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# Growth of mixed versus mono-specific stands of S. pine and E. beech in Europe. Results of the triplet study

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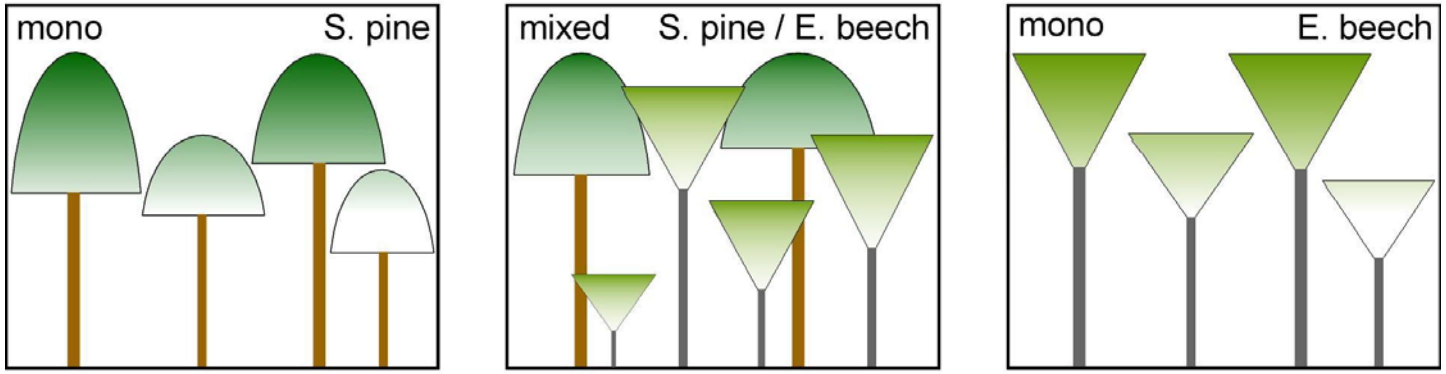
http://www.forestgrowth.wzw.tum.de/presentations.html




complementarity: Light-demanding/shade-tolerant, fast-/slow-growing evergreen/deciduous species

Relevance: $2 \times 10^6$ ha real, $32 \times 10^6$ ha potential occurence

EuMIXFOR Final Conference on "Integrating Scientific Knowledge in Mixed Forests",
COST Action FP 1206, 5.-7. Oct. 2016, Prague, Czech Republic

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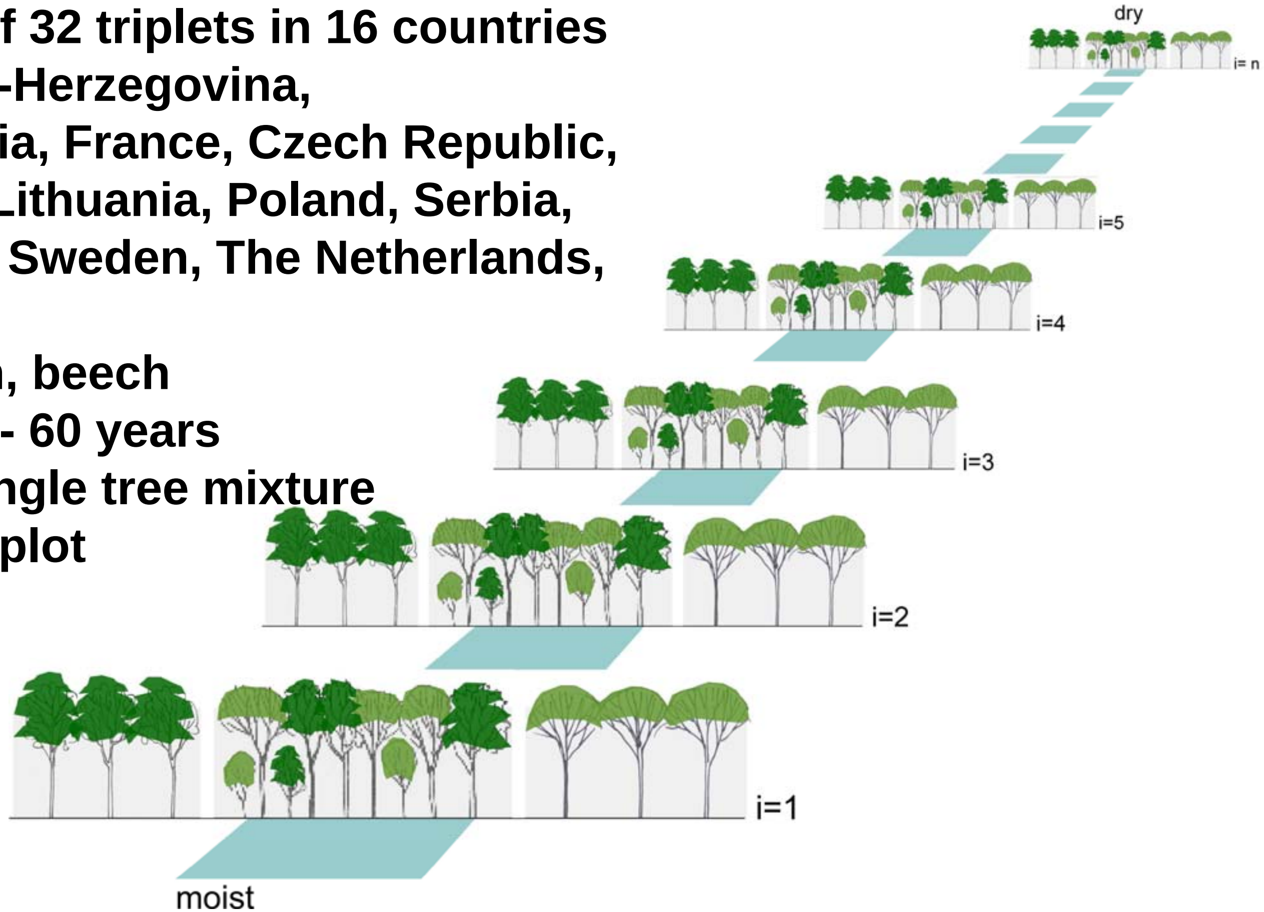
# EuMIXFOR FP1206: Transect study in mixed stands of Scots pine and European beech

