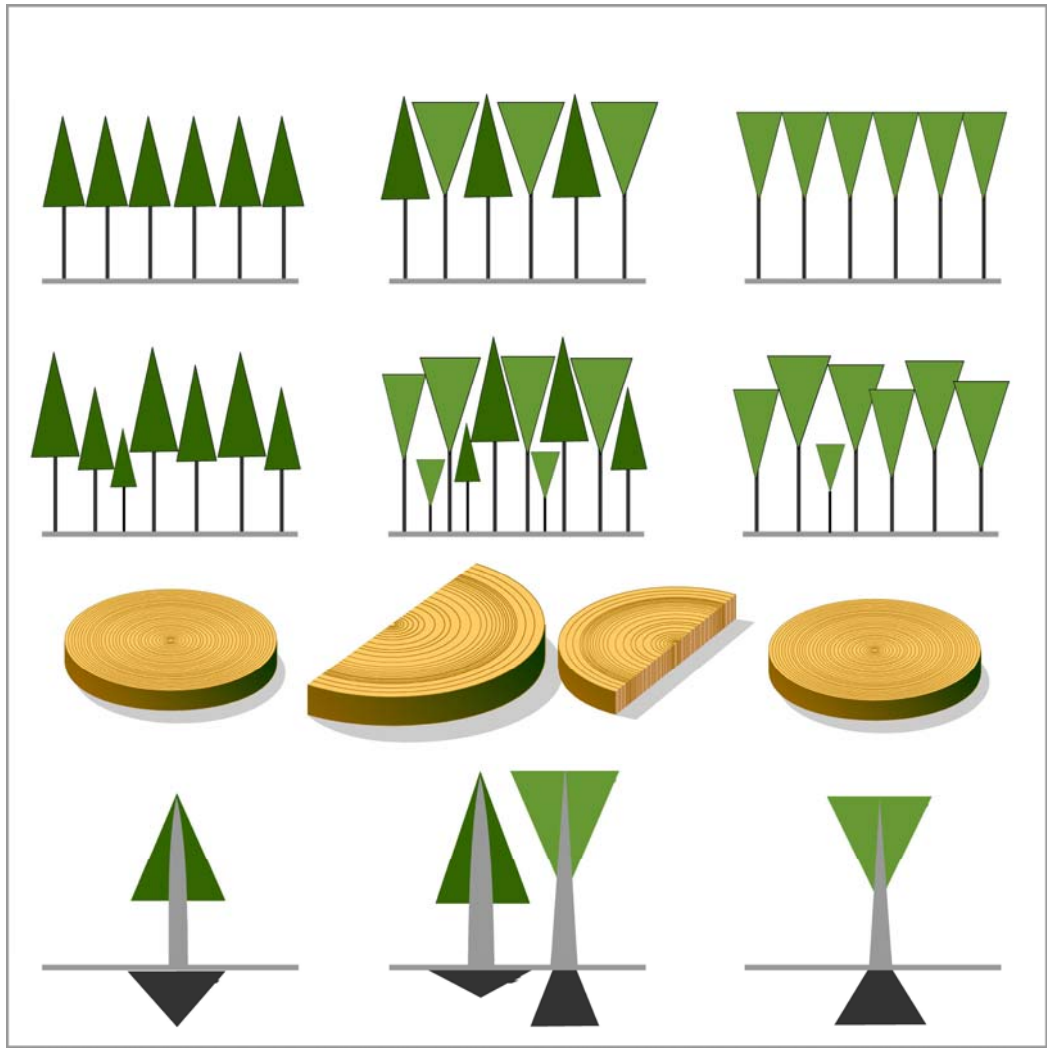
Tracing tree species mixing effects from the stand to the tree level

Stand and mean tree level

Size-structure level

Tree and organ level



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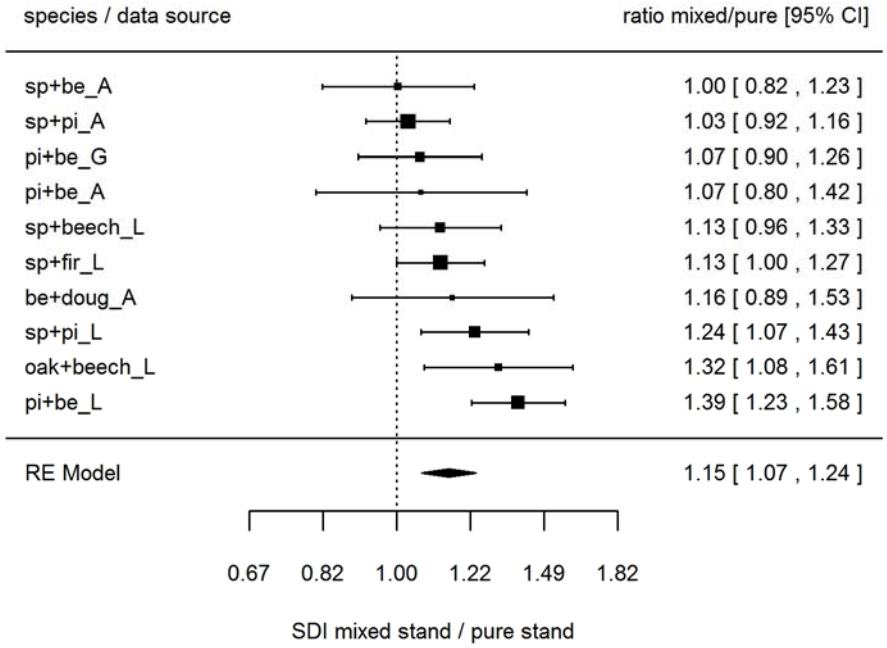
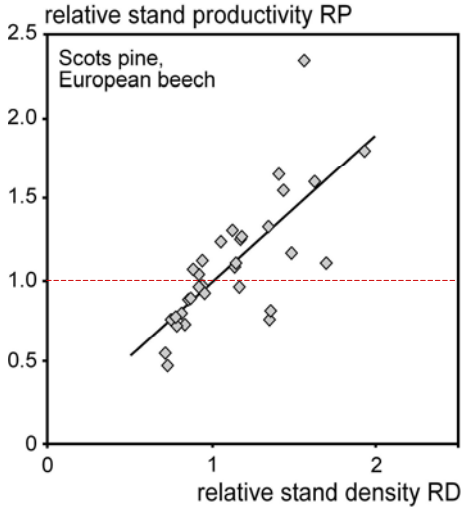
Meta-analysis of stand density in fully stocked mixed versus pure stands (left) and effect of stand density on overyielding of mixed Scots pine/E. beech stands (right)





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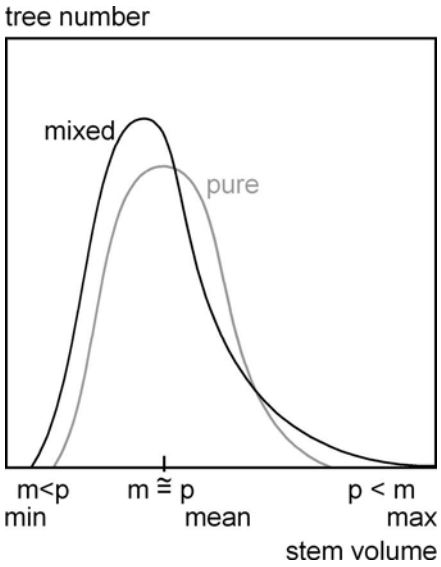
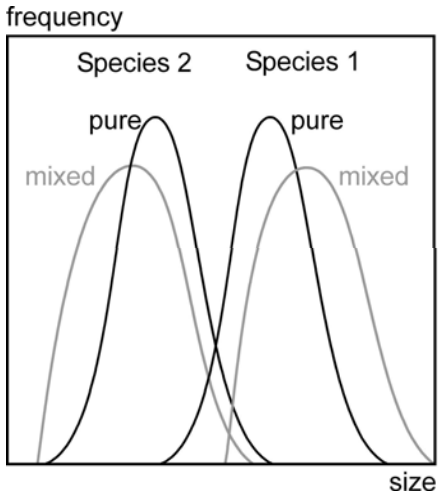
More trees, wider size range, stronger right-skewness in mixed stands; often species 1 ahead, species 2 behind the pure stand





Species	n	tree number (ha^{-1}) mean mixed	mean pure	tree number mixed/pure min	max	mean	SE
N.sp. / E.be	22	571±72	655±68	0.39	1.68	0.98	0.07
Sc.p. / E.be	14	1093±268	1057±185	0.51	4.01	1.32	0.23
D.-fir. / E.be	36	1051±218	902±136	0.32	3,83	1.39**	0.13
N.sp. / Sc.p.	12	1075±78	946±94	0.65	1.84	1.26*	0.13
total	84	935±109	869±70	0.32	4.01	1.25	0.07

Pretzsch, H., Schütze, G. (2014) Size-structure dynamics of mixed versus pure forest stands, Forest Systems, 23(3):560-572.

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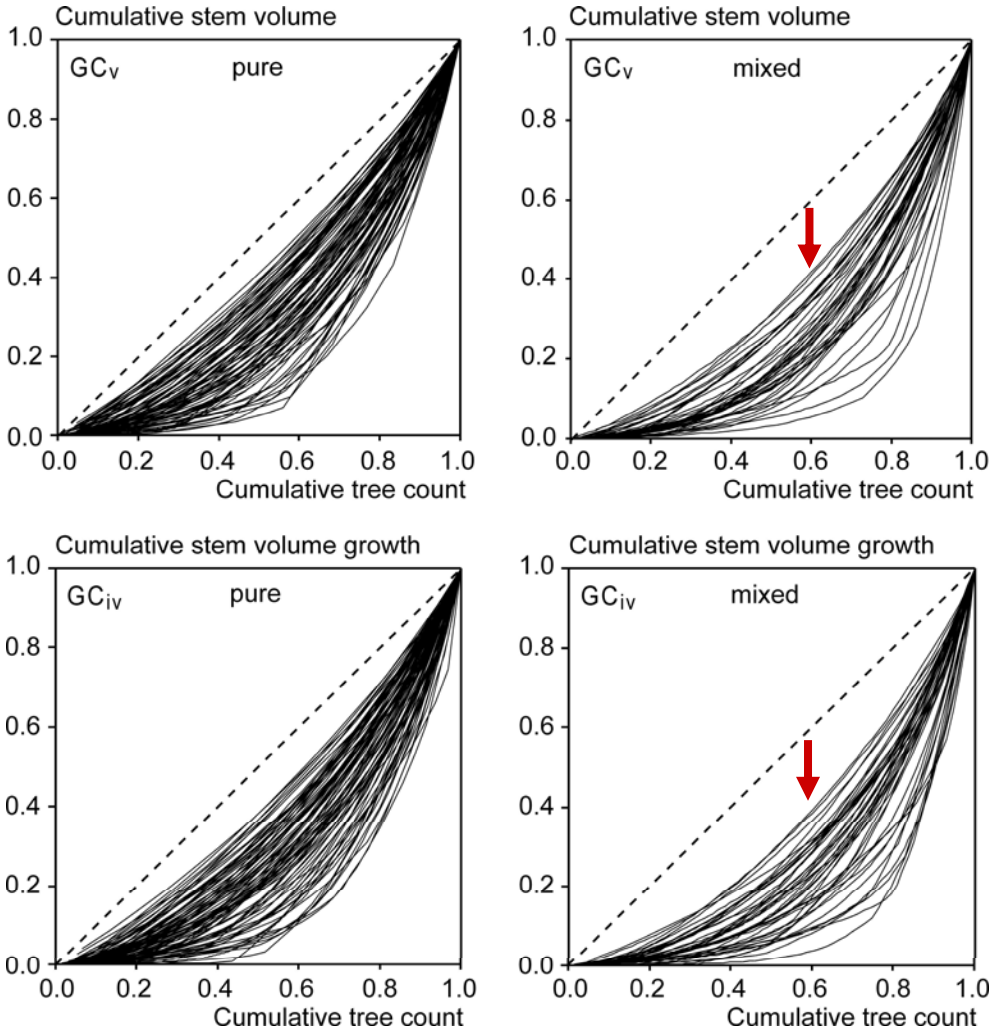
Cumulative distribution of stem volume (above) and stem growth (below) over cumulative tree count (Lorenz-curve Gini-coefficient)



