Waldwachstum
Systemanalyse

TECHNISCHE UNIVERSITÄT MÜNCHEN

Analyzing the effect of species mixing on the structure and productivity of temperate forests in Europe

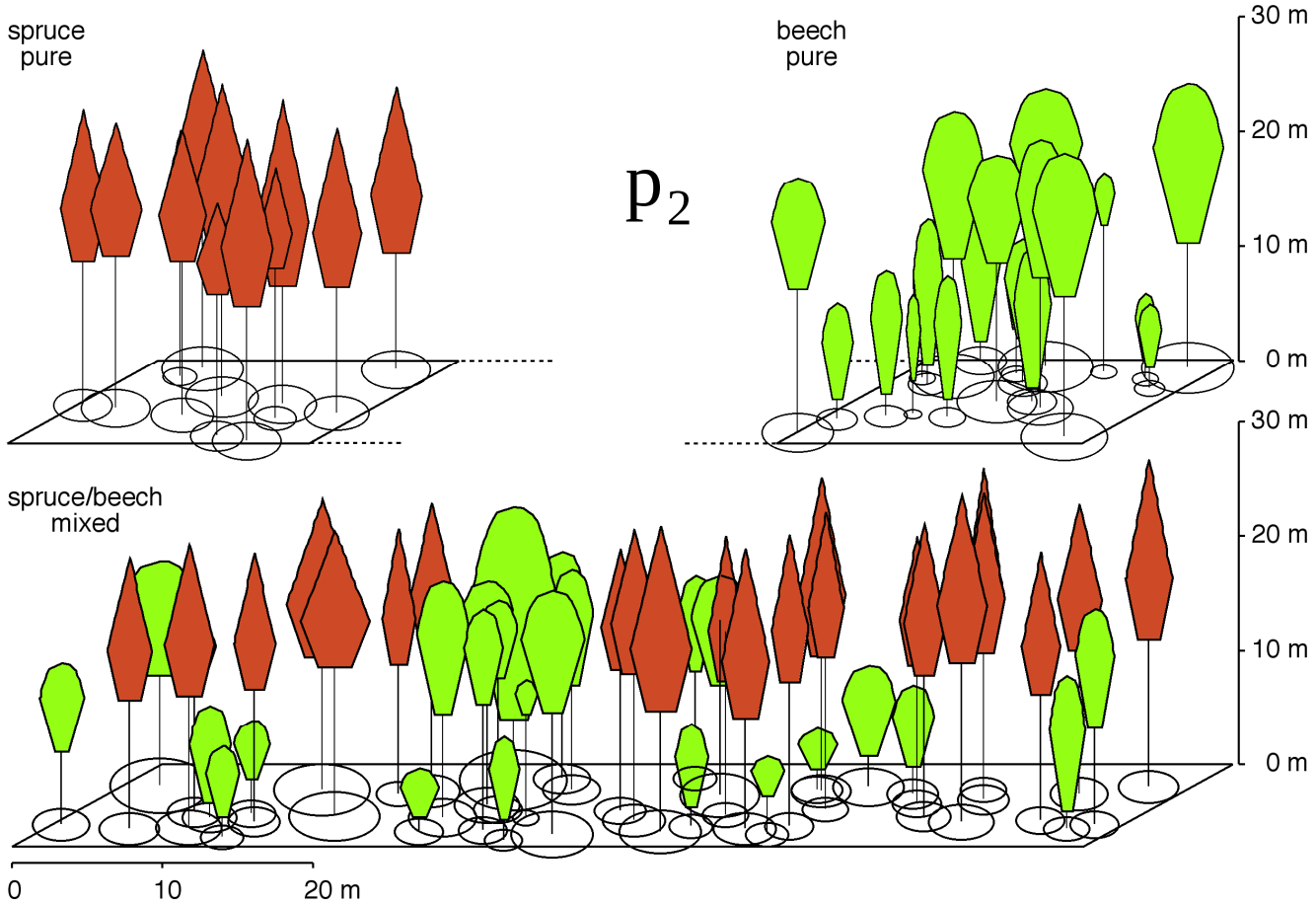
Hans Pretzsch
Chair for Forest Growth and Yield Science
Technische Universität München

http://www.wwk.forst.wzw.tum.de/info/presentations/

Keynote Cost Action FP1206 MC and WG meeting, 21st-23rd Oct, 2013 in Madrid, Spain


225
228
226
Fotos: Leonhard Steinacker

Experimental set-up and data base for analyzing crown allometry, tree efficiency, stand productivity



p_1

p_2

$p_{1,2}$

m_1

m_2

$pp_{1,(2)}$

$pp_{(1),2}$

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

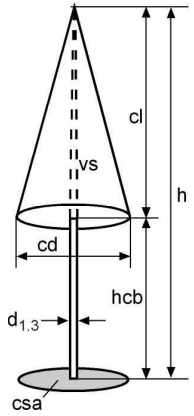
Analyzing the effect of species mixing on the structure and productivity of temperate forests in Europe

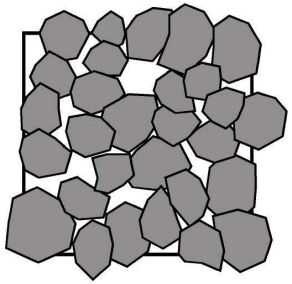
1 Crown and canopy structure in mixed versus pure stands

2 Crown and stand area efficiency in inter- vs. intra-specific neighbourhood

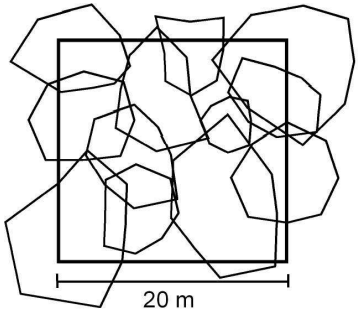
3 Over-/underyielding of mixed versus pure forests. Effect of site conditions

1 Crown maps for analyzing tree allometry in mixed versus pure stands

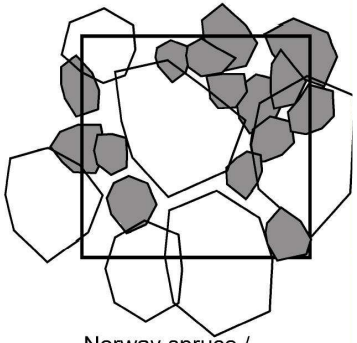




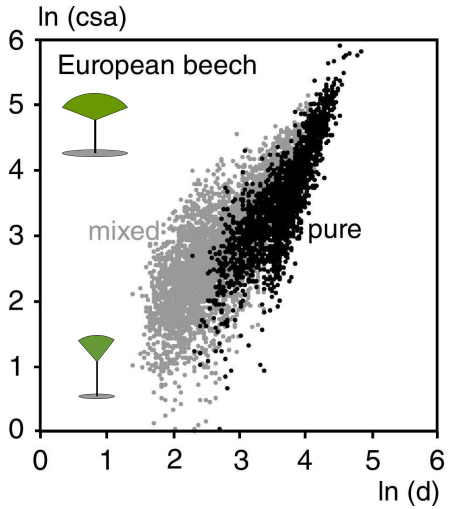
Norway spruce
pure



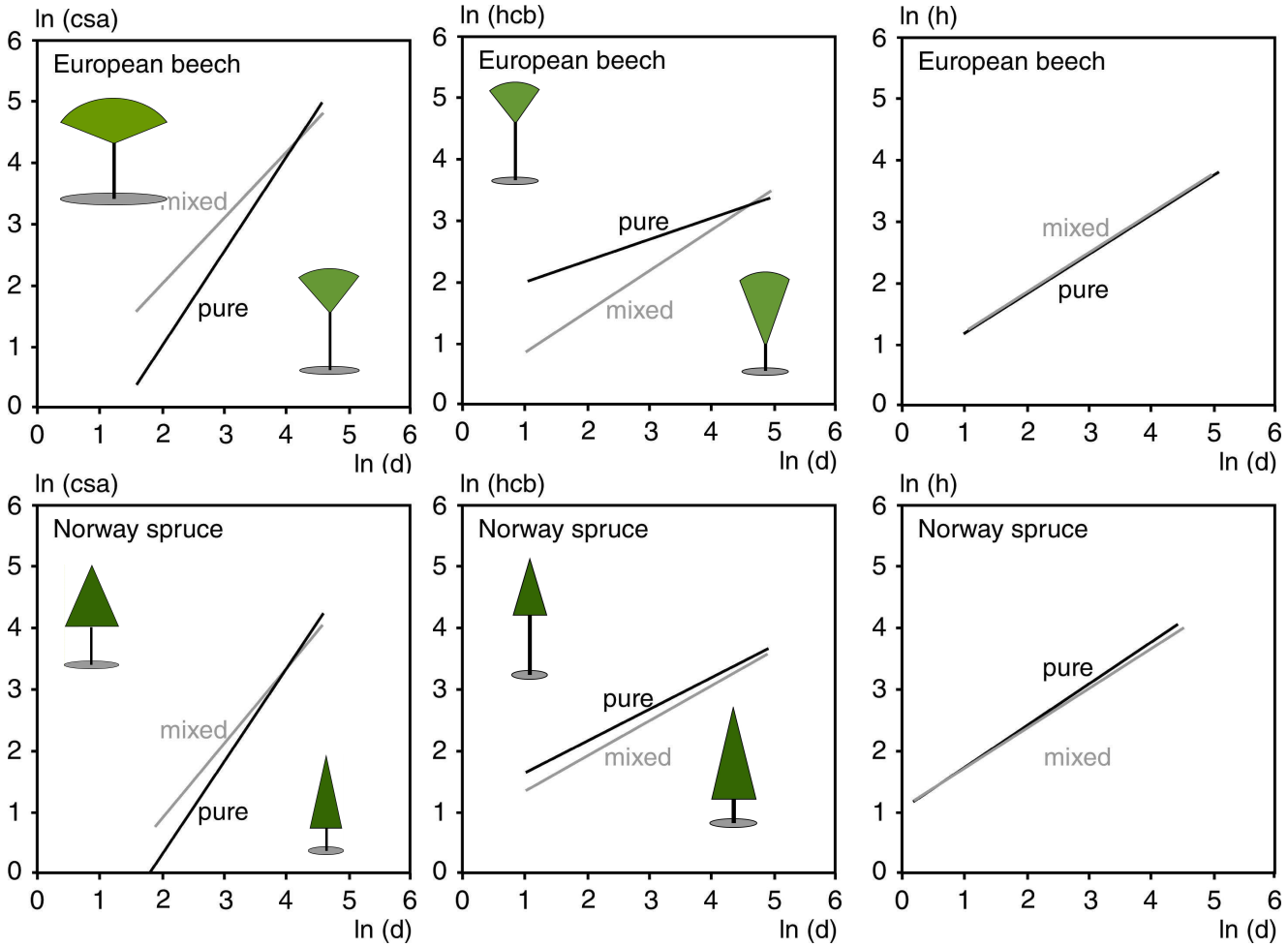
European beech
pure



Norway spruce /
European beech
mixed

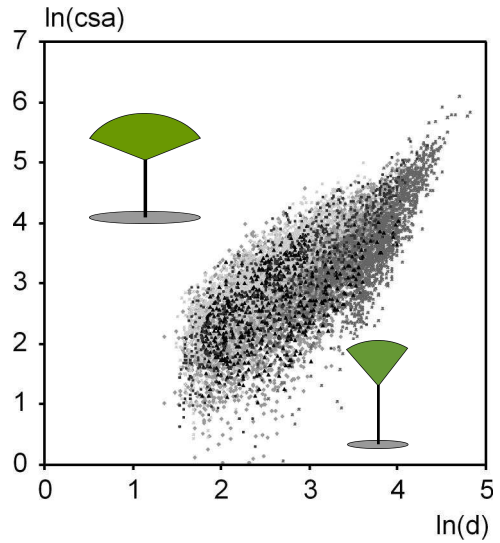


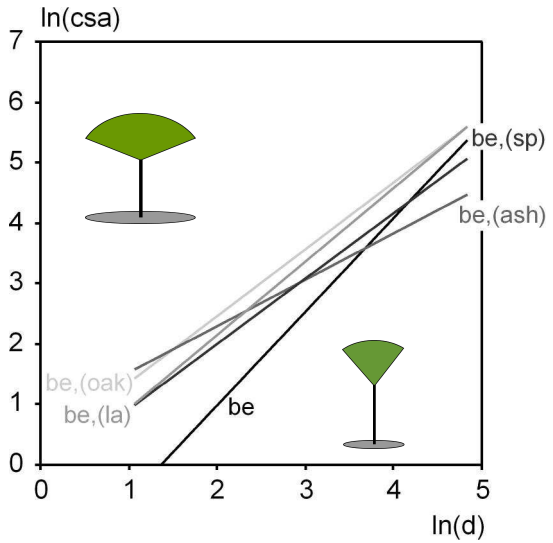
1 Crown allomtery of beech and spruce in mixed versus pure forest stands