- **Establishment of 32 triplets in 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**
- **stand variables**
- **increment cores**




Pretzsch, H., del Río, M., Ammer Ch. et al. 2015: Growth and yield of mixed versus pure stands of Scots pine (*Pinus sylvestris* L.) and European beech (*Fagus sylvativa* L.) along an ecological gradient through Europe, European Journal of Forest Research, 134(5): 927-947

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# Map of the 32 triplets in pure and mixed stands (temp.: 6-10.5°C, precip.: 520-1.175 mm $yr^{-1}$)

# Growth of mixed versus mono-specific stands of S. pine and E. beech in Europe. Results of the triplet study

- Mixing effect on stand productivity
- stand height, density, yield level
- size distribution  stand structure
- tree allometry and allocation
- variation along the environmental gradient

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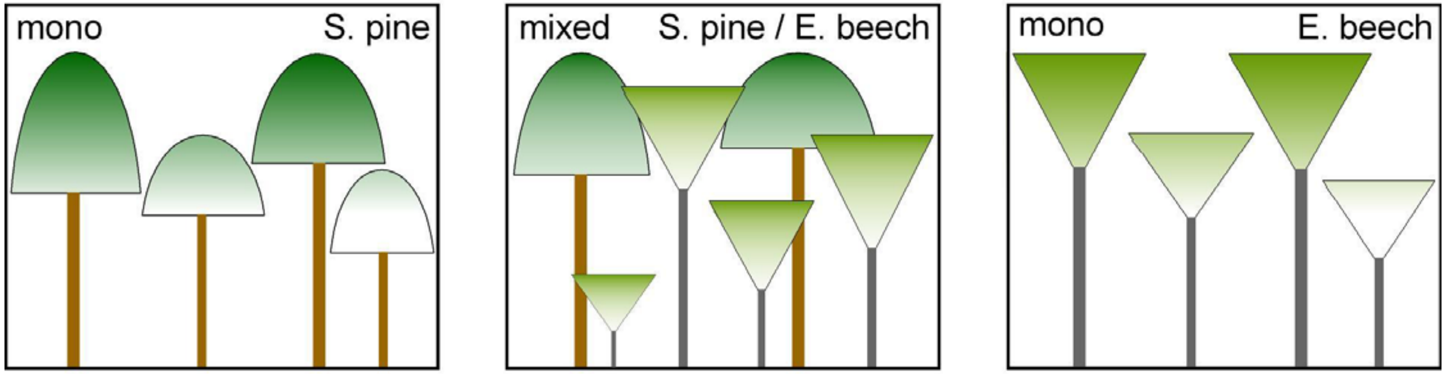
# Comparing mixed-species stands with mono-specific stands




$p_1$ $p_{1,2}$ $m_1$ $m_2$ $p_2$

$$\widehat{p}_{1,2} = p_1 m_1 + p_2 m_2$$

$$RP_{1,2} = \frac{p_{1,2}}{m_1 \times p_1 + m_2 \times p_2}$$

$$RP_{1,(2)} = pp_{1,(2)} / m_1 / p_1 \quad RP_{(1),2} = pp_{(1),2} / m_2 / p_2$$