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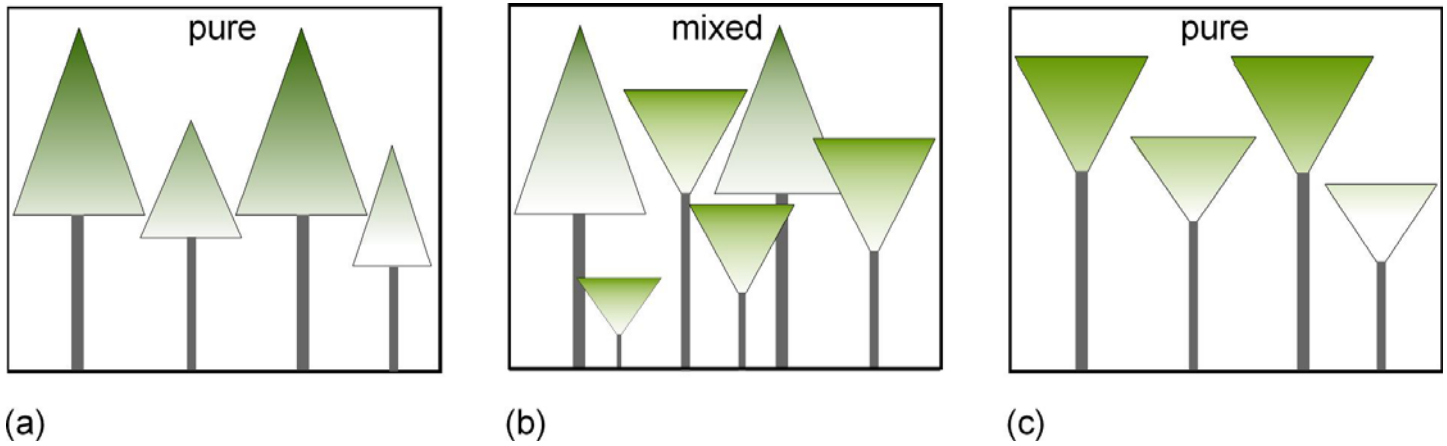
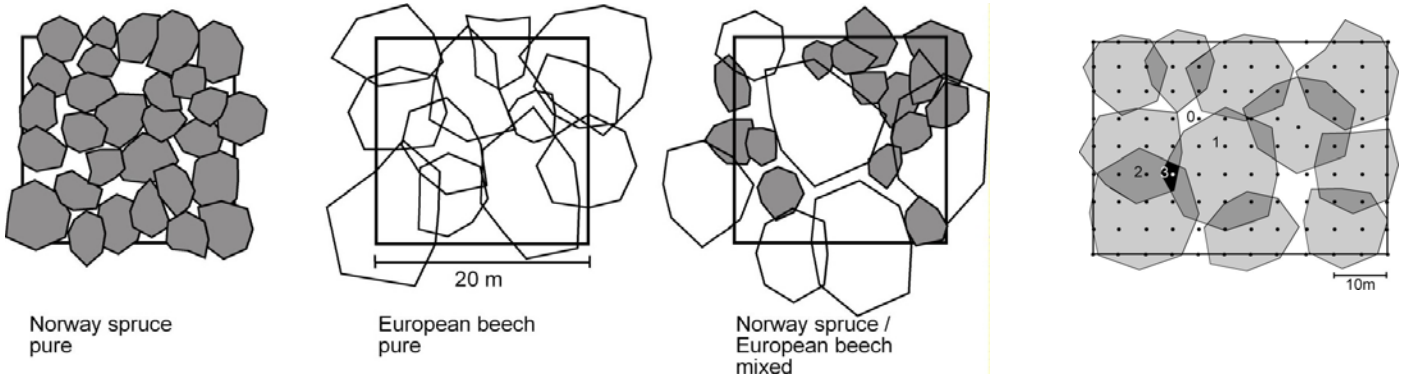
Complementary in light ecology enables more smaller trees to survive and grow efficiently





Pretzsch, H. (2014) Canopy space filling and tree crown morphology in mixed-species stands compared with monocultures. Forest Ecology and Management, 327: 251-264.

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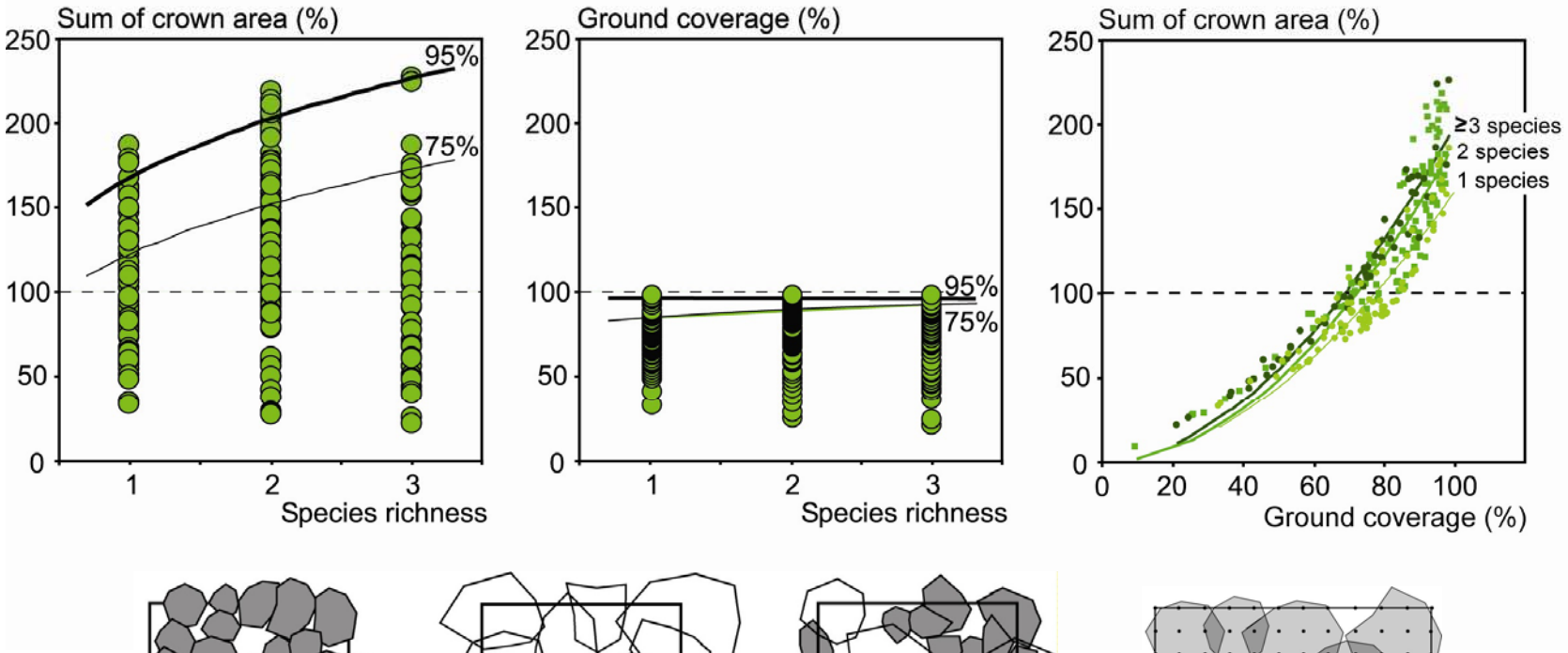
Denser canopy space filling in mixed stands: higher sum of crown area and multiple ground coverage



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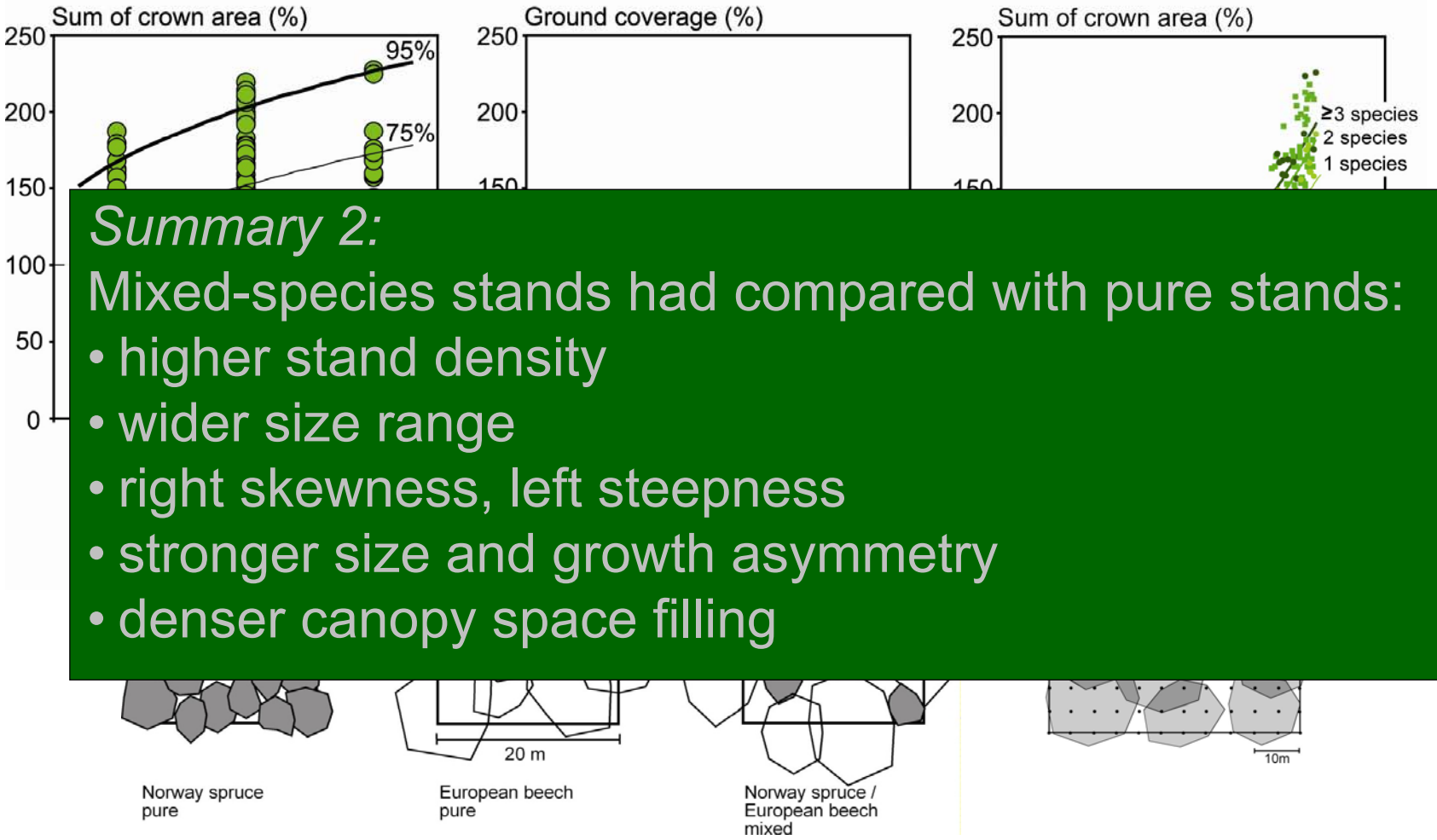

Summary 2:

Mixed-species stands had compared with pure stands:

- higher stand density
- wider size range
- right skewness, left steepness
- stronger size and growth asymmetry
- denser canopy space filling

Pretzsch, H. (2014) Canopy space filling and tree crown morphology in mixed-species stands compared with monocultures. Forest Ecology and Management, 327: 251-264.