Bolte et al. (2004); Pretzsch und Dieler (2011); Sprauer, Schmidt, Nagel (2003)

1 Crown expansion in mixed versus pure stands: shift of ln(csa)-ln(d) allometry

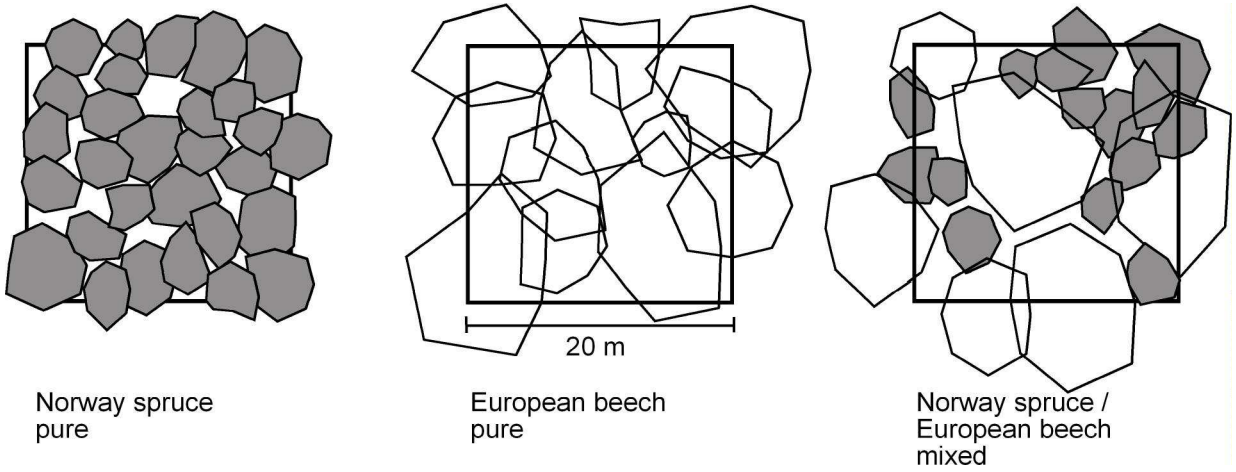


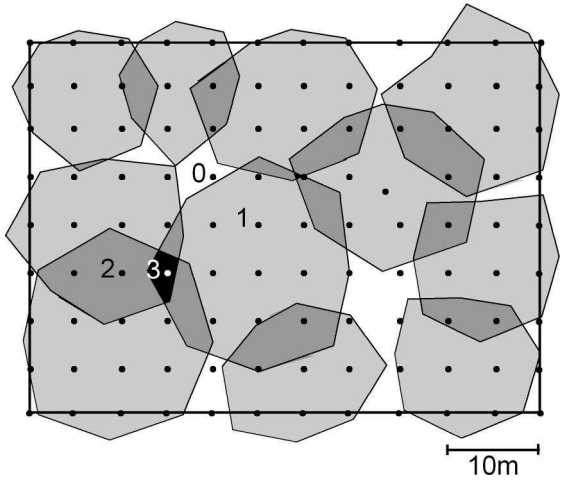


oak
ash
larch
spruce

Dieler and Pretzsch (2012, 2013); Kurth (1994, 2012); Kurth und Sloboda (1997); Sloboda (1984)

1 Ground coverage and sum of crown area in dependence on species richness

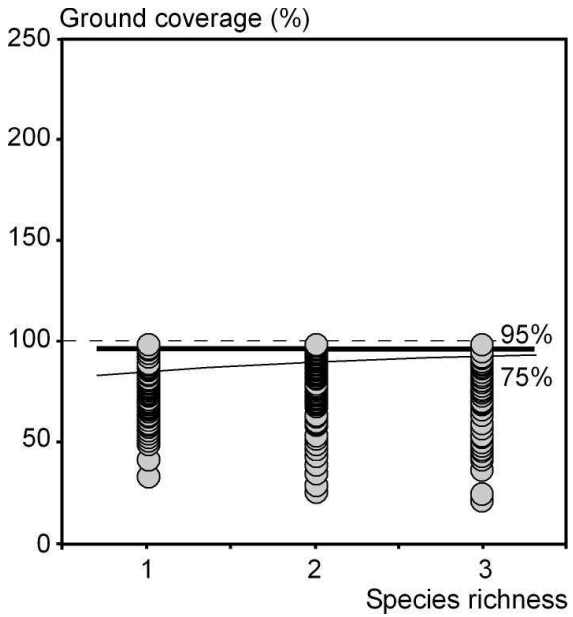


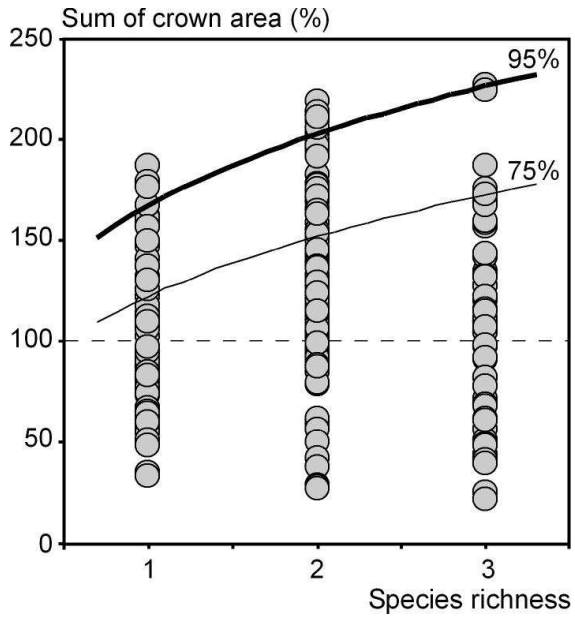


example:

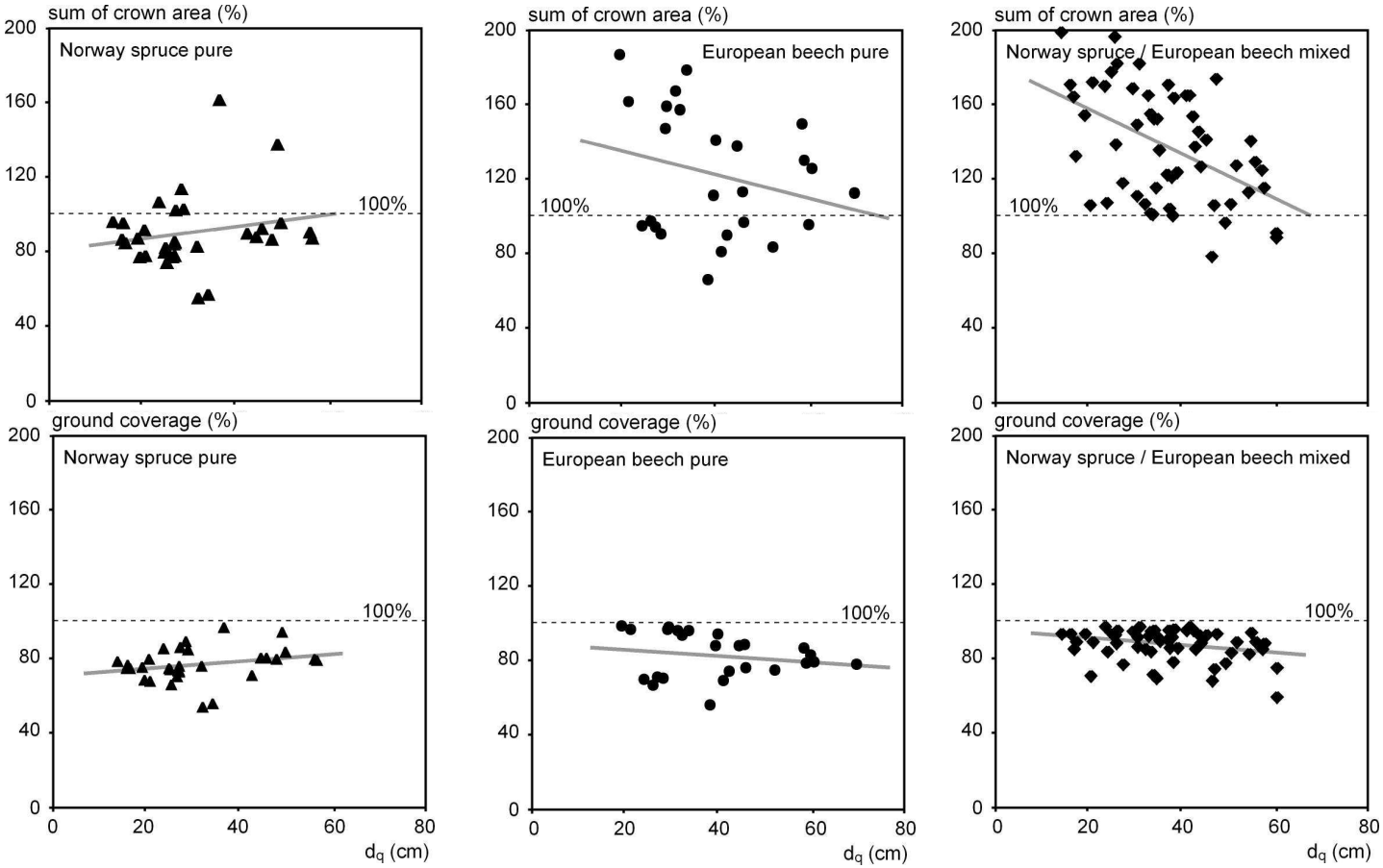
ground coverage 90 %
sum of crown area 120 %

1 Ground coverage and sum of crown area in dependence on species richness



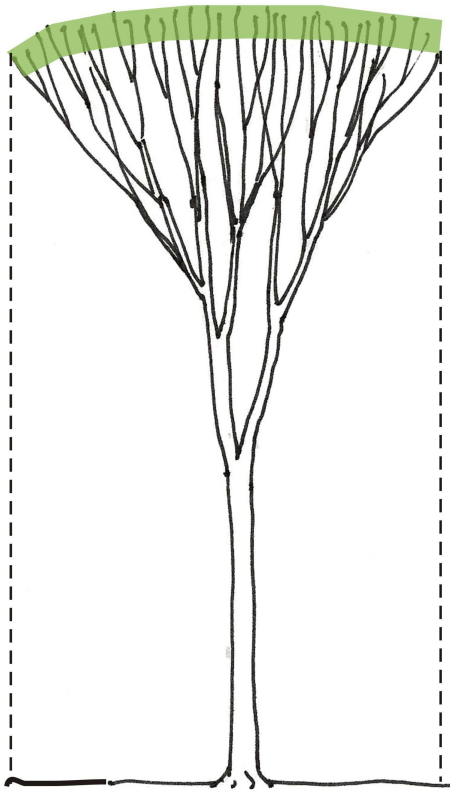


1 Sum of crown area (above) and ground coverage (below) for spruce and beech in pure and mixed stands during stand development