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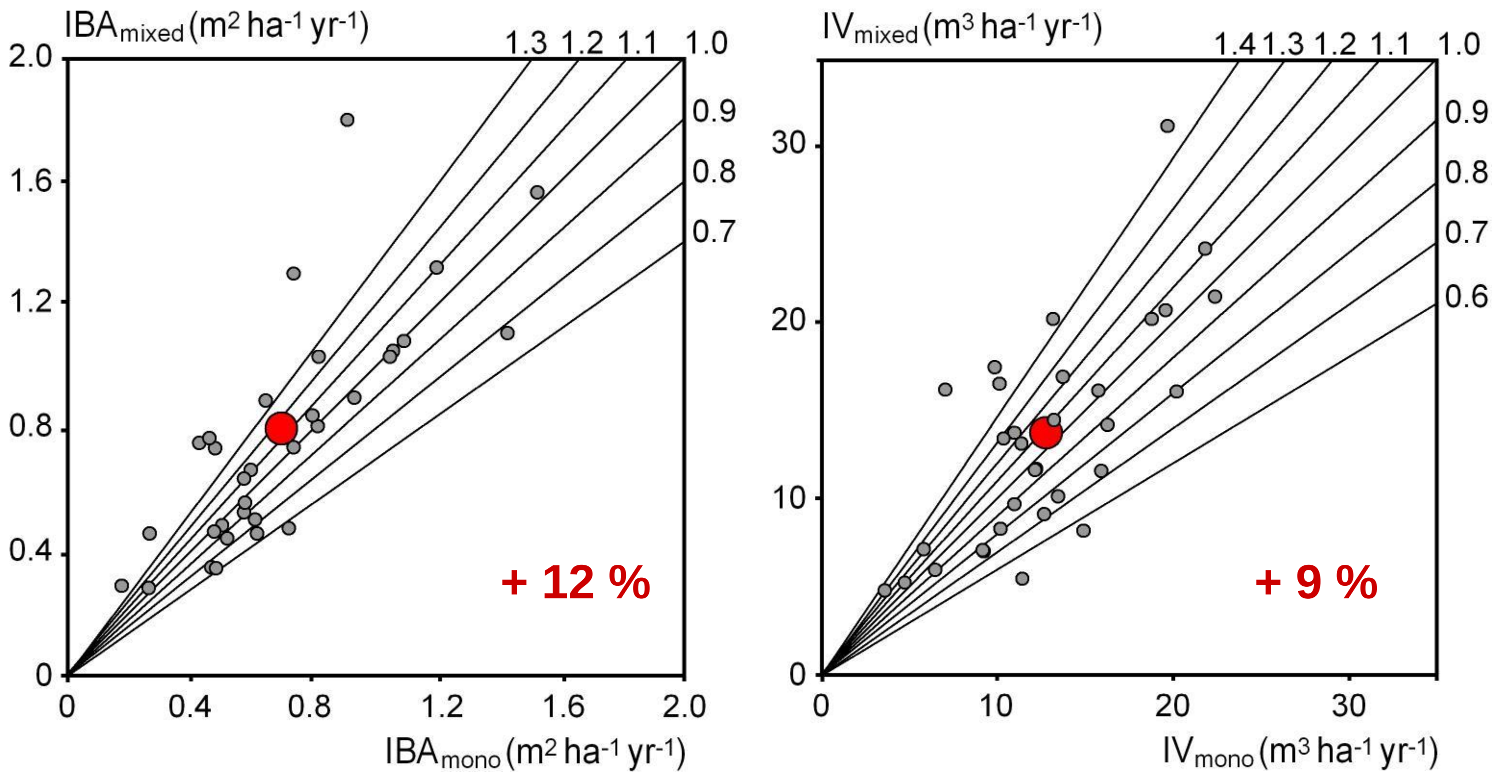
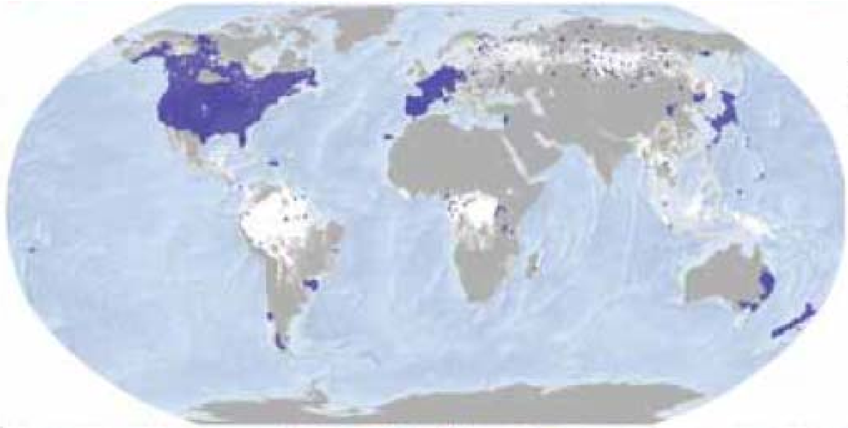
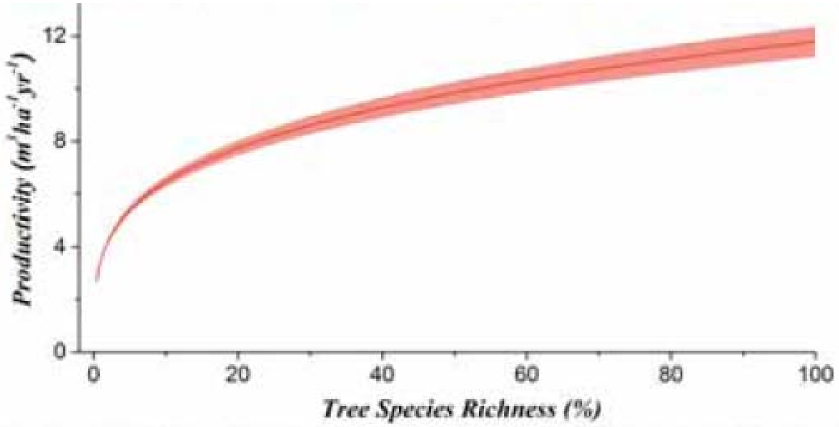
# Mixing can increase stand basal are and volume increment by 12 and 9 %, respectively