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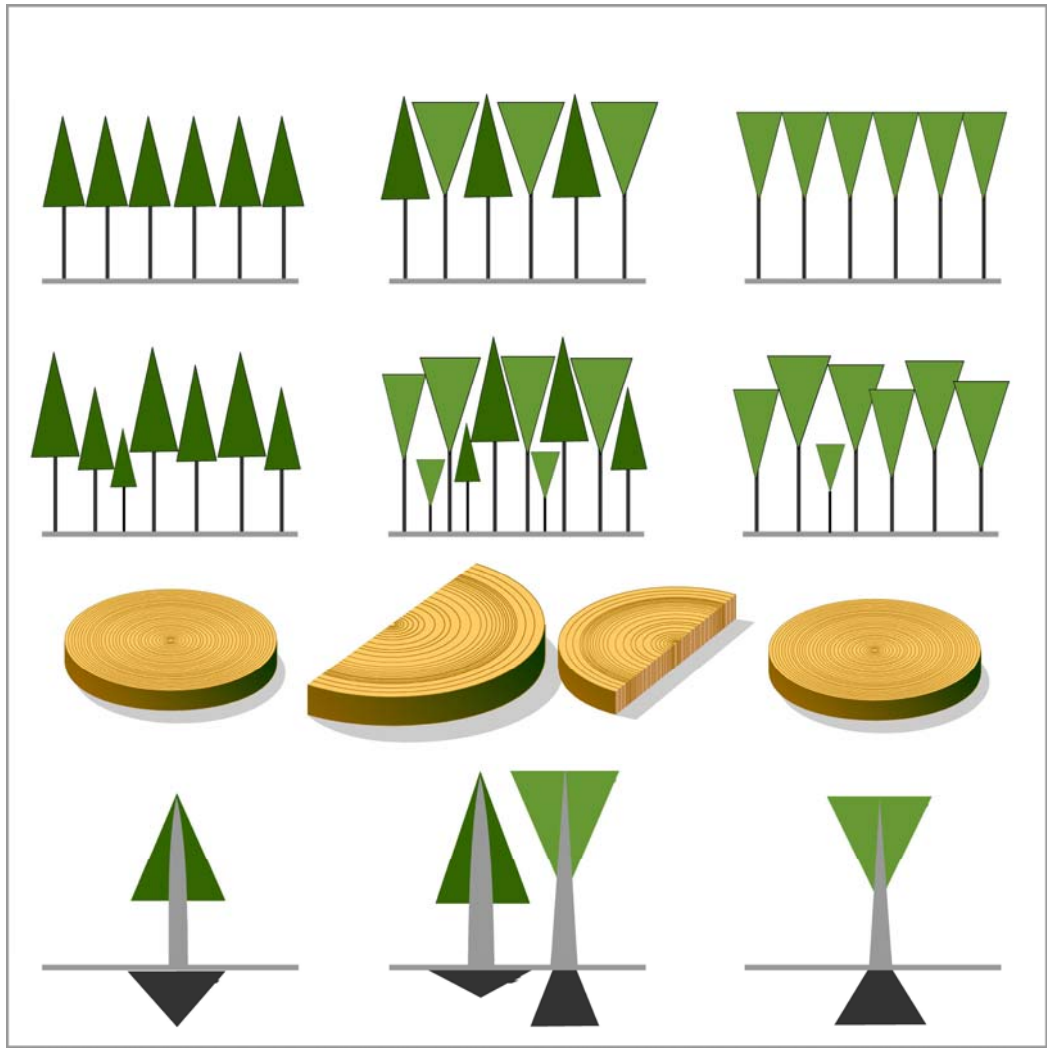
Tracing tree species mixing effects from the stand to the tree level

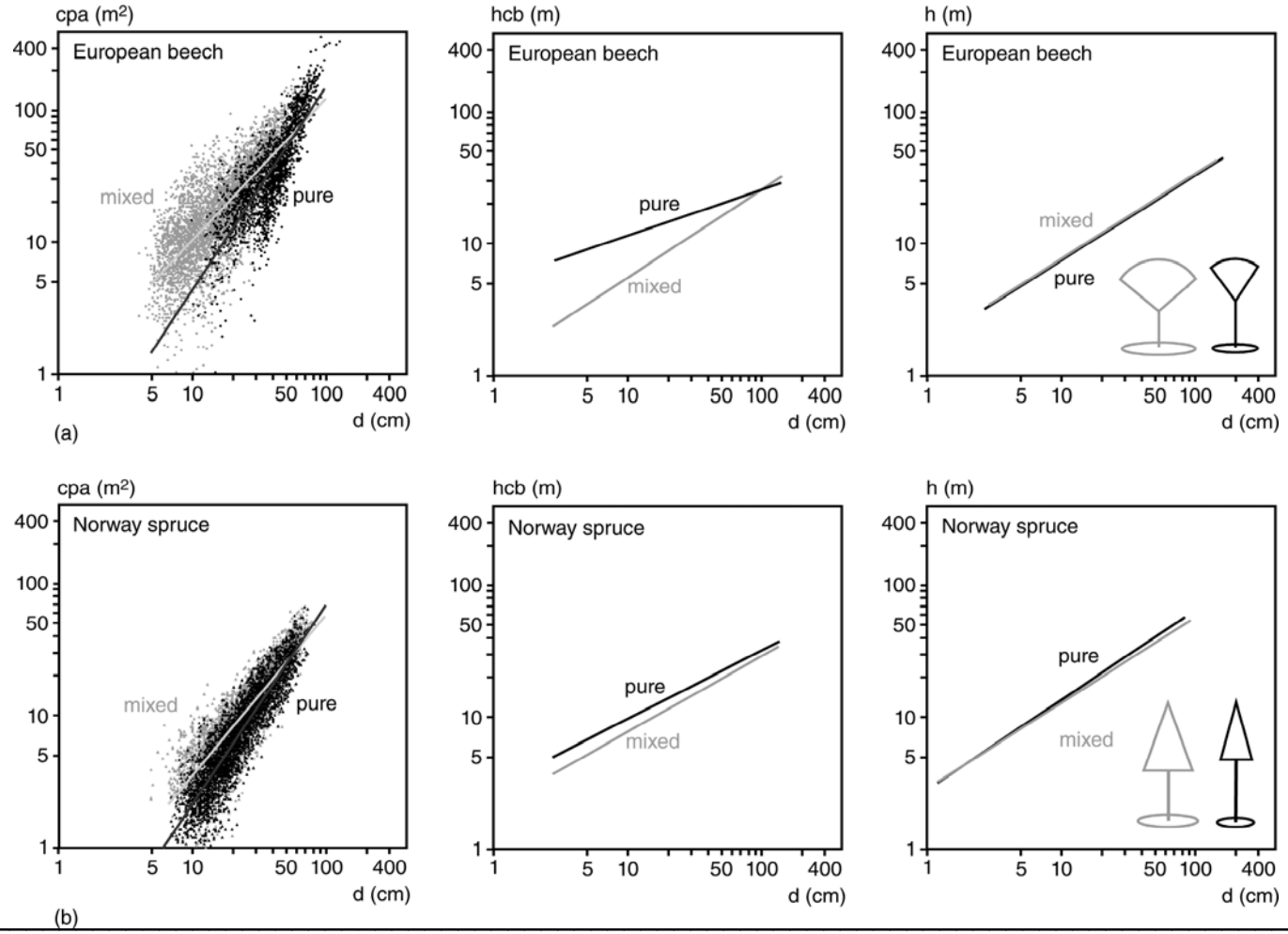
Stand and mean tree level

Size-structure level

Tree and organ level

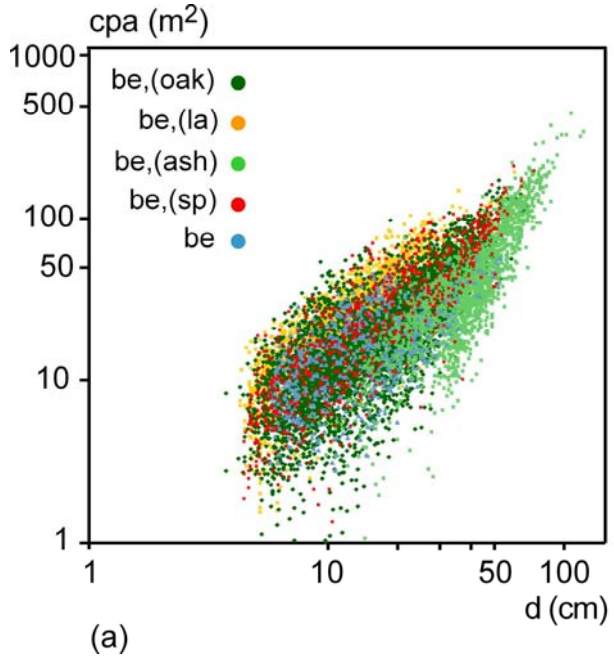


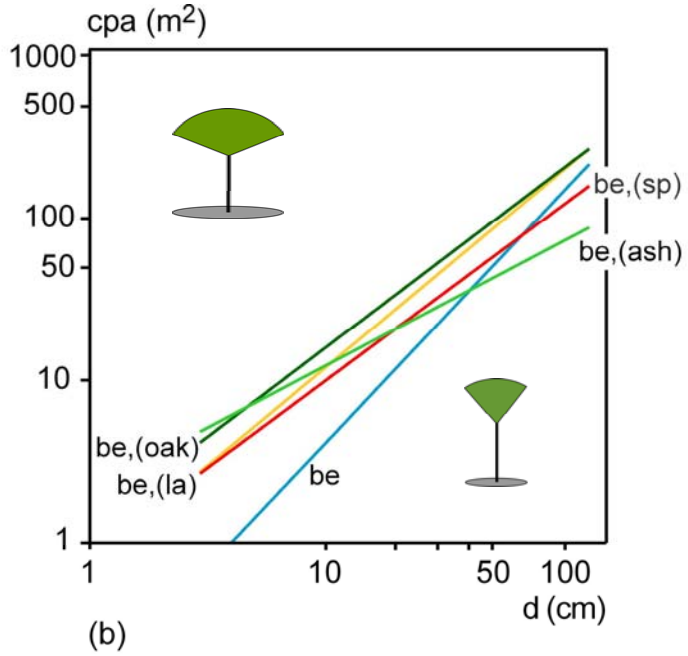
Effect of species mixing on the crown allometry of European beech and Norway spruce



Pretzsch, H. (2014) Canopy space filling and tree crown morphology in mixed-species stands compared with monocultures. Forest Ecology and Management, 327: 251-264.