1 Morphological differences in intra- vs. inter-specific environment despite of equal biomass

beech beside beech



branch number
19 vs. 36

branch length
4.8 m vs. 4.3 m

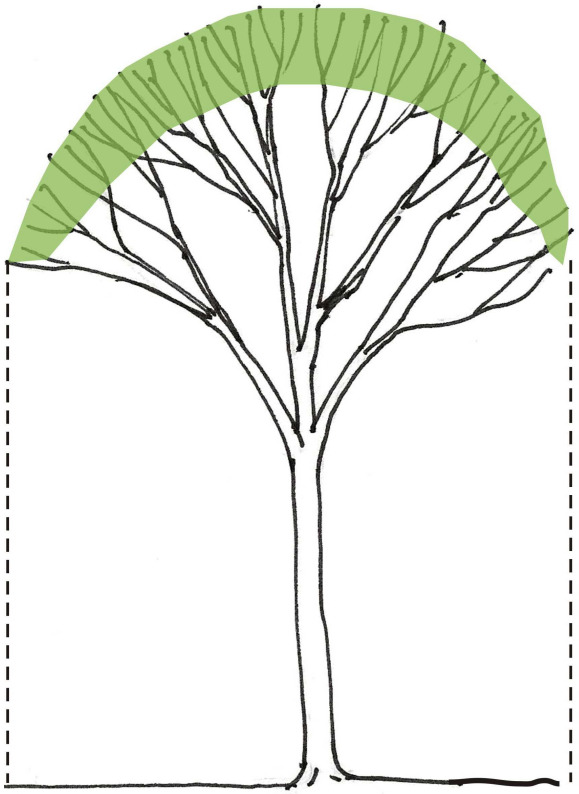
branch angle
139° vs. 128°

branch straightness
96 vs. 94

stem inclination
2° vs. 3.5°

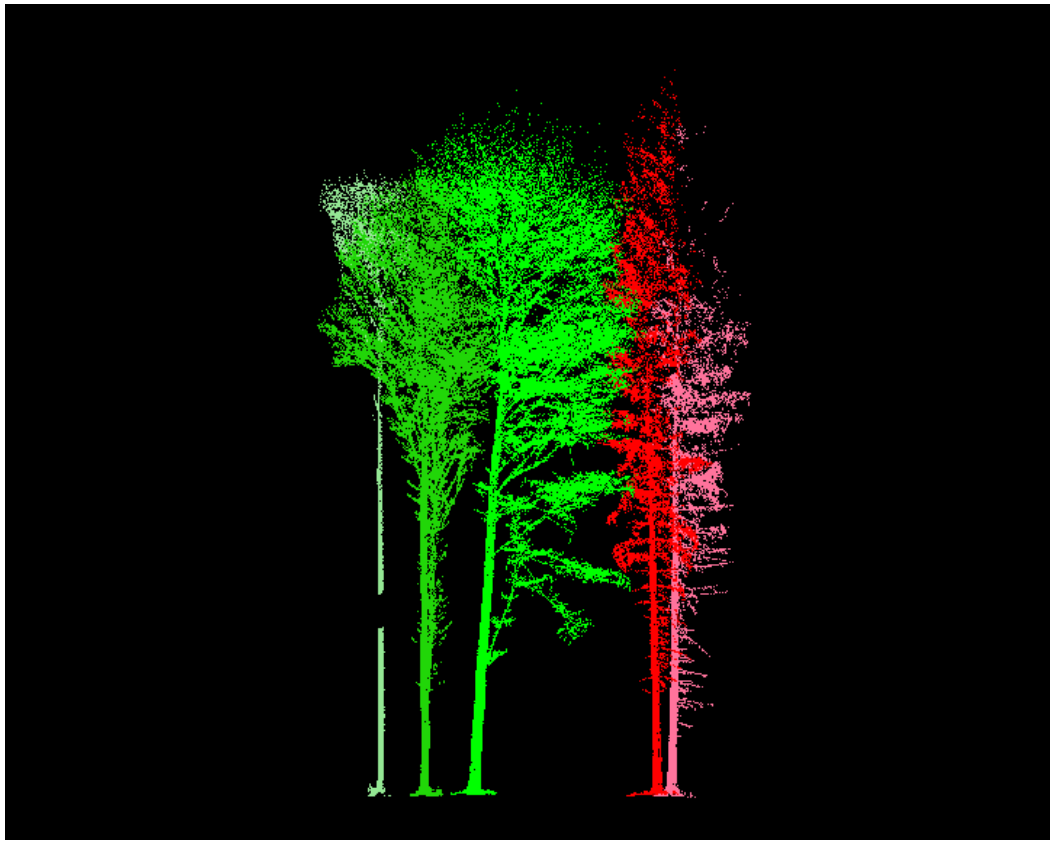
crown volume
25 m^3 vs. 59 m^3

beech beside spruce



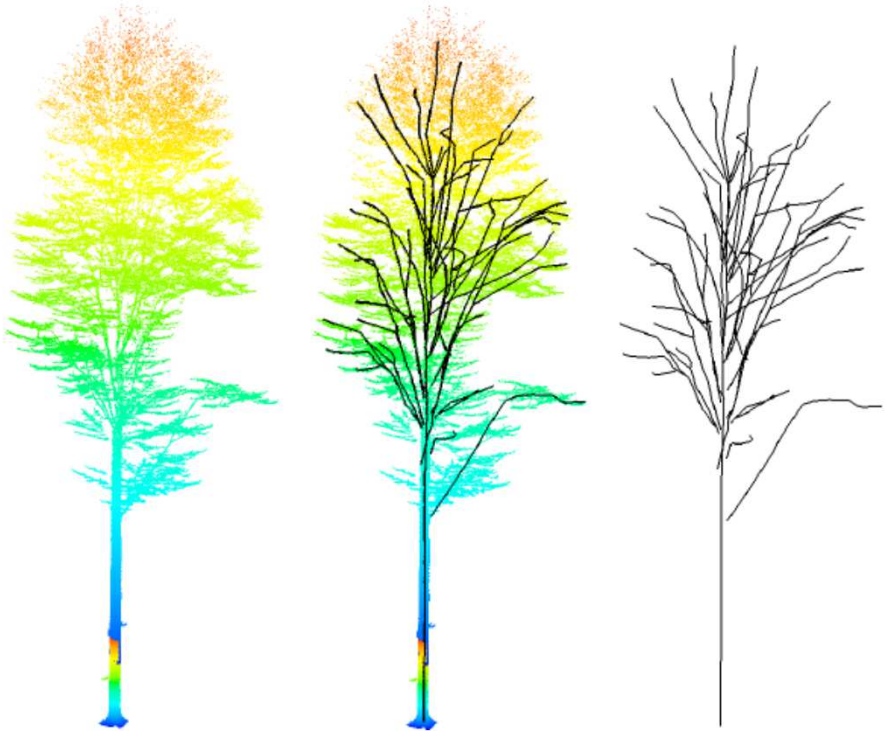
Arz (2013); Bayer, Seifert, Pretzsch (2012) Structural crown properties of Norway spruce and European beech in mixed versus pure stands revealed by terrestrial laser scanning, Trees

1 TLidar Riegl Z420i for measuring crown morphology and space occupation

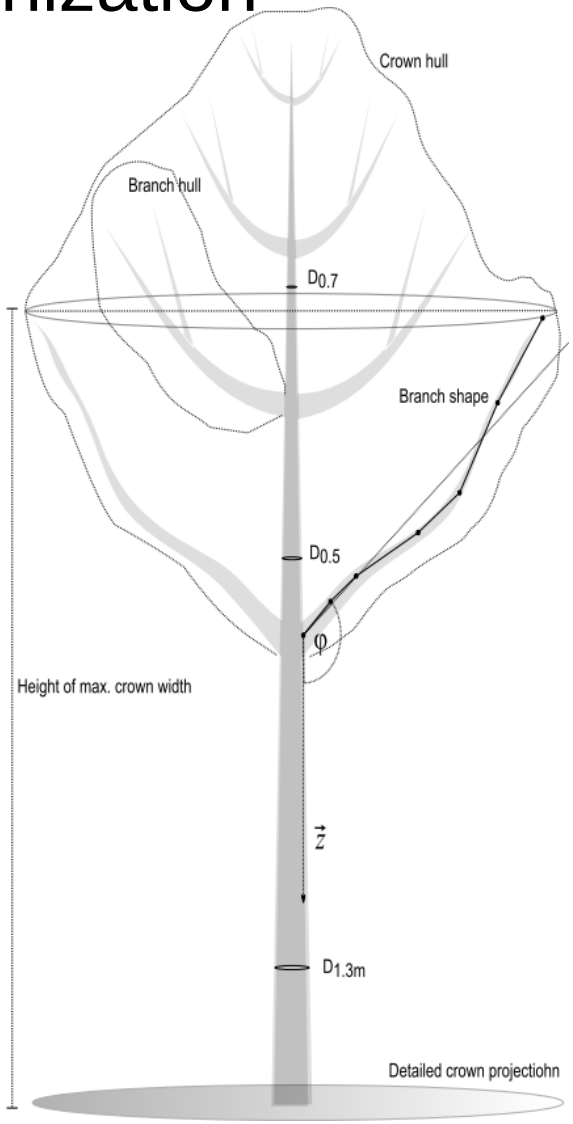


measurement range: 2 – 1,000 m, accuracy (dist 50 m): <10 mm
minimum angle stepwidth: 0.004°, field of view: 80° × 360 °

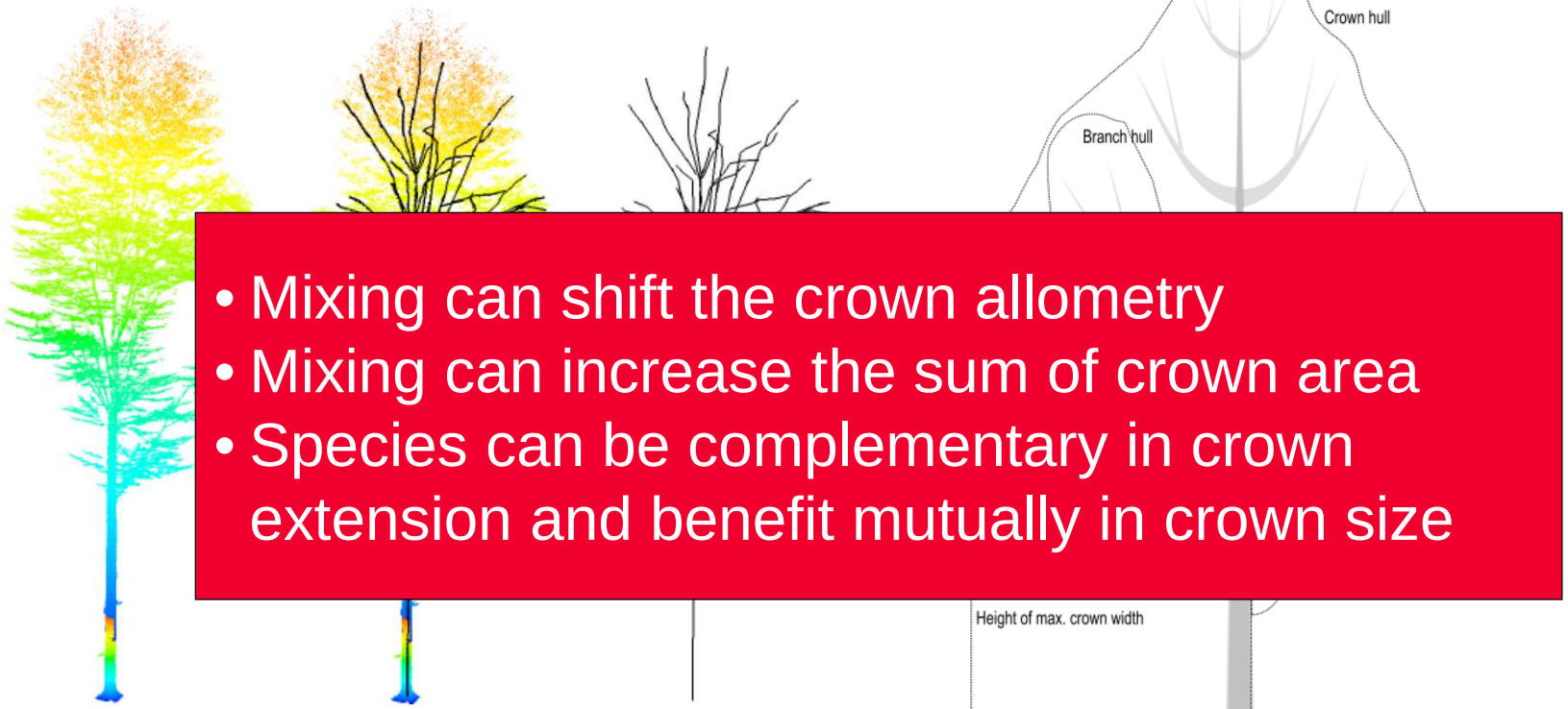
1 TLidar for measuring crown morphology after tree structure skeletonization



- convex hull of crown or branches
- stem diameter, height, inclination
- branch number, length, angle
- wood quality