Allometry between crown projection area and stem diameter of European in pure stands and when mixed with other tree species



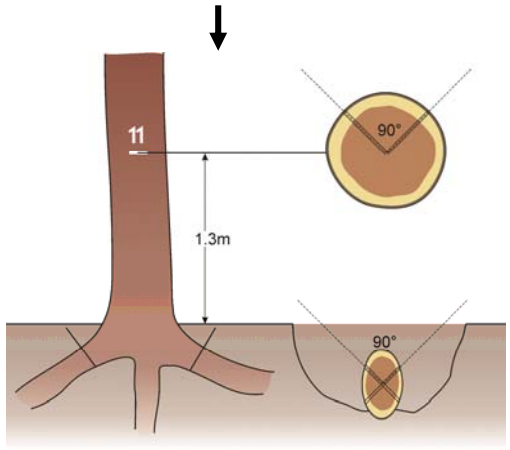


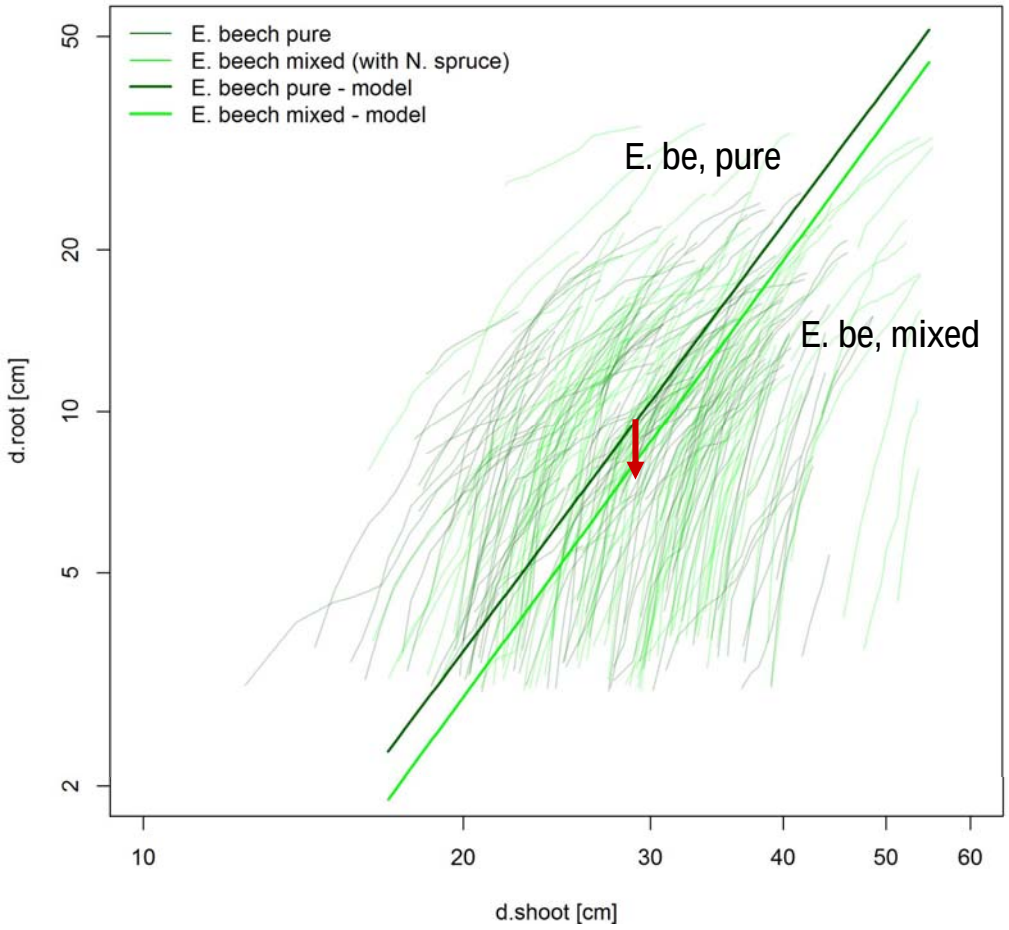
s. oak
E. ash
E. larch
N. spruce

Pretzsch, H. (2014) Canopy space filling and tree crown morphology in mixed-species stands compared with monocultures. Forest Ecology and Management, 327: 251-264.

Allometry between coarse root and stem growth of E. be. in pure stands and mixed with N. sp.

n=230 trees
($n_{be=63}$, $n_{(sp),be}$=56)
sampled along the ecological gradient from Arnstein to Kelheim, Allershausen, Wasserburg, Traunstein





Pretzsch, H., Heym, M., Pinna, S., and Schneider, R. (2014) Effect of variable retention cutting on the relationship between growth of coarse roots and stem of Picea mariana. *Scand. Journal of Forest Research*, *29*(3), 222-233.

Allometry between coarse root and stem growth of E. be. in pure stands and mixed with N. sp.

n=230 trees
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sample
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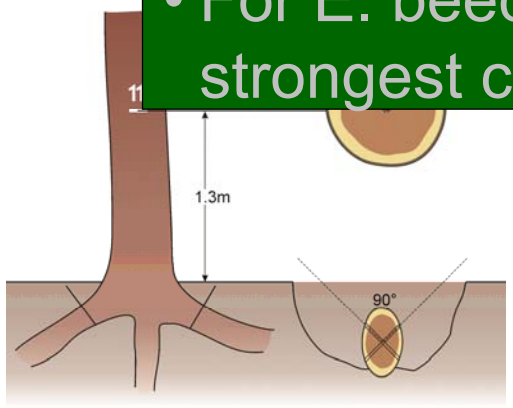

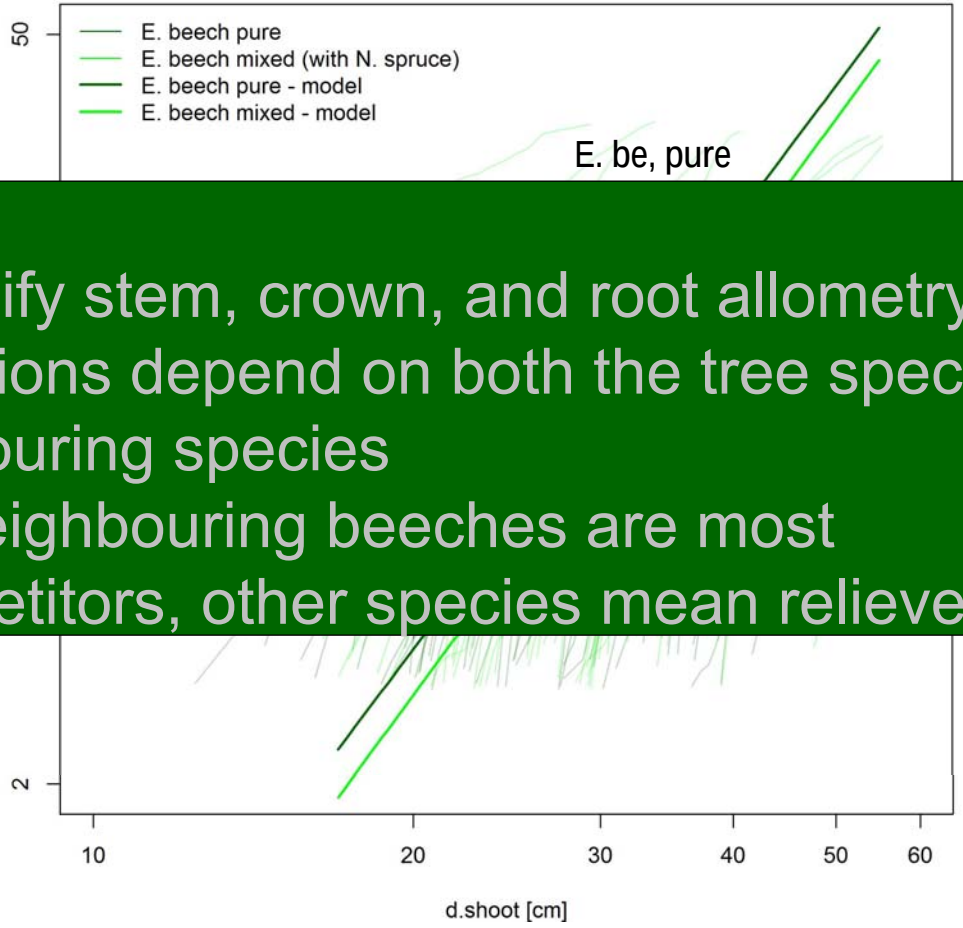

Summary 3:

- Mixing can modify stem, crown, and root allometry
- Allometric reactions depend on both the tree species and the neighbouring species
- For E. beech neighbouring beeches are most strongest competitors, other species mean relieve

Pretzsch, H., Heym, M., Pinna, S., and Schneider, R. (2014) Effect of variable retention cutting on the relationship between growth of coarse roots and stem of Picea mariana. *Scand. Journal of Forest Research*, *29*(3), 222-233.

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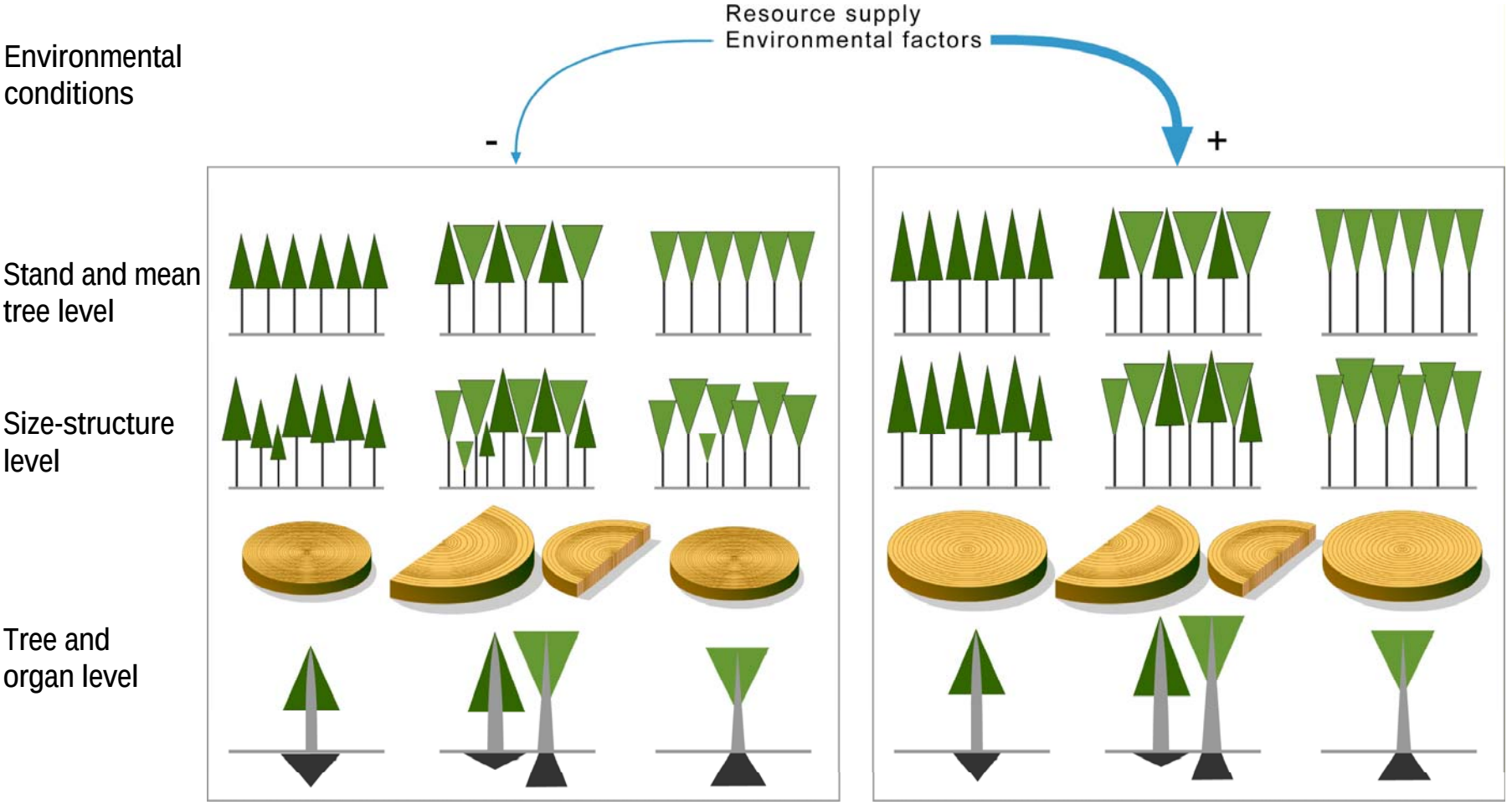
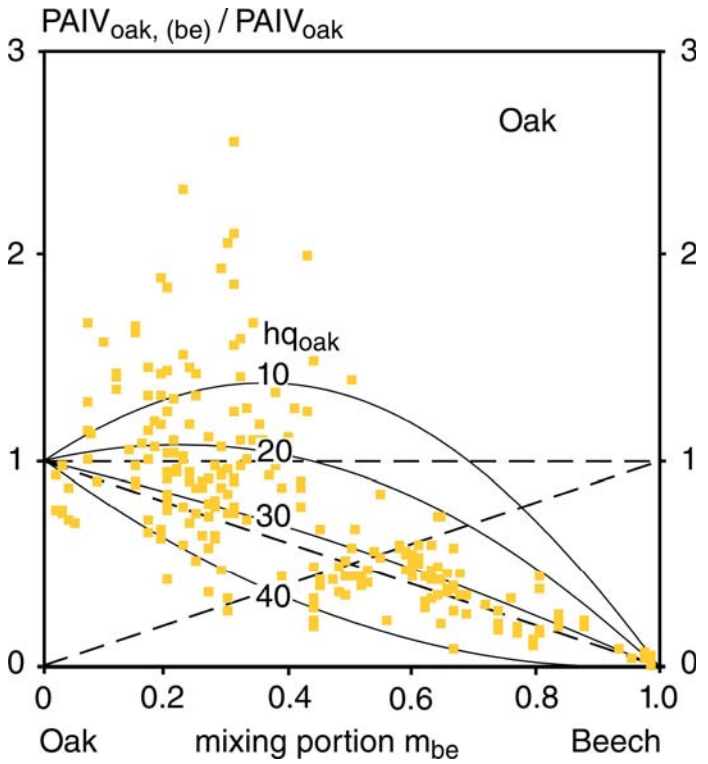
Spatial and temporal variation of species mixing effects on stand and tree growth

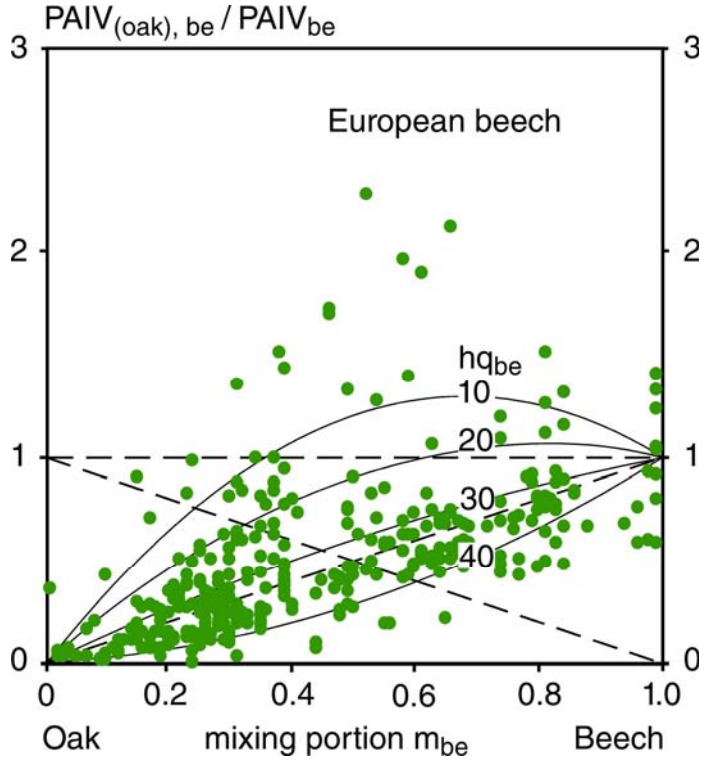


Site index (hq in m at age 100) as modifier of mixing reactions between sessile oak and E. beech



$RP_{oak,(be)} = m_{oak} \times (1 + 4.685 \times m_{be} - 0.145 \times m_{be} \times hq_{oak})$

$n = 296, R^2 = 0.46, p<0.01$



$RP_{(oak),be} = m_{be} \times (1 + 4.033 \times m_{oak} - 0.122 \times m_{oak} \times hq_{be})$

$n = 428, R^2 = 0.37, p<0.01$

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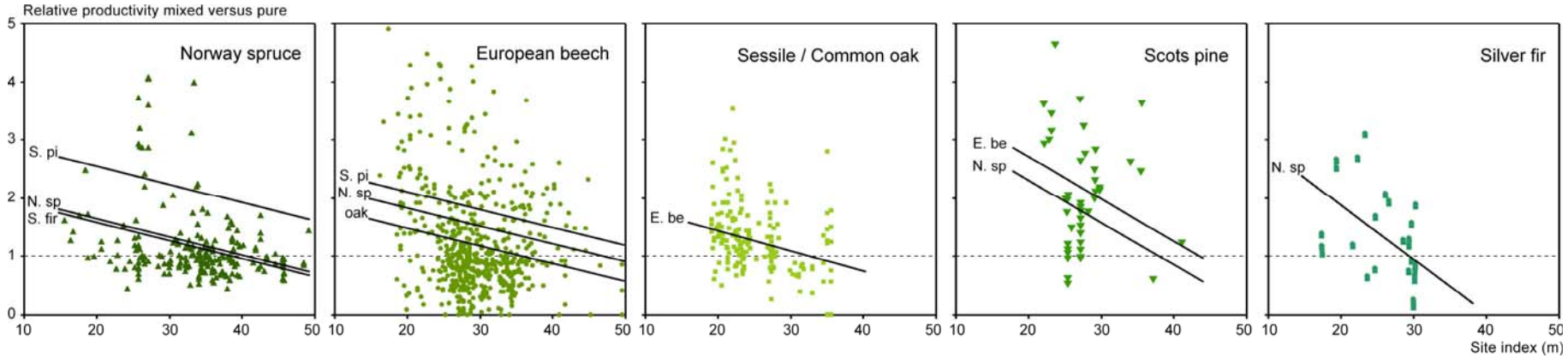
Decrease of the overyielding of mixed versus pure stands with increase of the site index



Target species sp_1 Admixed species sp_2, sp_3, sp_4	**N. spruce** S. fir, E. be S. pine	**E. beech** S. oak, N. sp, S. pine	**S. oak** E. be	**S. pine** N. sp, S. pine	**S. fir** N. sp
$rp'_{1,(2)}$					
intercept	1.54	-0.03	1.84	4.45	3.30
m_2	0.88	1.42	-0.33	-1.82	1.02
hq_1	-	0.02	0.02	-	-
hq_1/hq_2	-	1.01	-	-	-
site index sp_1	-0.03	-0.31	-0.03	-0.07	-0.10
dummy sp_3	0.10	0.33	-	0.52	-
dummy sp_4	1.19	0.60	-	-	-
n total	223	648	215	49	32
whole model R^2	0.38	0.18	0.14	0.24	0.42

Pretzsch et al. 2013: Species mixing and productivity of forests, German Journal of Forest Research, 184 (7/8): 177-196

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Decrease of the overyielding of mixed versus pure stands with increase of the site index

Summary 4:

- Stronger benefit on poor than on fertile sites
- Level of the benefit varies by species combination