1 TLidar for measuring crown morphology after tree structure skeletonization



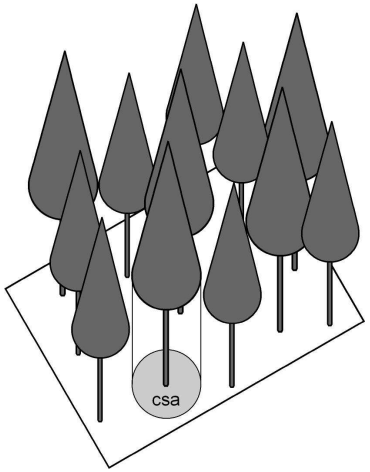
- Mixing can shift the crown allometry
- Mixing can increase the sum of crown area
- Species can be complementary in crown extension and benefit mutually in crown size

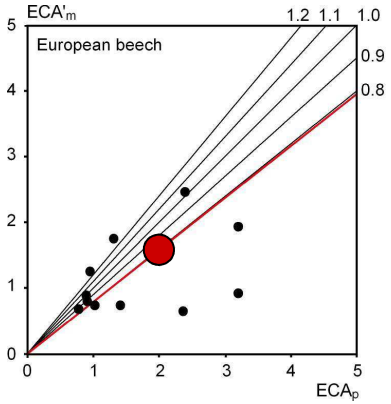
- convex hull of crown or branches
- stem diameter, height, inclination
- branch number, length, angle
- wood quality

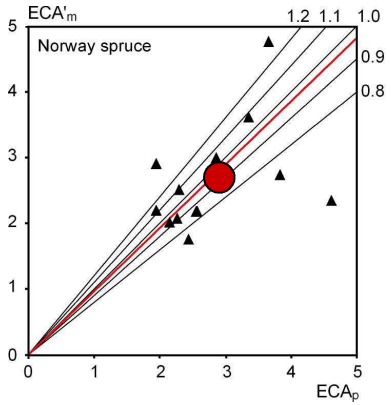
2 Growth efficiency at tree level: mean tree records for 12 triplets in spruce and beech NOR, FRE, SON

iv/csa

Growth efficiency of the crown area



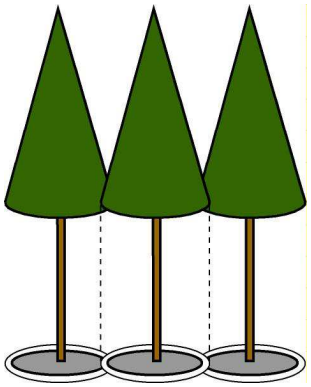


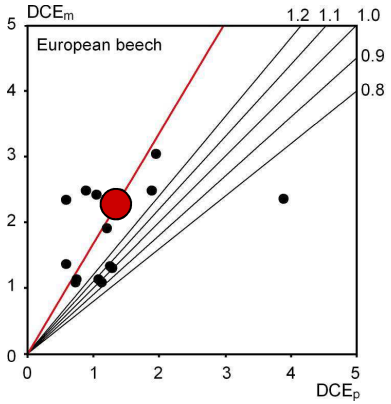


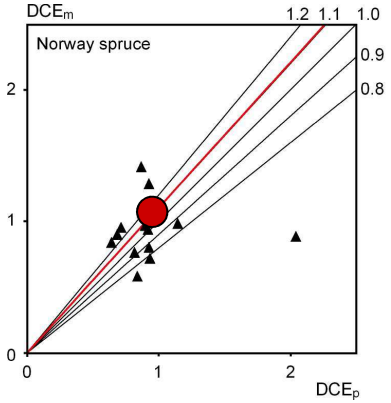
2 Growth efficiency at tree level: mean tree records for 12 triplets in spruce and beech NOR, FRE, SON

csa/sa

Crown extension beyond the tree stand area



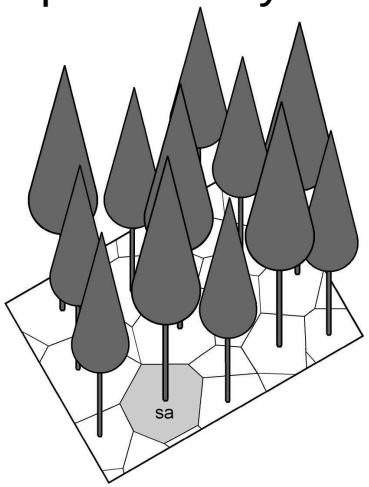


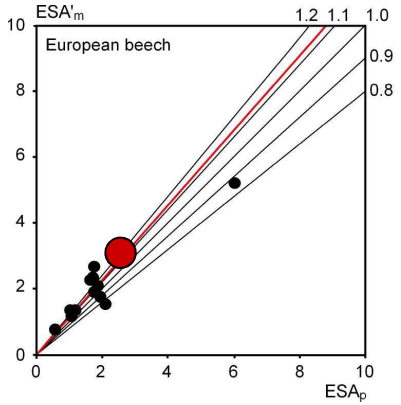


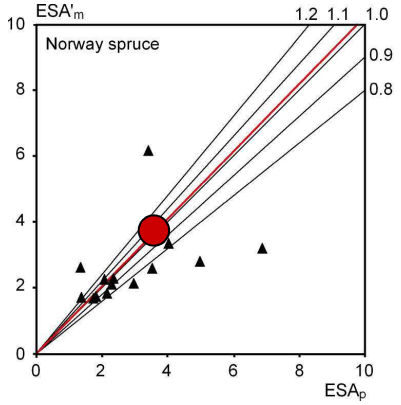
2 Growth efficiency at tree level: mean tree records for 12 triplets in spruce and beech NOR, FRE, SON