Target species sp_1	**N. spruce**	**E. beech**	**S. oak**	**S. pine**	**S. fir**
Admixed species sp_2, sp_3, sp_4	S. fir, E. be S. pine	S. oak, N. sp, S. pine	E. be	N. sp, S. pine	N. sp
$rp'_{1,(2)}$					
intercept	1.54	-0.03	1.84	4.45	3.30
m_2	0.88	1.42	-0.33	-1.82	1.02
hq_1	-	0.02	0.02	-	-
hq_1/hq_2	-	1.01	-	-	-
site index sp_1	-0.03	-0.31	-0.03	-0.07	-0.10
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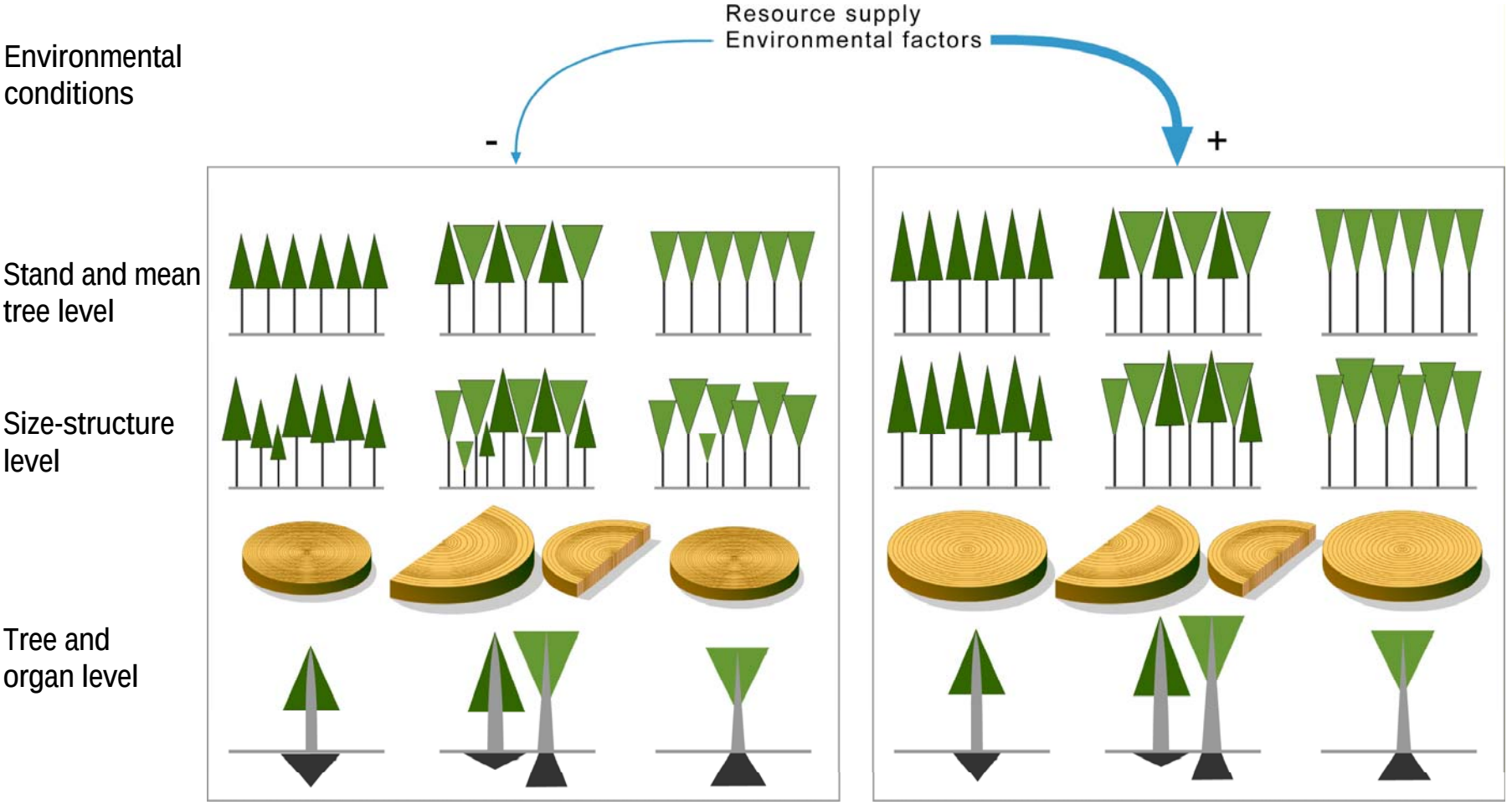
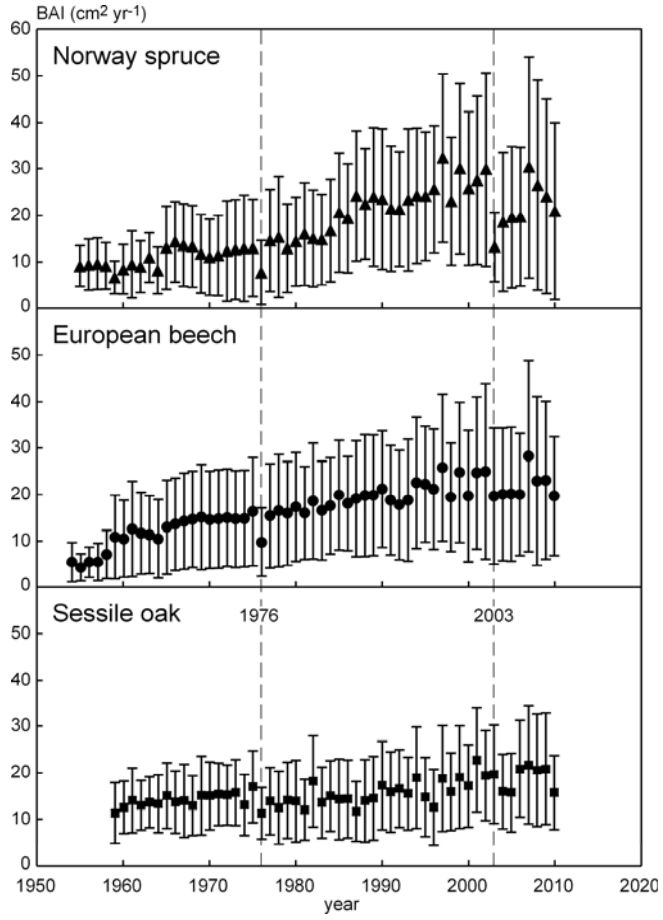
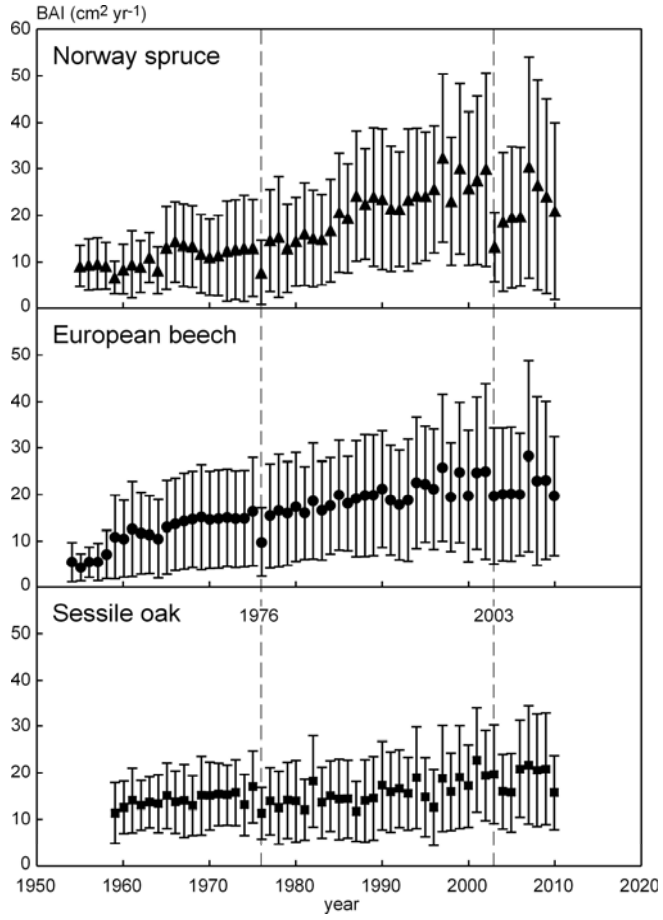


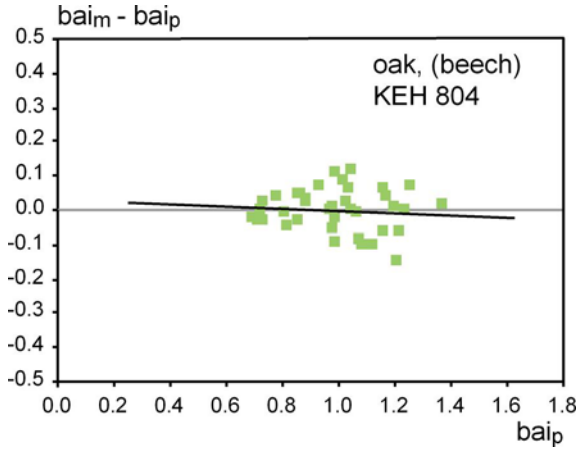
Mean (± std.dev.) tree growth in pure and mixed species stands in Bavaria (143 sp, 287 be, 129 oak)

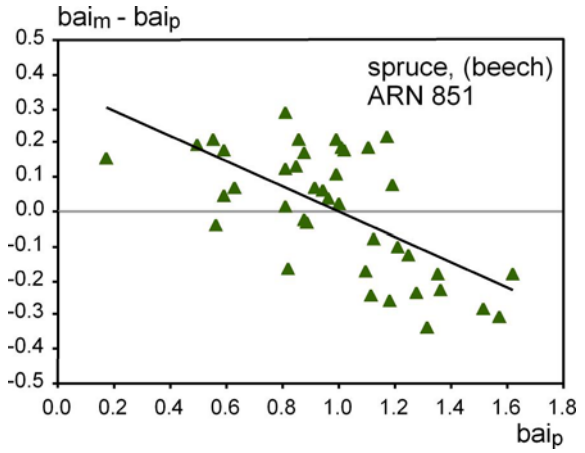


Pretzsch H, Schütze G, Uhl E, 2013: Resistance of European tree species to drought stress ... Plant Biology, 15: 483-495
Lebourgeois et al. 2013: Mixed stands reduce *Abies alba* tree-ring sensitivity to summer drought ...
Forest Ecology and Management 303, 61-71

Analysis of temporal variation of mixing effects: Retrospective analyses based on increment cores







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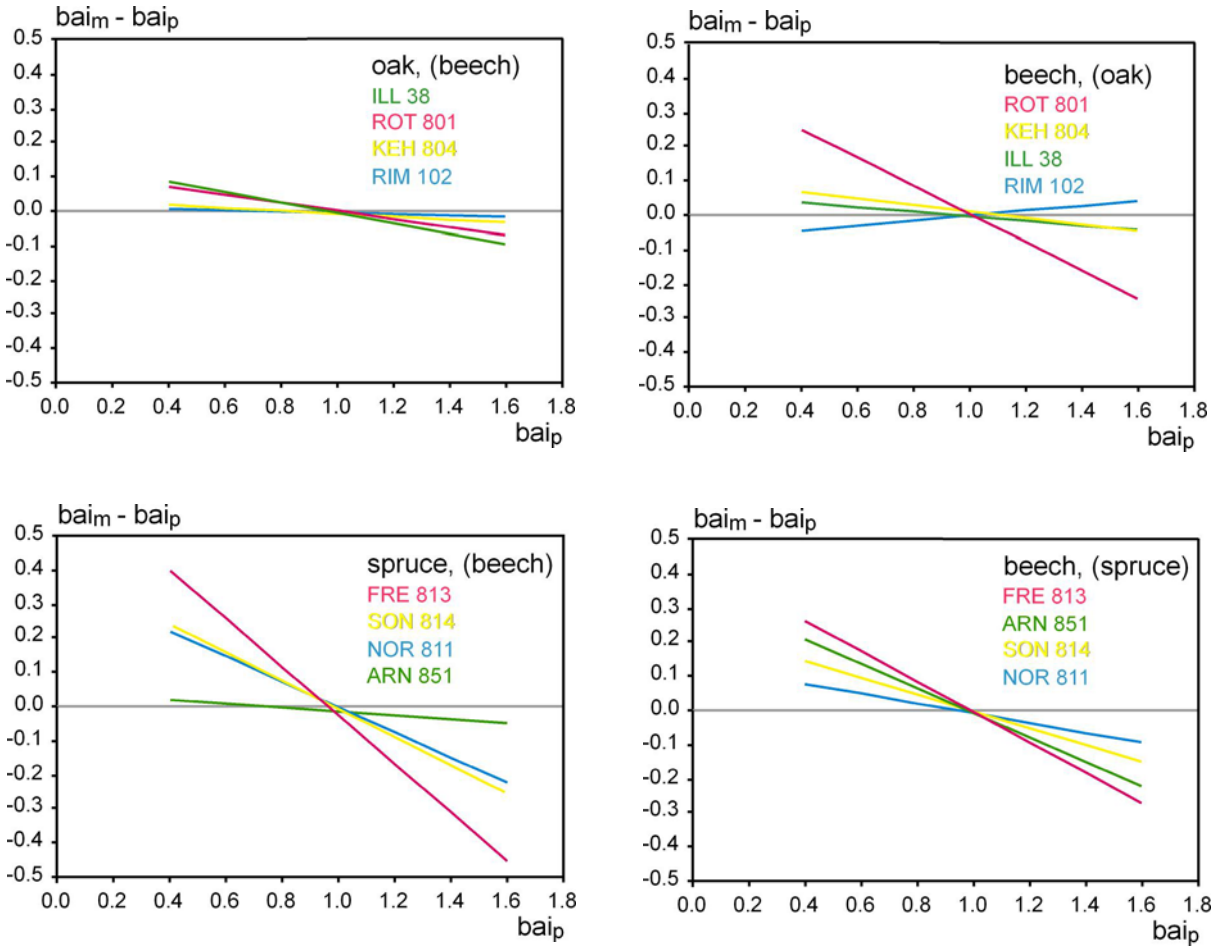
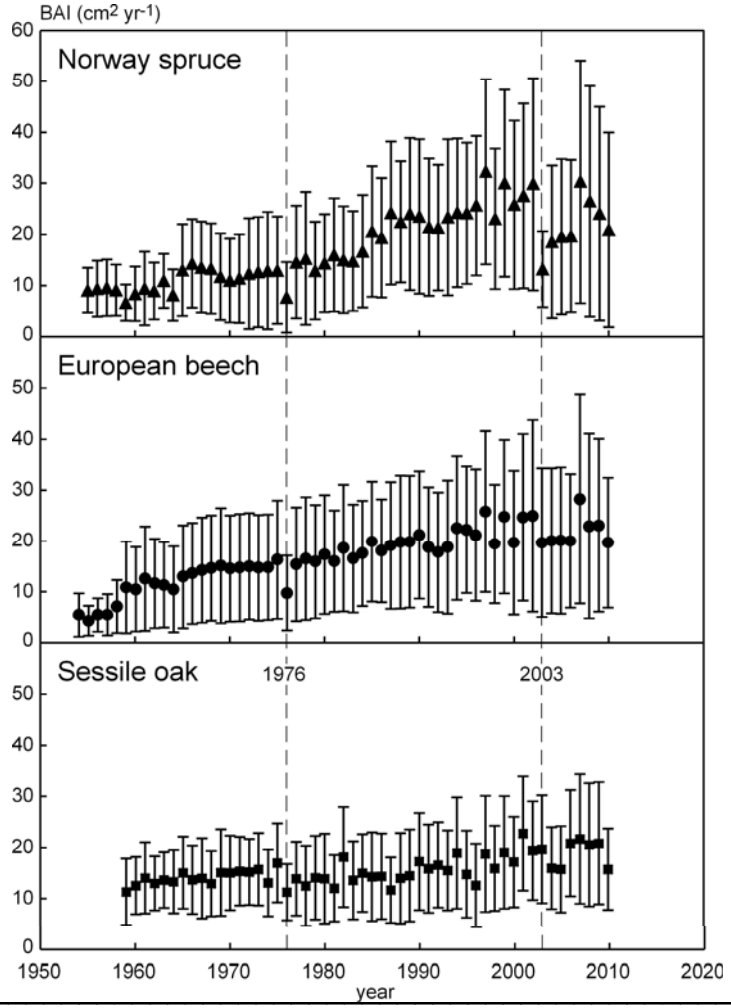
Forest Ecology and Management 303, 61-71

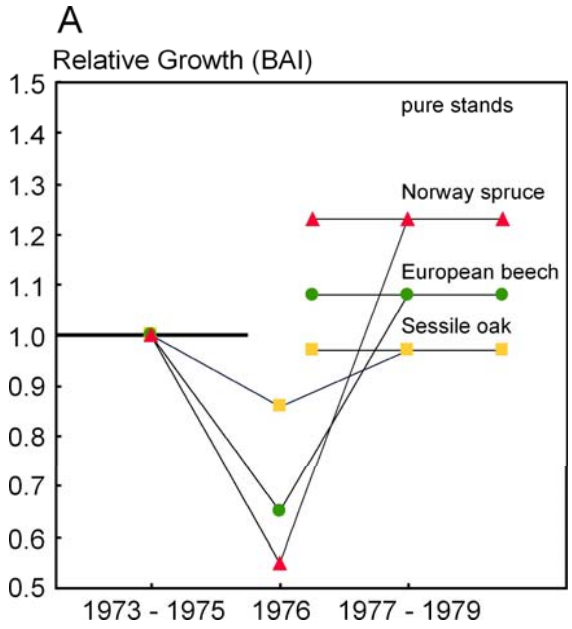
Temporal variation of mixing effects: Retrospective analyses based on increment cores



Río del, M. et al. 2014: Temporal variation of competition and facilitation in mixed species forests in Central Europe, Plant Biology, 16:166-176

Mean (± std.dev.) growth curves in pure and mixed species stands in Bavaria (143 sp, 287 be, 129 oak)





Pretzsch H, Schütze G, Uhl E, 2013: Resistance of European tree species to drought stress ... Plant Biology, 15: 483-495
Lebourgeois et al. 2013: Mixed stands reduce *Abies alba* tree-ring sensitivity to summer drought ... Forest Ecology and Management 303, 61-71

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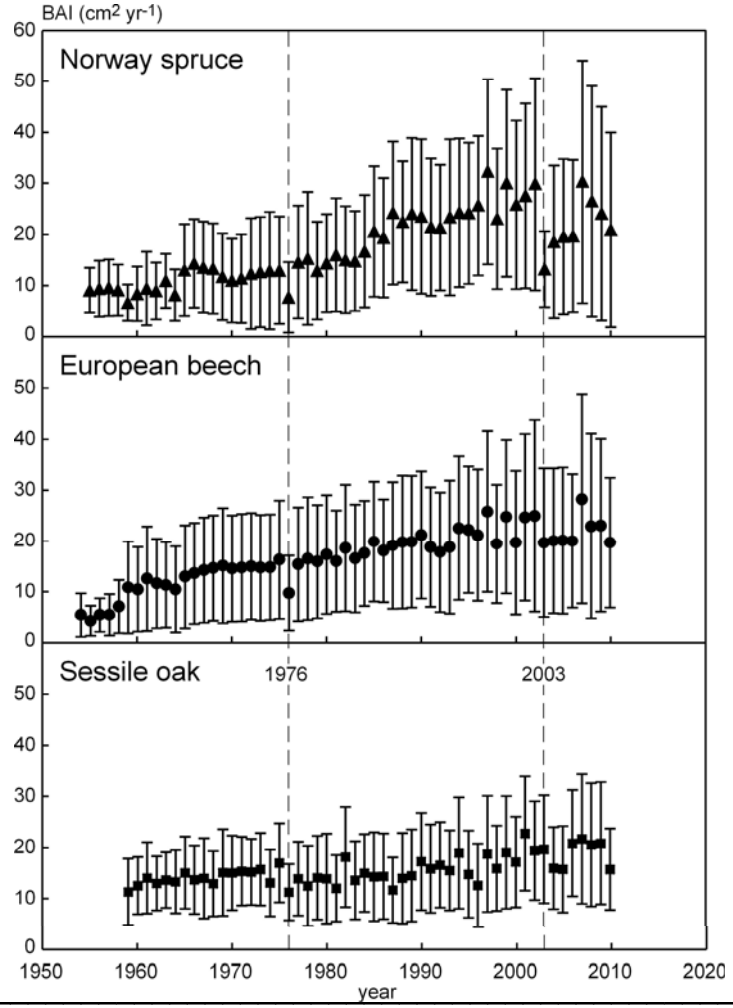

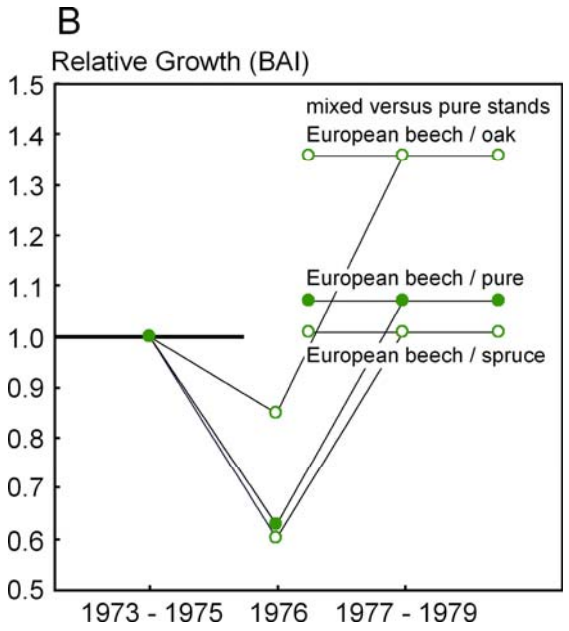

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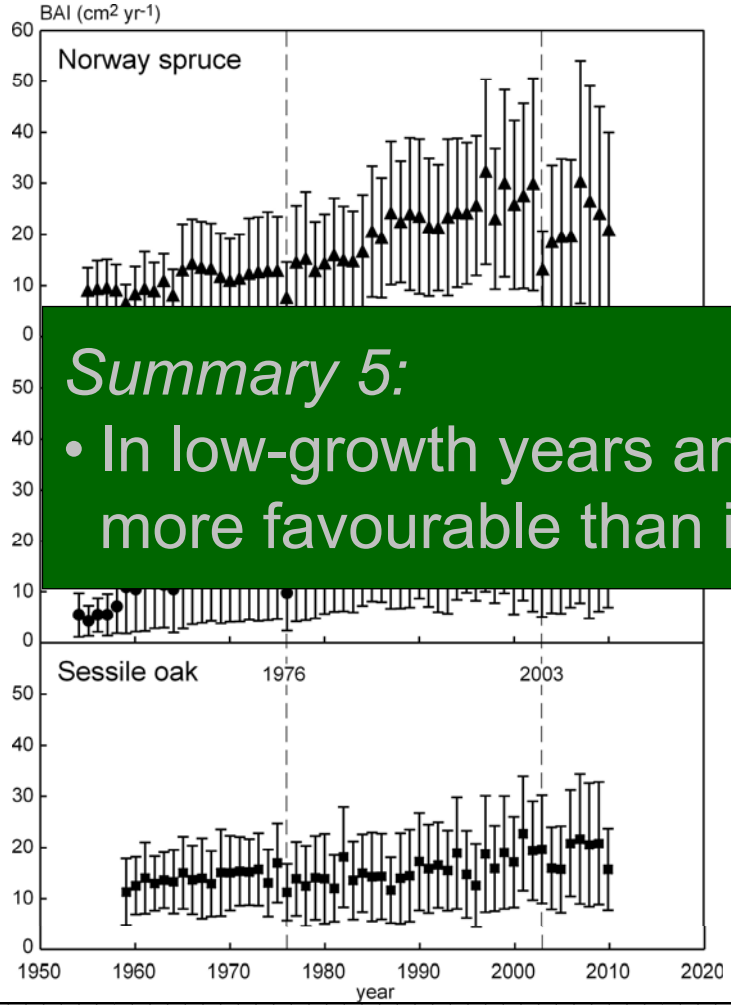
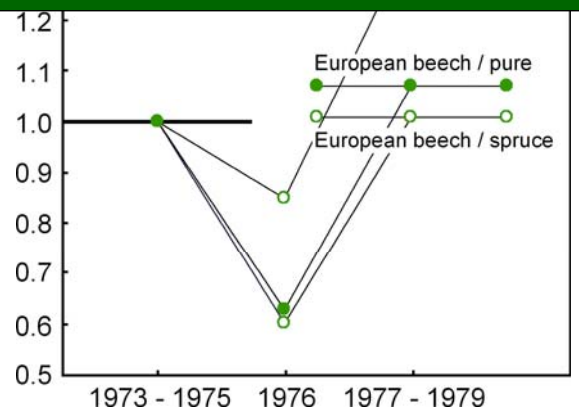


Summary 5:

- In low-growth years and dry years mixing can be more favourable than in high-growth years



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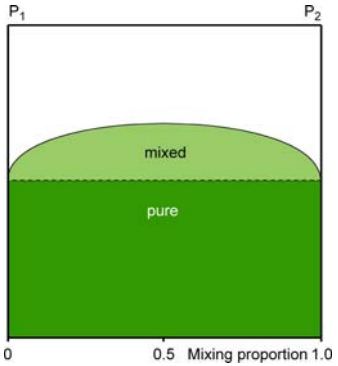
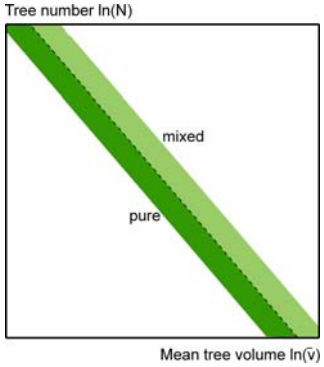
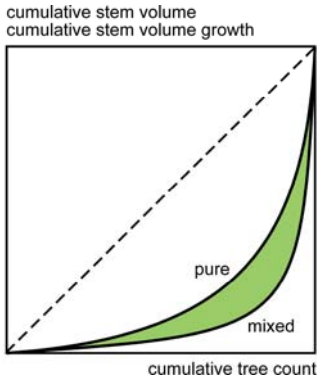
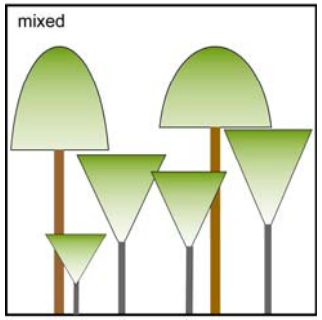
Summary and working hypotheses on reaction patterns