iv/sa

Growth efficiency of the growing area = productivity



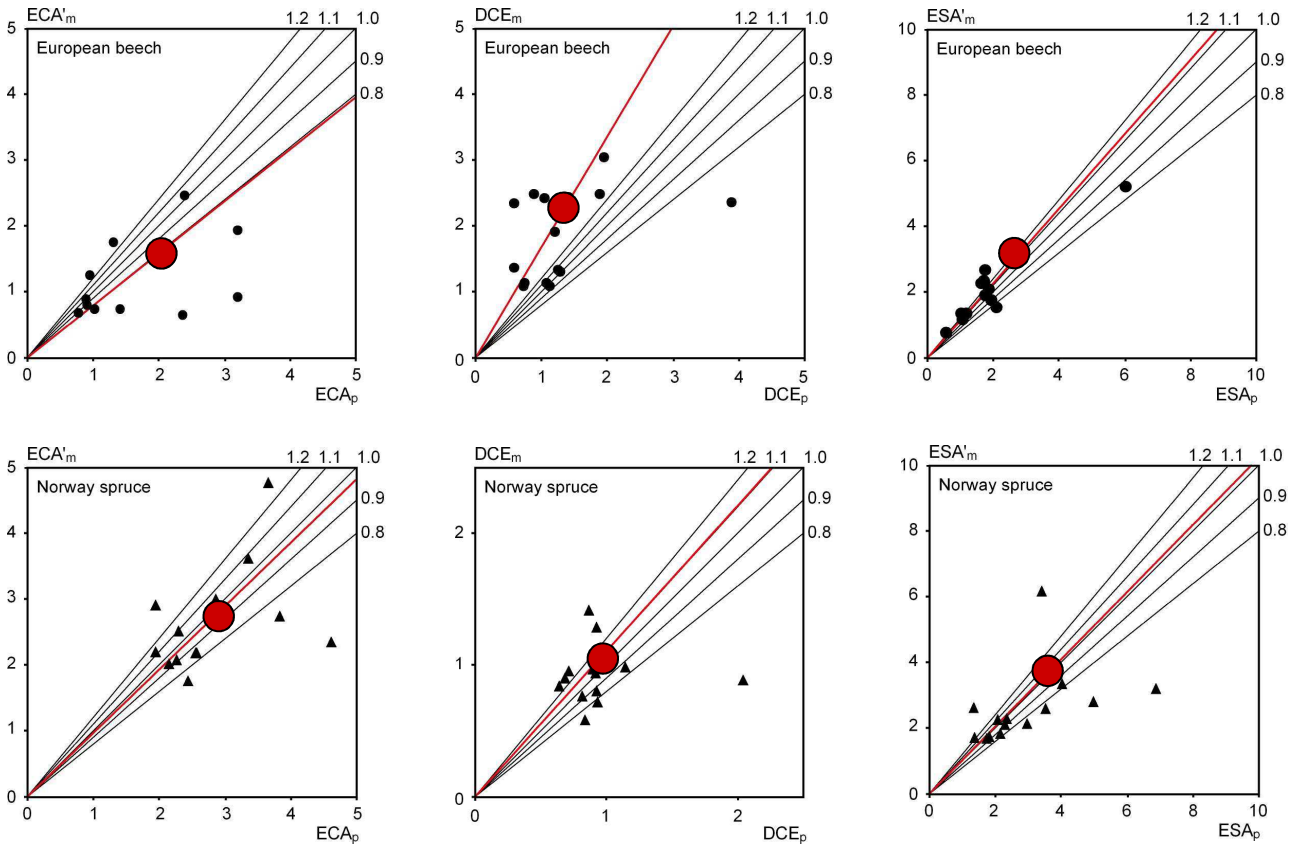




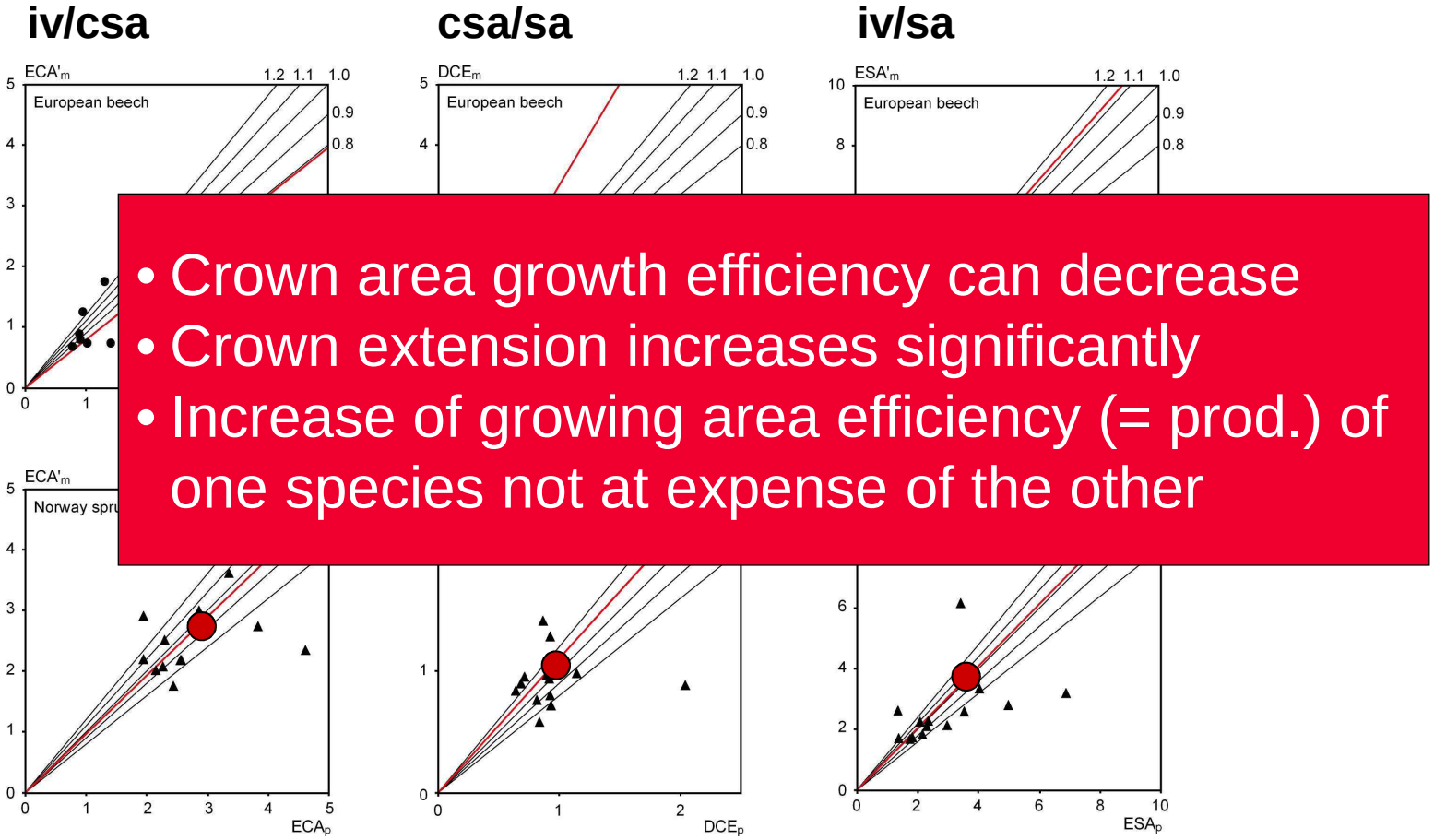
Waldwachstum
Systemanalyse

2 Growth efficiency at tree level: mean tree records for 12 triplets in spruce and beech NOR, FRE, SON

iv/csa **csa/sa** **iv/sa**

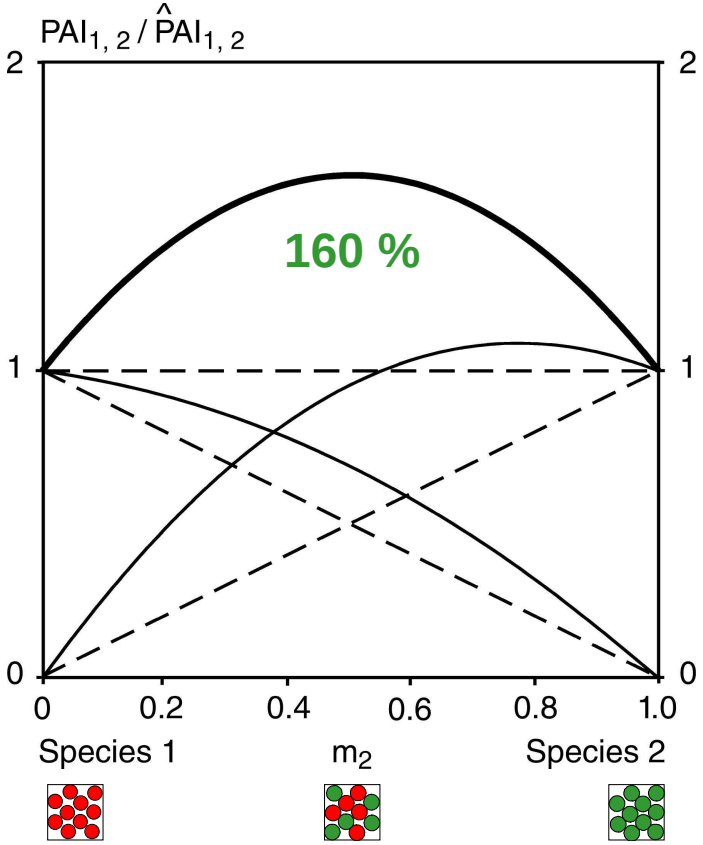


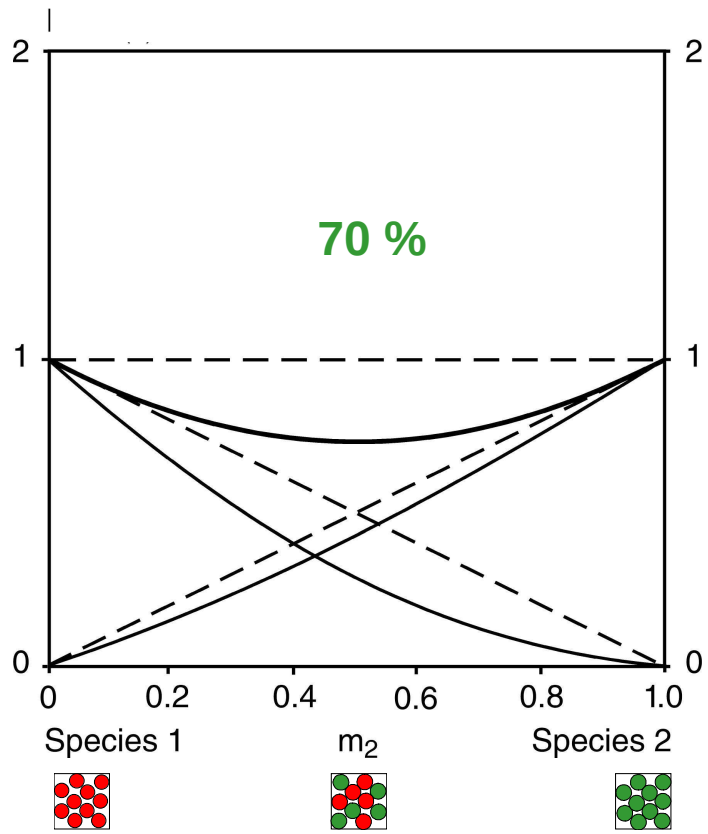
2 Growth efficiency at tree level: mean tree records for 12 triplets in spruce and beech NOR, FRE, SON



- Crown area growth efficiency can decrease
- Crown extension increases significantly
- Increase of growing area efficiency (= prod.) of one species not at expense of the other

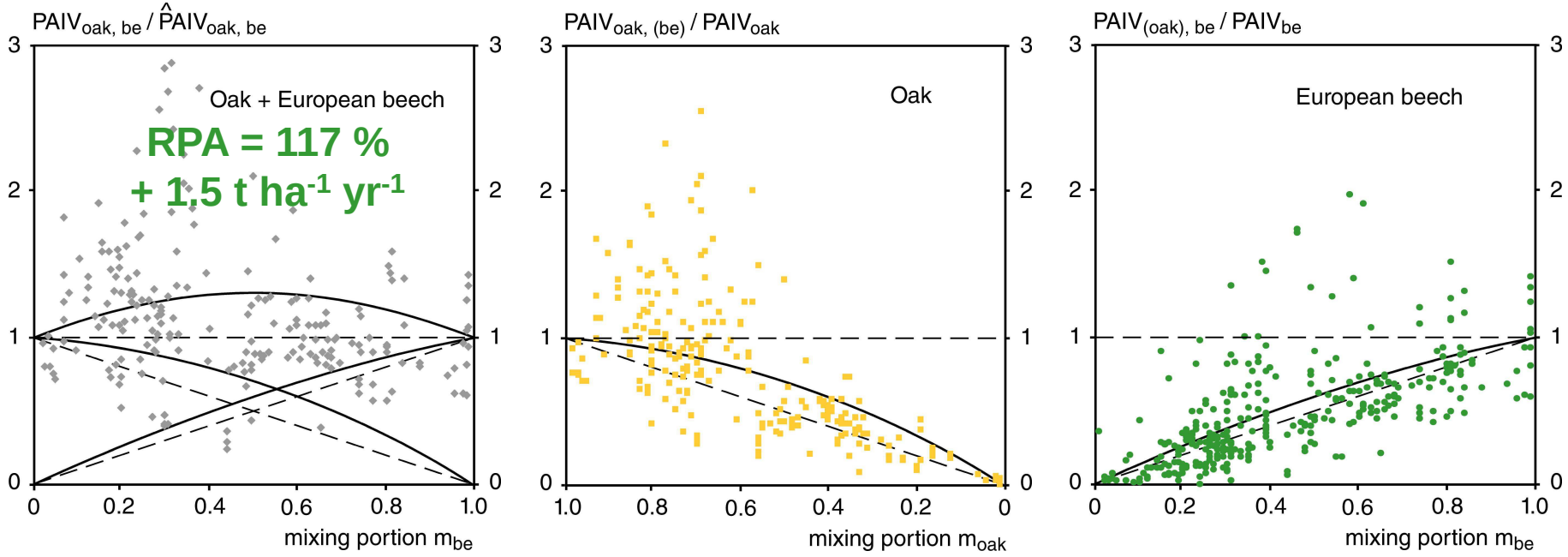
3 Cross diagrams for illustration of mixing effects in mixed versus pure stands: schematic example





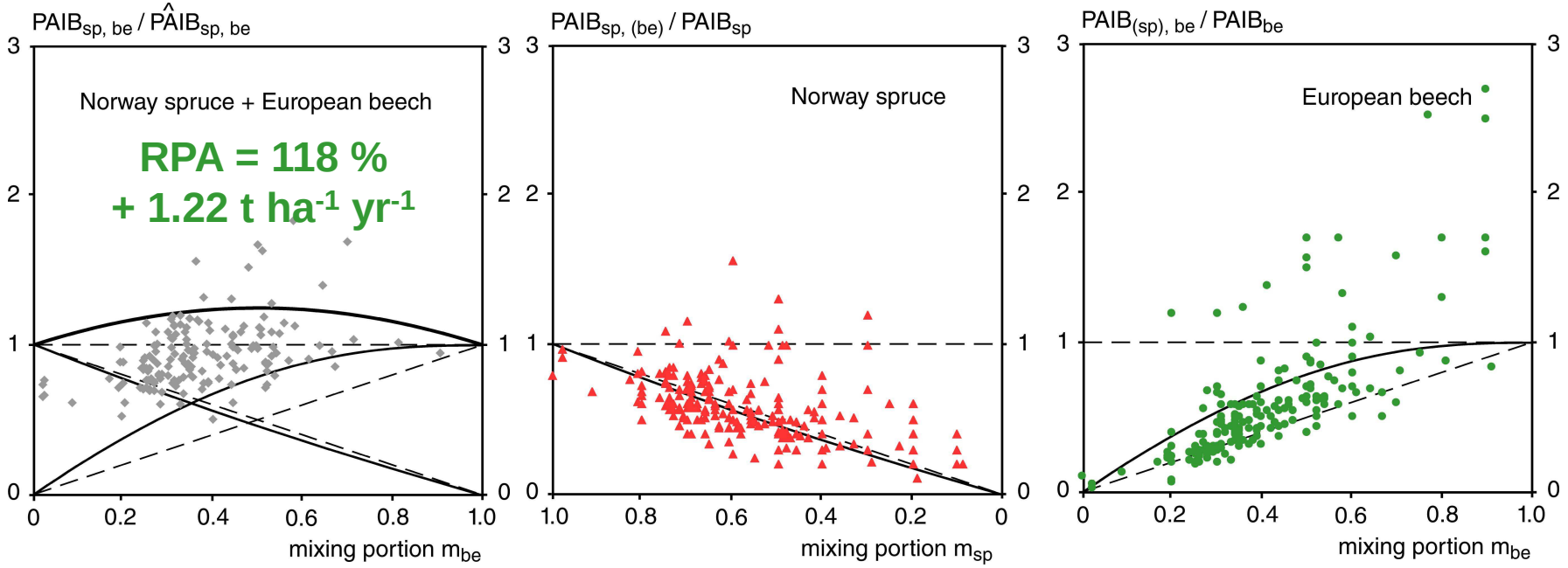
Harper J L (1977), Population biology of plants, Academic Press, London, 277-304
Kelty M J (1992) Comparative productivity of monocultures and mixed stands, Kluwer Acad. Publishers

3 Relative productivity of mixed oak/ beech versus pure stands



Pretzsch et al. (2013) Productivity of mixed versus pure stands of oak and European beech
Eur J Forest Res, DOI 10.1007/s10342-012-0673-y

3 Relative productivity of mixed Norway spruce/ European beech versus pure stands



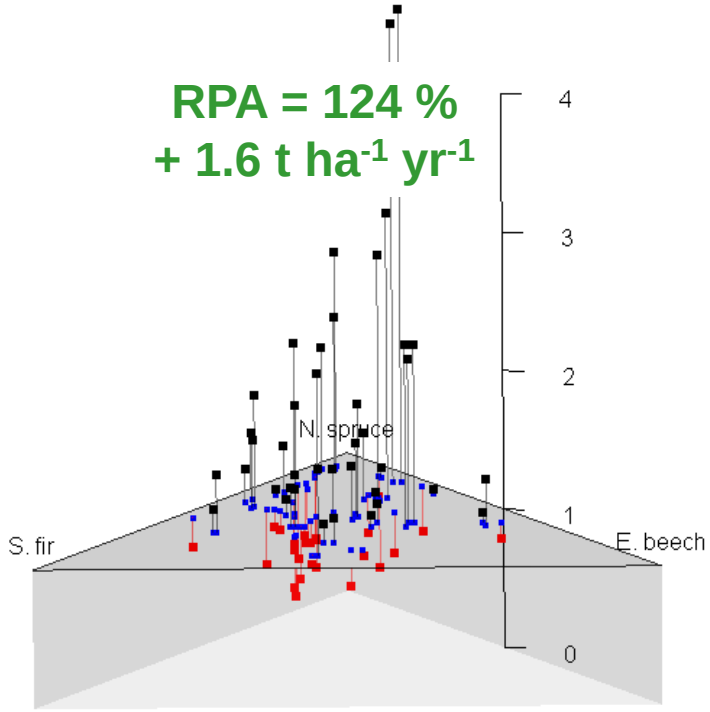
$RP_{sp,be} = RPP_{sp,(be)} + RPP_{(sp),be}$