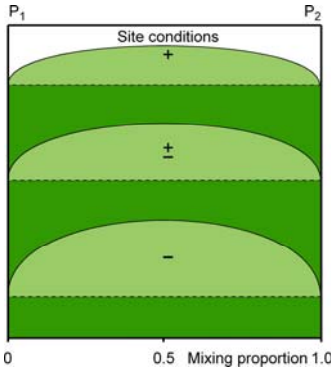
stand productivity and stand density can be increased by species mixing

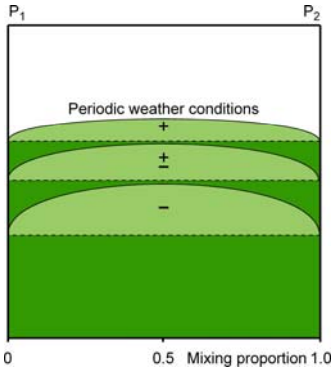




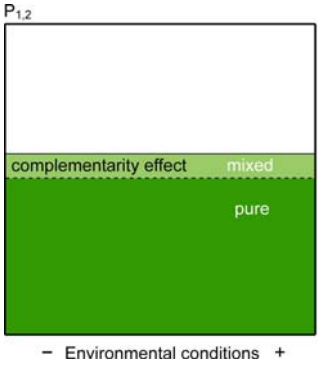
size-asymmetry and canopy space filling can be increased by mixing

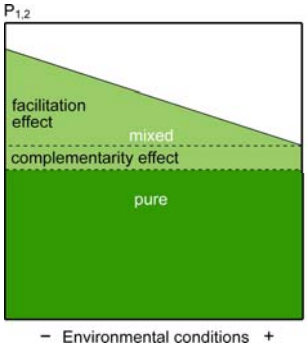
Summary and working hypotheses on reaction patterns





poor site conditions and low-growth years can increase mixing effects





light complementarity and facilitation as main causes for productivity gains by mixing

Waldwachstumskunde
Systemanalyse

Discussion

- Magnitude of the mixing effects on productivity, density, structure dynamics, and morphology can be relevant for forest practice.
  → *Worth while further research*

- Full exploitation of the ecological complementarity requires close intertwining of the species
  → *Individual tree or group mixture*

- More positive mixing effects on poor sites and in low-growth years substantiate SGH
  → *Mitigation of growth losses due to stress*

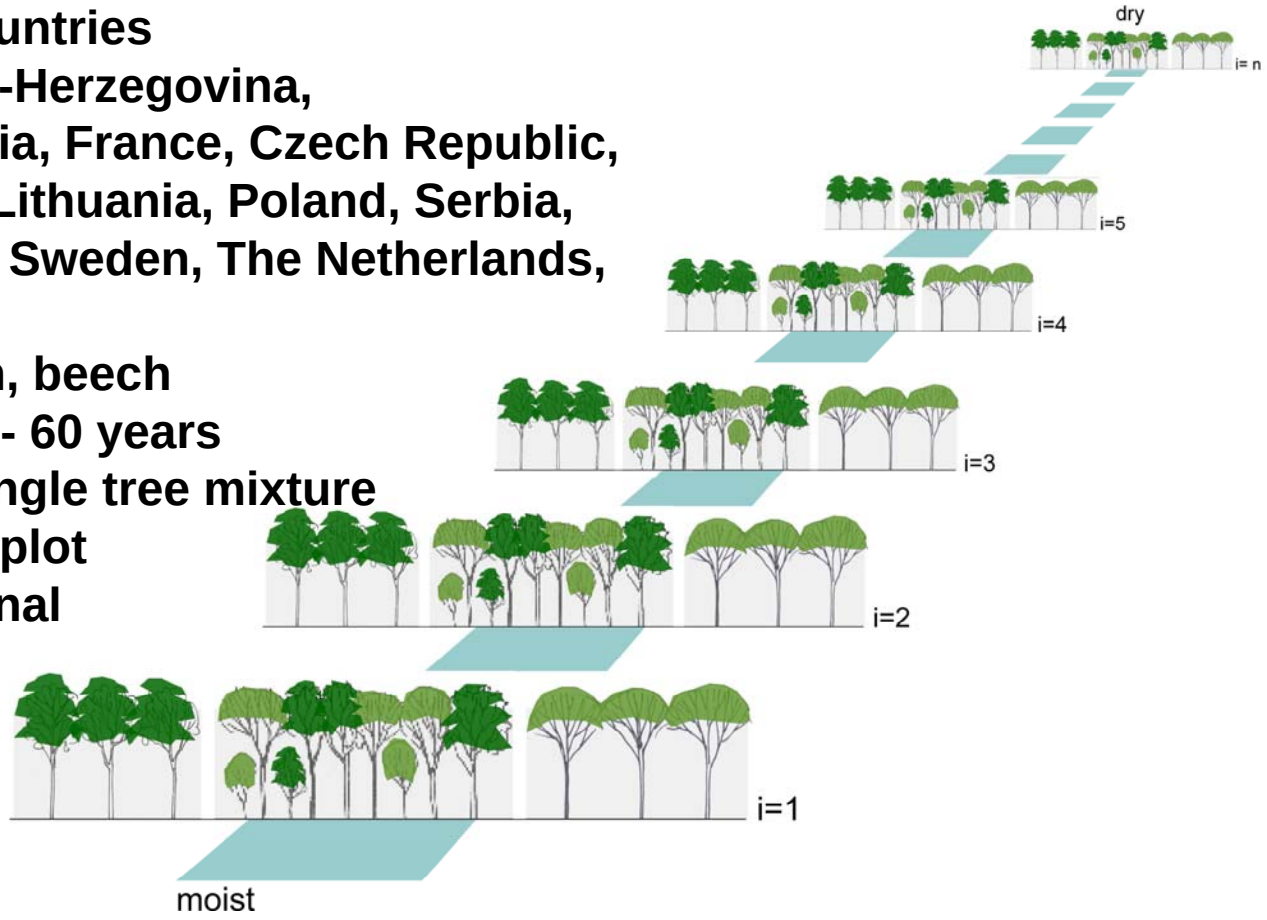
Waldwachstumskunde
Systemanalyse

Critique

- Material: site inhomogeneity, insufficient variation in density, mixing proportion and pattern, small n
  → from artificial time series and snapshots to extensive long-term experiments
- Methods: quantification of mixing portions, stand density, overyielding
  → need for biomass functions, standardization, sensitivity analysis
- Results: statistical relationships, unspecific site characteristics based on, e. g. site index
  → transition to causalities by studies along gradients and by experiments

EuMIXFOR FP1206: Transect study in mixed stands of Scots pine and European beech

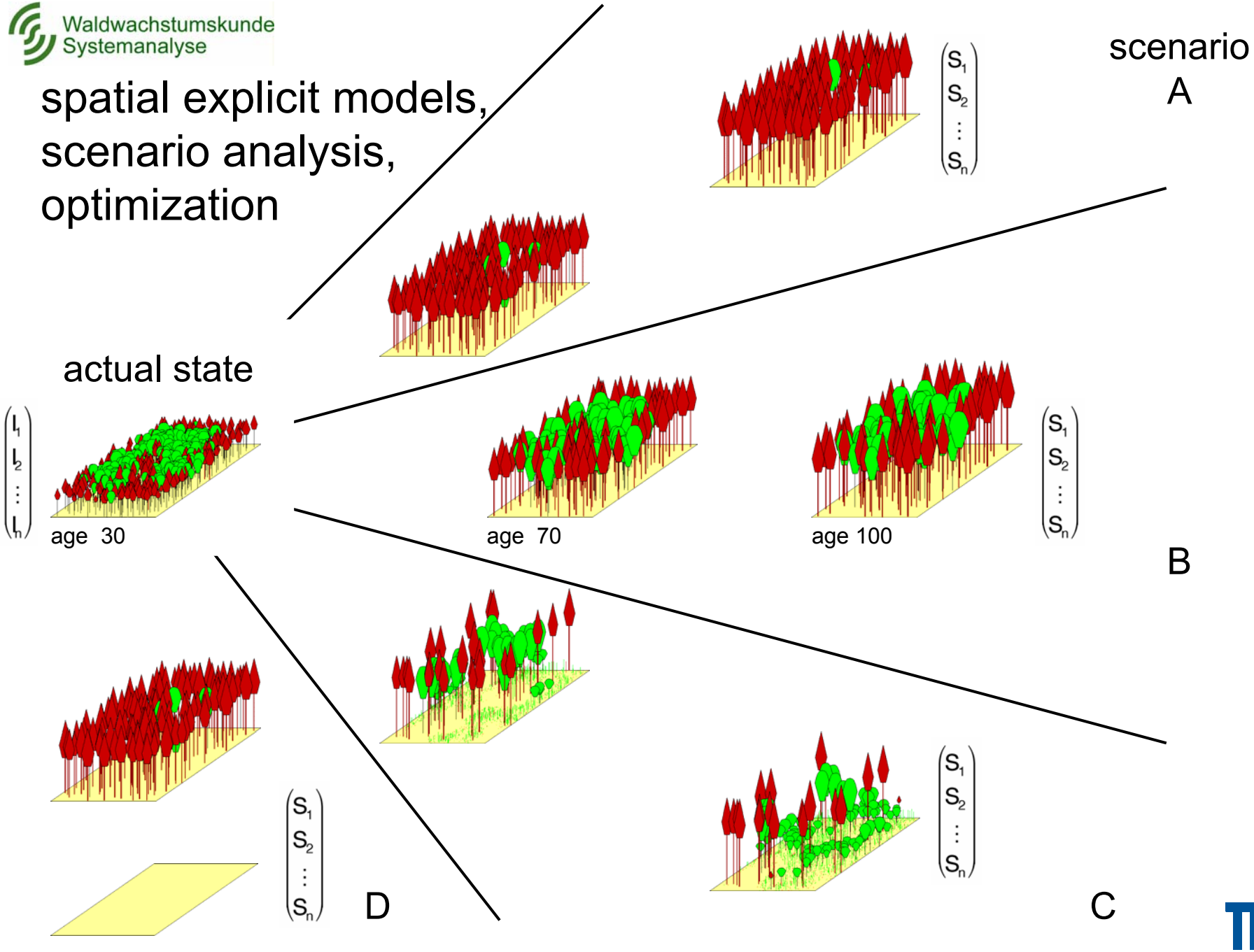
- **32 triplets 16 countries (Austria, Bosnia-Herzegovina, Belgium, Bulgaria, France, Czech Republic, Germany, Italy, Lithuania, Poland, Serbia, Slovakia, Spain, Sweden, The Netherlands, Ukraine)**
- **pine, pine/beech, beech**
- **± even-aged, 40 - 60 years**
- **fully stocked, single tree mixture**
- **~ 20/40/20 trees/plot**
- **obligatory/optional measurements**




KROOF experiment TUM

Waldwachstumskunde
Systemanalyse

spatial explicit models, scenario analysis, optimization



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Bavarian Ministry for Environment and Consumer Protection
European Union
AUDI foundation for the Environment