$RPP_{sp,(be)} = m_{sp} \times (1 - 0.013 \times m_{be})$, $n = 236$, $R^2 = 0.12$, $p<0.05$

$RPP_{(sp),be} = m_{be} \times (1 + 1.115 \times m_{sp})$, $n = 221$, $R^2 = 0.33$, $p<0.001$

Pretzsch (2005) Ecological Studies 176
Pretzsch et al. (2010) Ann. For. Sci. 67

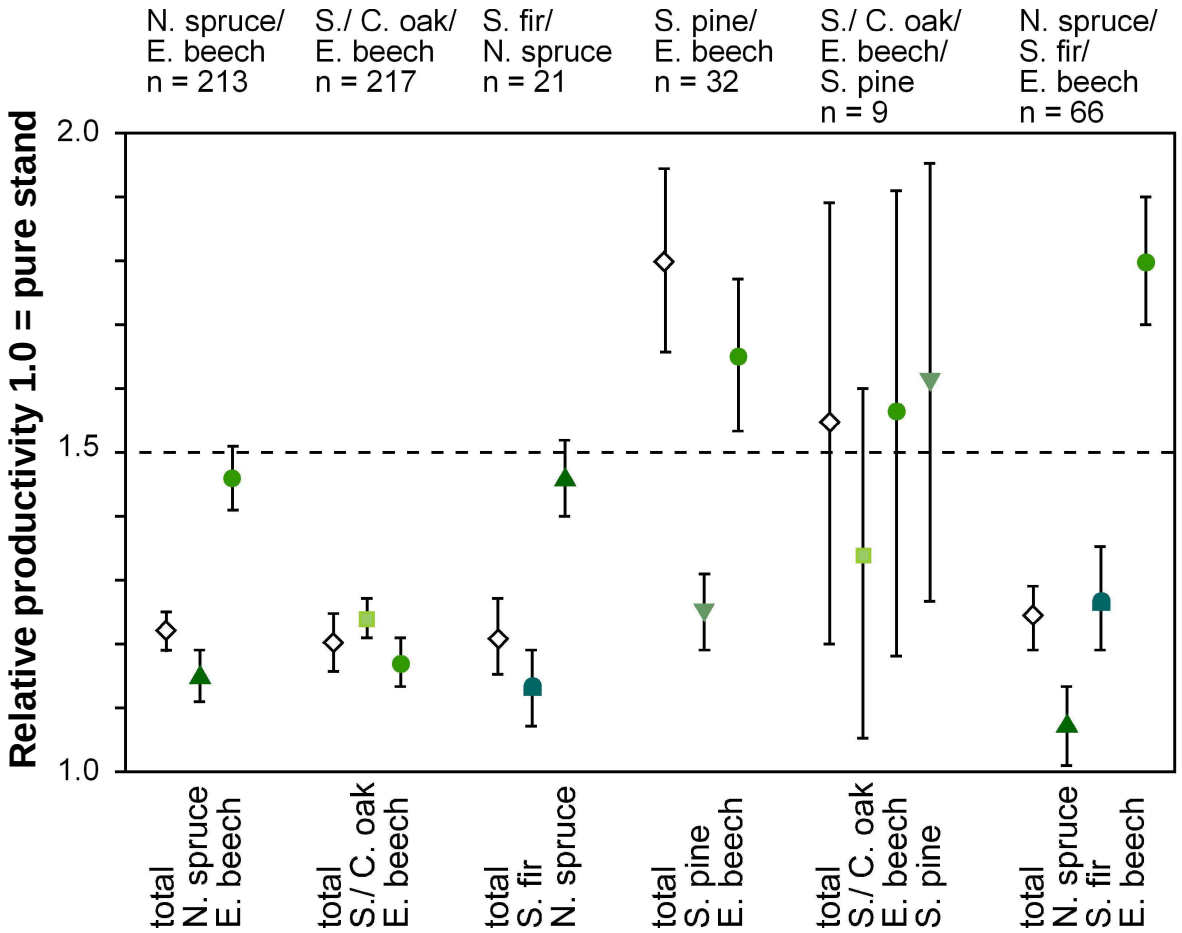
3 Productivity of mixed stands with three species versus pure stands
Norway spruce, Silver fir, and European beech



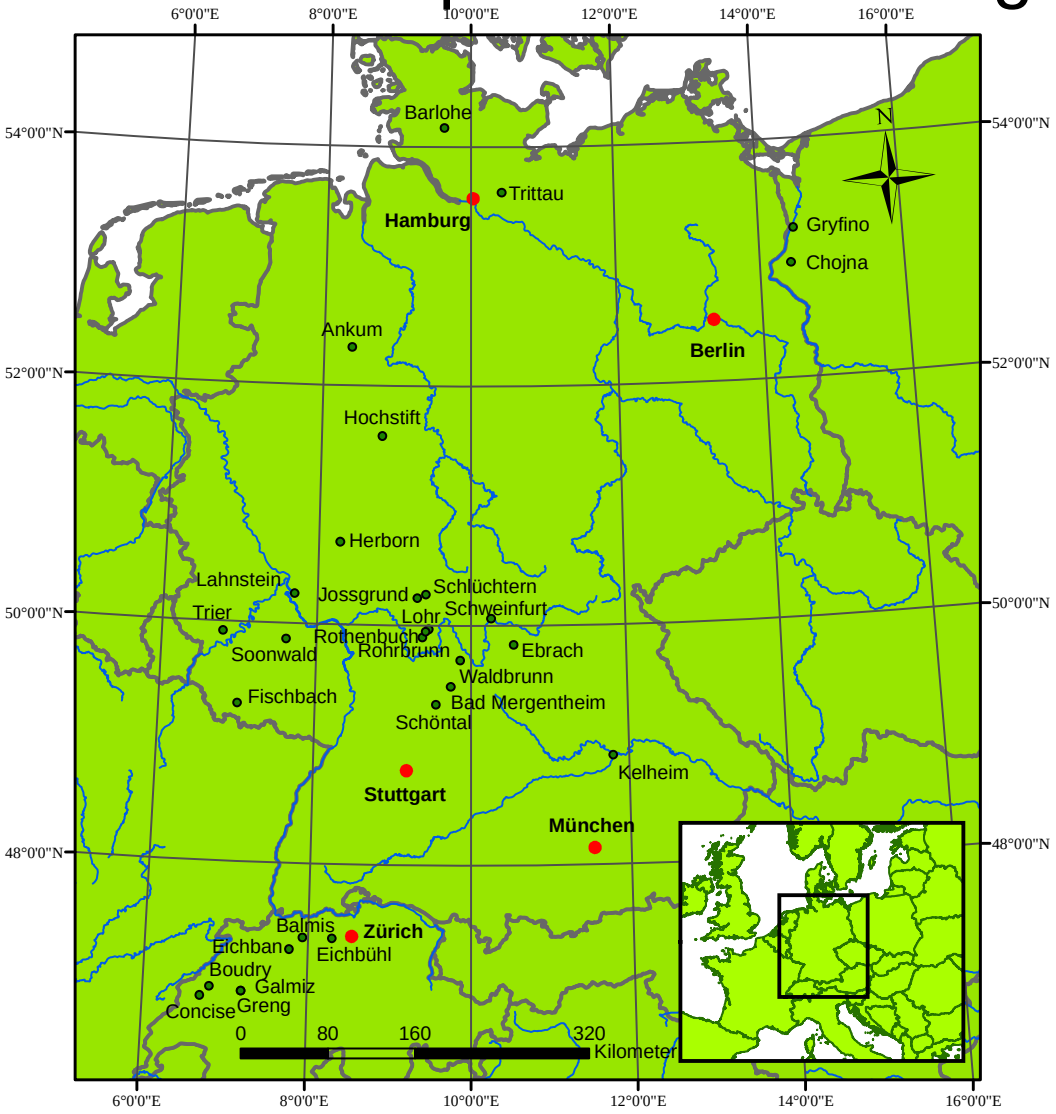
RP: sp/fir/be 1.24 (± 0.05)
AP: sp/fir/be 1.60 t ha^{-1} yr^{-1}

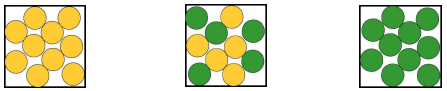
Pretzsch (2013) Acta Nova Leopoldina, NF 114

3 Overyielding of mixed stands compared with pure stands of spruce, pine, fir beech, and, oak



3 Pure and mixed species stands of Sessile/Common oak and European beech along an ecological transect





29 experiments
65 triplets
525 surveys

time span: 1890 - 2011

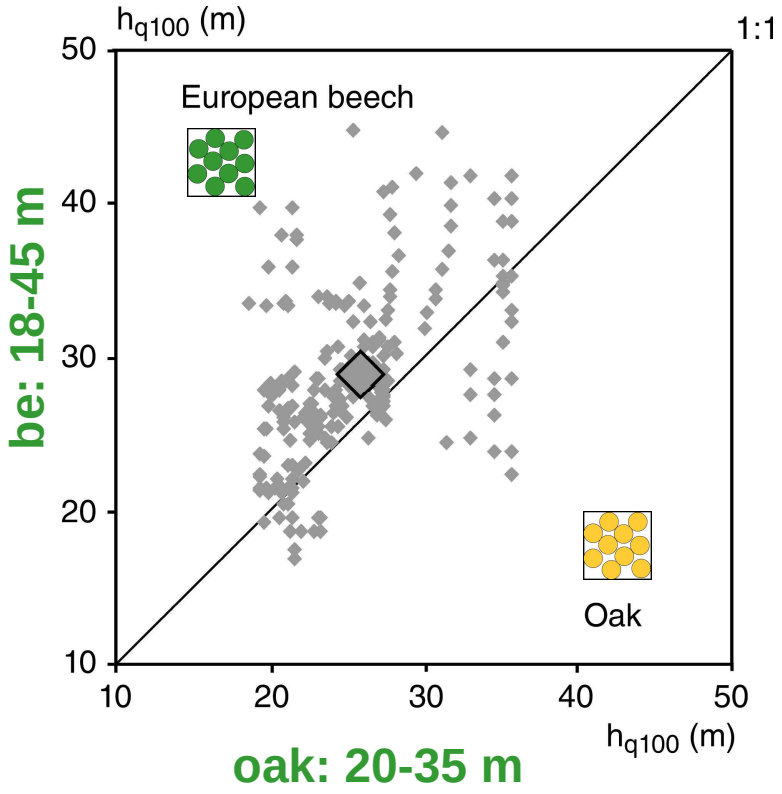
stand age: 17- 217

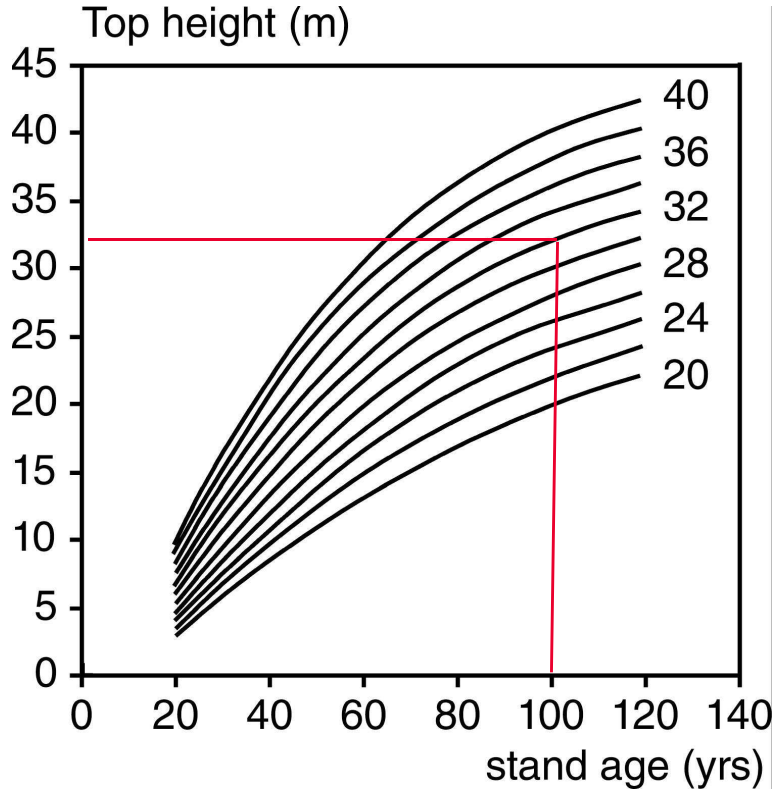
mean temp (°C): 6.0 - 9.5
precip (myr^{-1}): 550 - 1120
nut. supp.: acid - alcaline

from m_{oak} / m_{be}: 0.05:0.95
to m_{be} / m_{oaki}: 0.95:0.05

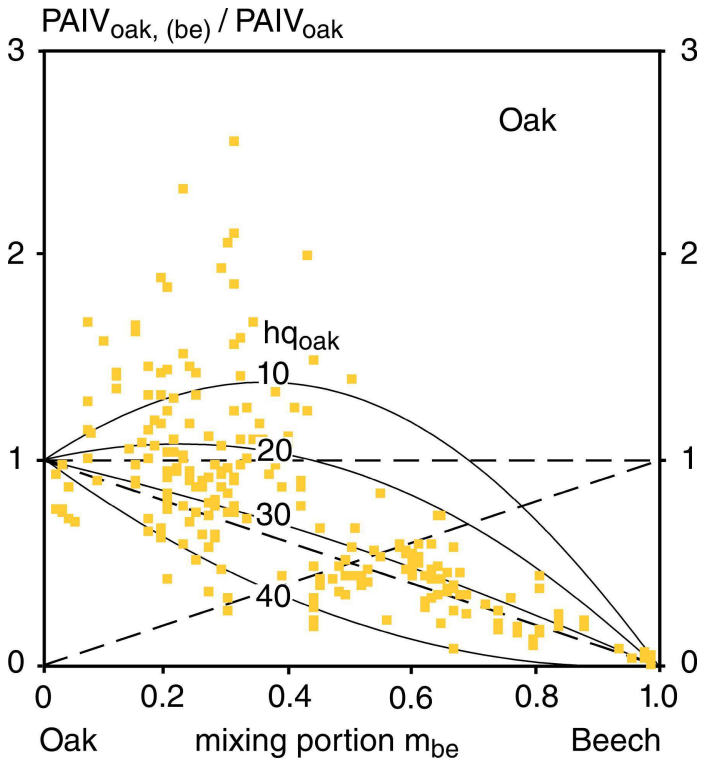
from: unthinned
to: heavily thinned

3 Mean height of the pure oak and beech stands at age 100 as indicator for site quality

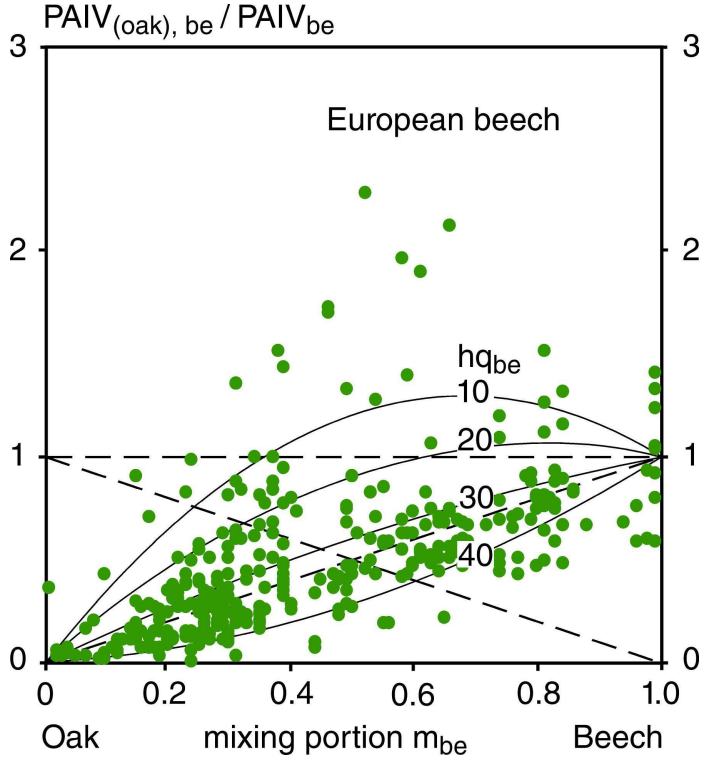




3 Site index (hq in m at age 100) as modifier of mixing reactions between oak and beeh



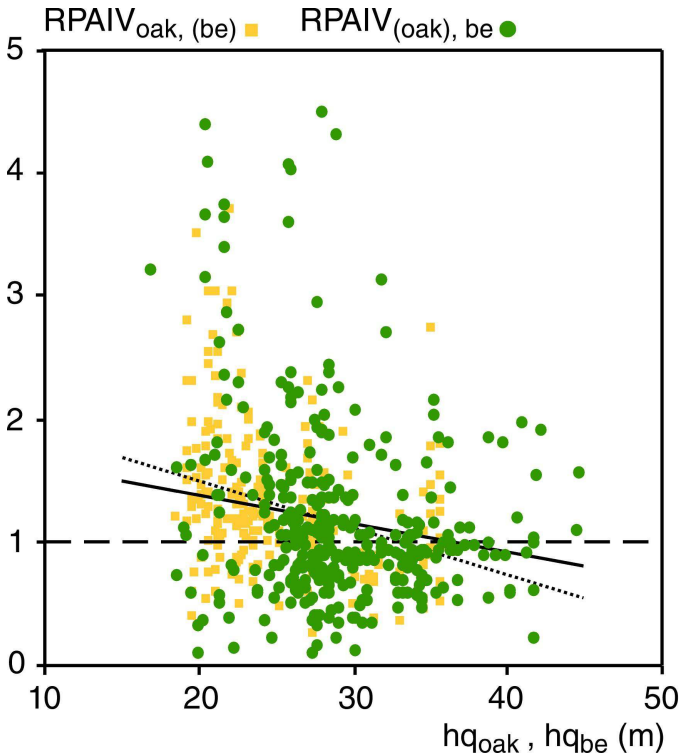
$RPP_{oak,(be)} = m_{oak} \times (1 + 4.685 \times m_{be} - 0.145 \times m_{be} \times hq_{oak})$
n = 296, R^2 = 0.46, p<0.01



$RPP_{(oak),be} = m_{be} \times (1 + 4.033 \times m_{oak} - 0.122 \times m_{oak} \times hq_{be})$
n = 428, R^2 = 0.37, p<0.01

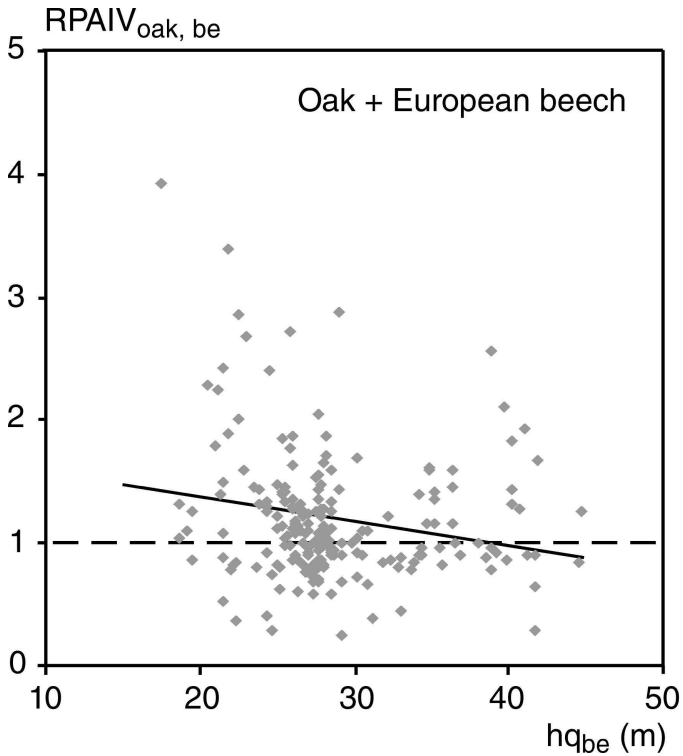
Waldwachstum
Systemanalyse

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



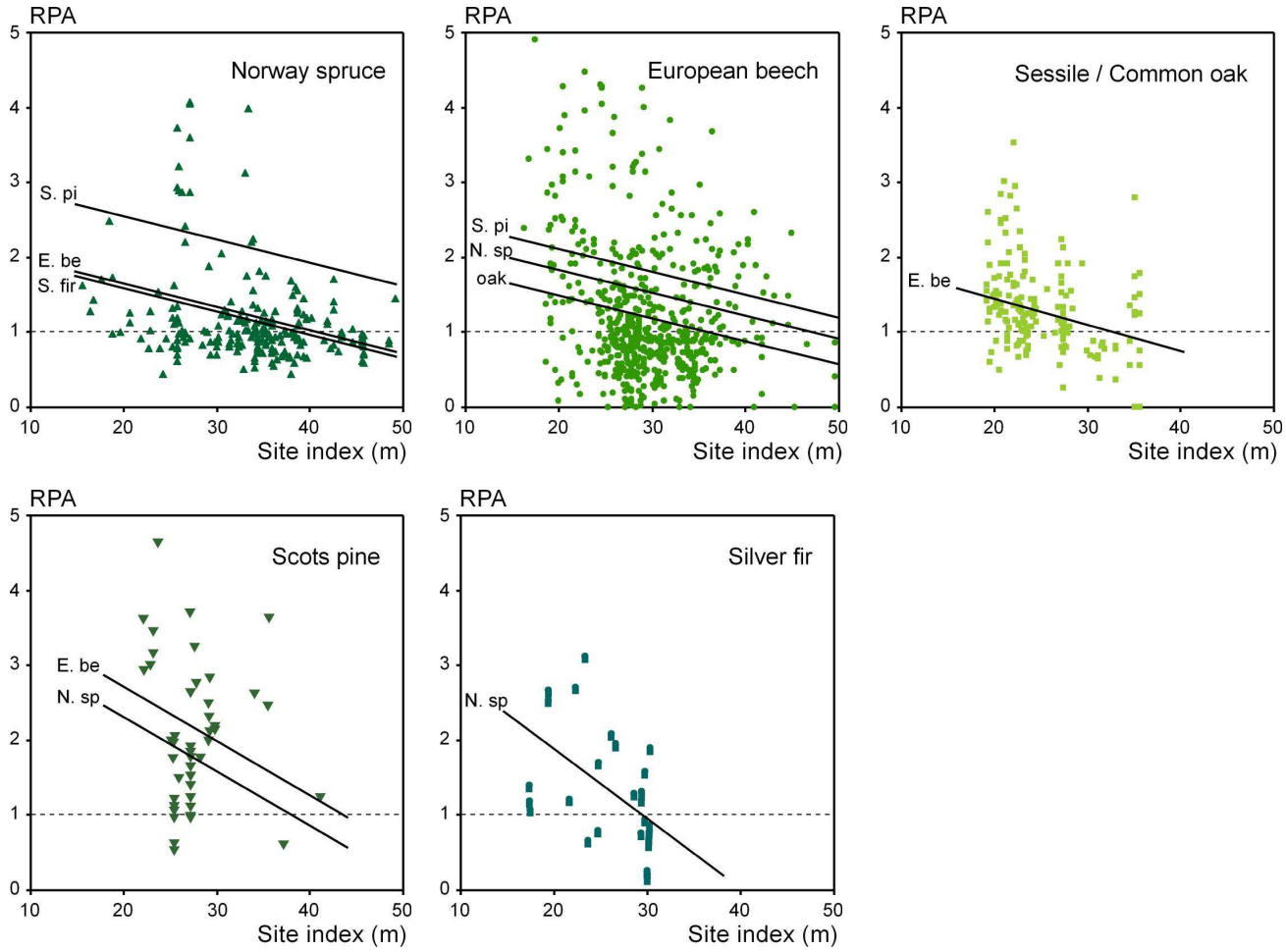
$RP_{oak,(be)}$ = 2.250 - 0.038 × hq_{oak}
n = 289, R^2=0.14, p<0.001,***

$RP_{(oak),be}$ = 1.841 - 0.023 × hq_{be}
n = 420, R^2=0.05, p<0.01, **

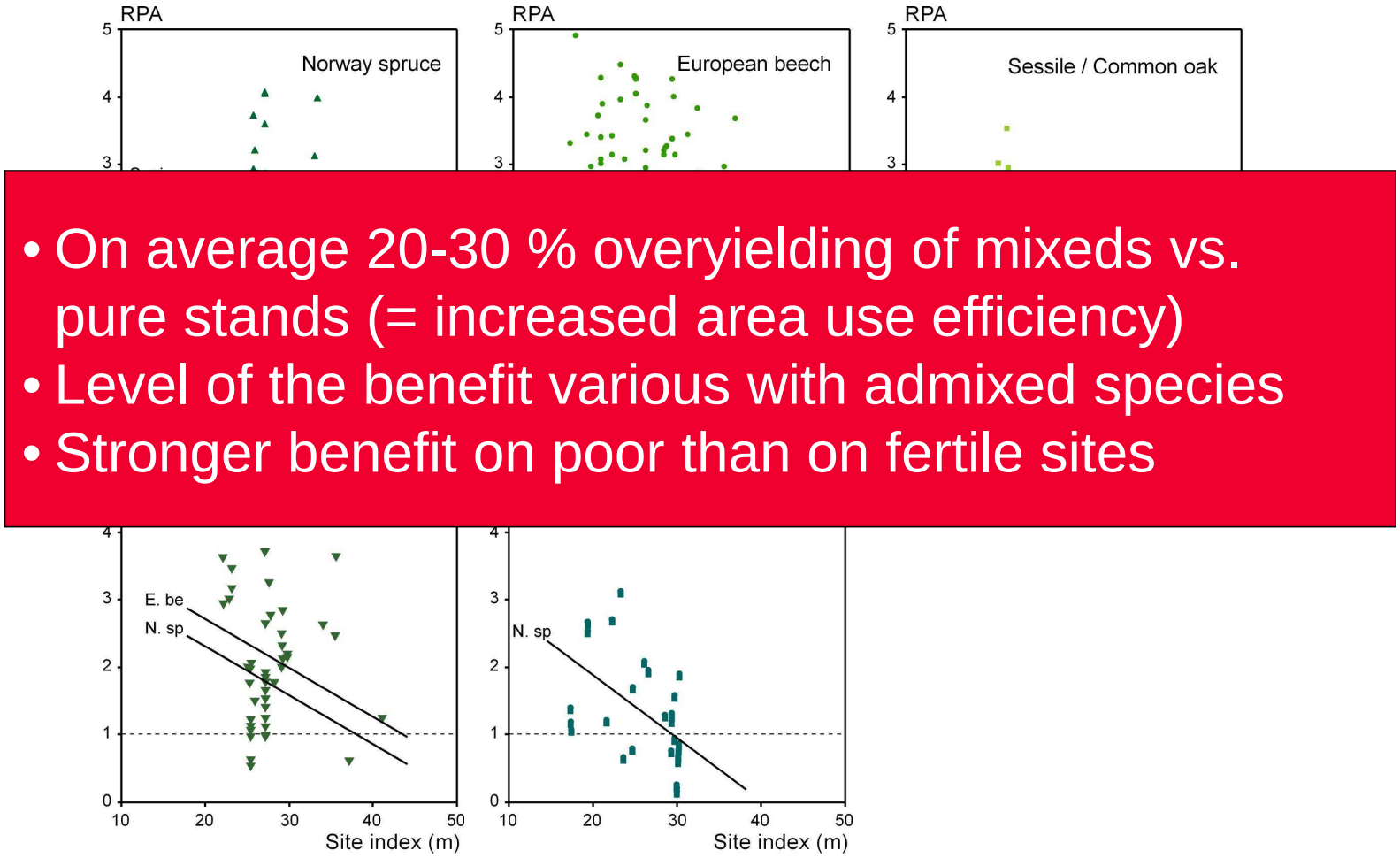


$RP_{oak,be}$ =1.816 -0.025 × hq_{oak}
n = 242, R^2=0.07
1.816 (± 0.165), p<0.001, ***
-0.025 (± 0.006), p<0.001, ***

3 Modification of mixing effects by site conditions



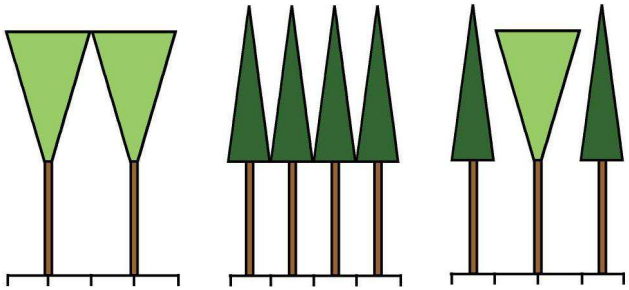
3 Modification of mixing effects by site conditions



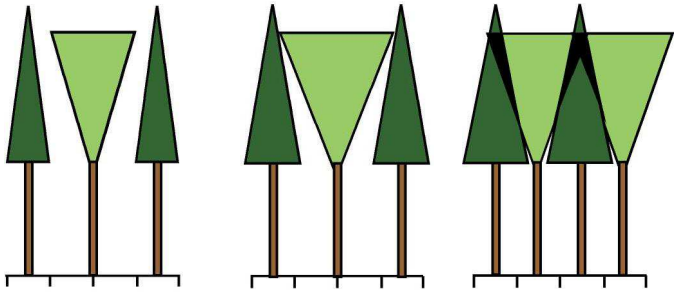
- On average 20-30 % overyielding of mixeds vs. pure stands (= increased area use efficiency)
- Level of the benefit various with admixed species
- Stronger benefit on poor than on fertile sites

Graphical summary: Mixing can increase crown size, canopy density, and stand productivity

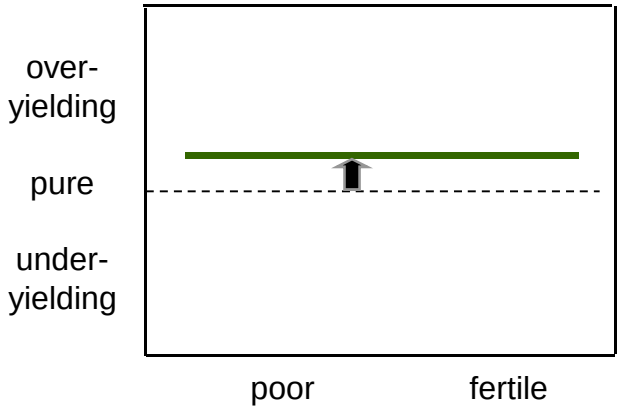
Without emergent behaviour:



With increase of canopy space filling and stand productivity:

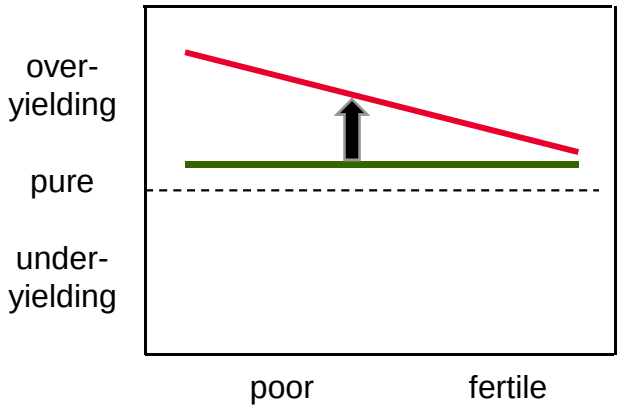


Working hypothesis for explaining the mixing reaction patterns and for further research



Hypotheses

Effect of crown plasticity and light use complementarity is rather independent from site conditions.

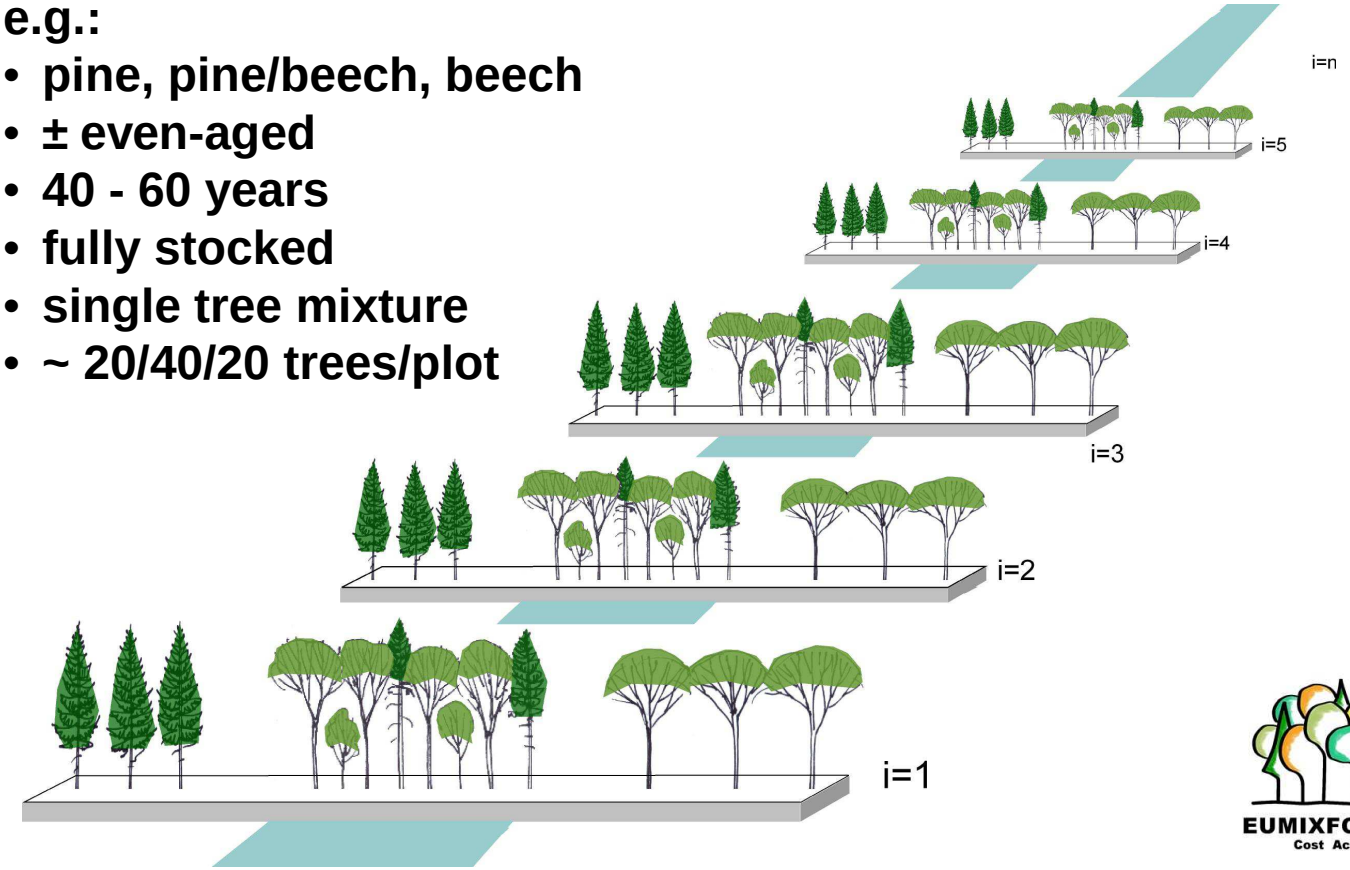


Effect on below ground resource supply higher on poor than on rich sites.

EuMIXFOR FP1206: Proposal for a transect study

e.g.:

- **pine, pine/beech, beech**
- **± even-aged**
- **40 - 60 years**
- **fully stocked**
- **single tree mixture**
- **~ 20/40/20 trees/plot**



EUMIXFOR
Cost Action

Thanks to:

Hermann Spellmann/NW-FVA Göttingen
Hans-Peter Ehrhart/FAWF Trippstadt
Ulrich Kohnle/FVA Freiburg
Andreas Zingg/WSL Birmensdorf, Zürich
Kamil Bielak, Michal Zasada, Warsawa
Arkadiusz Bruchwald/Univ. Warsawa
Axel Martin Jensen, Kopenhagen
for contributing valuable datasets
from long-term experimental plots
in pure and mixed stands to this study.

German Science Foundation for funding SFB 607 'Growth and Defence in Plants‘, SFB/TRR 38 'Chicken creek catchment project‘, PR 292/10-1 'Interaction between beech and spruce‘.

Analyzing the effect of species mixing on the structure and productivity of temperate forests in Europe

1 Crown and canopy structure in mixed versus pure stands

2 Crown and stand area efficiency in inter- vs. intra-specific neighbourhood

3 Over-/underyielding of mixed versus pure forests. Effect of site conditions