Pretzsch, H., del Río, M., Ammer Ch. et al. 2015: Growth and yield of mixed versus pure stands of Scots pine (*Pinus sylvestris* L.) and European beech (*Fagus sylvativa* L.) along an ecological gradient through Europe, European Journal of Forest Research, 134(5): 927-947

# Mixing effects on productivity of forests worldwide and in Central Europe






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

| 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

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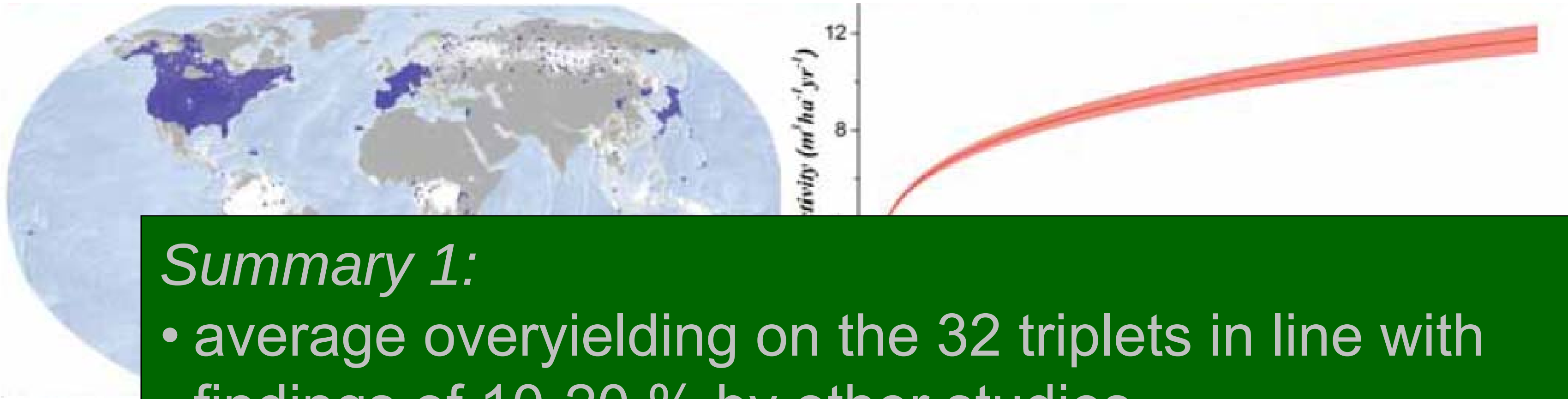
# Mixing effects on productivity of forests worldwide and in Central Europe




Liang, J.
Global F

*Summary 1:*

- average overyielding on the 32 triplets in line with findings of 10-20 % by other studies
- conservative correction factor: $iv_{pure}$ × 1.10 to 1.20

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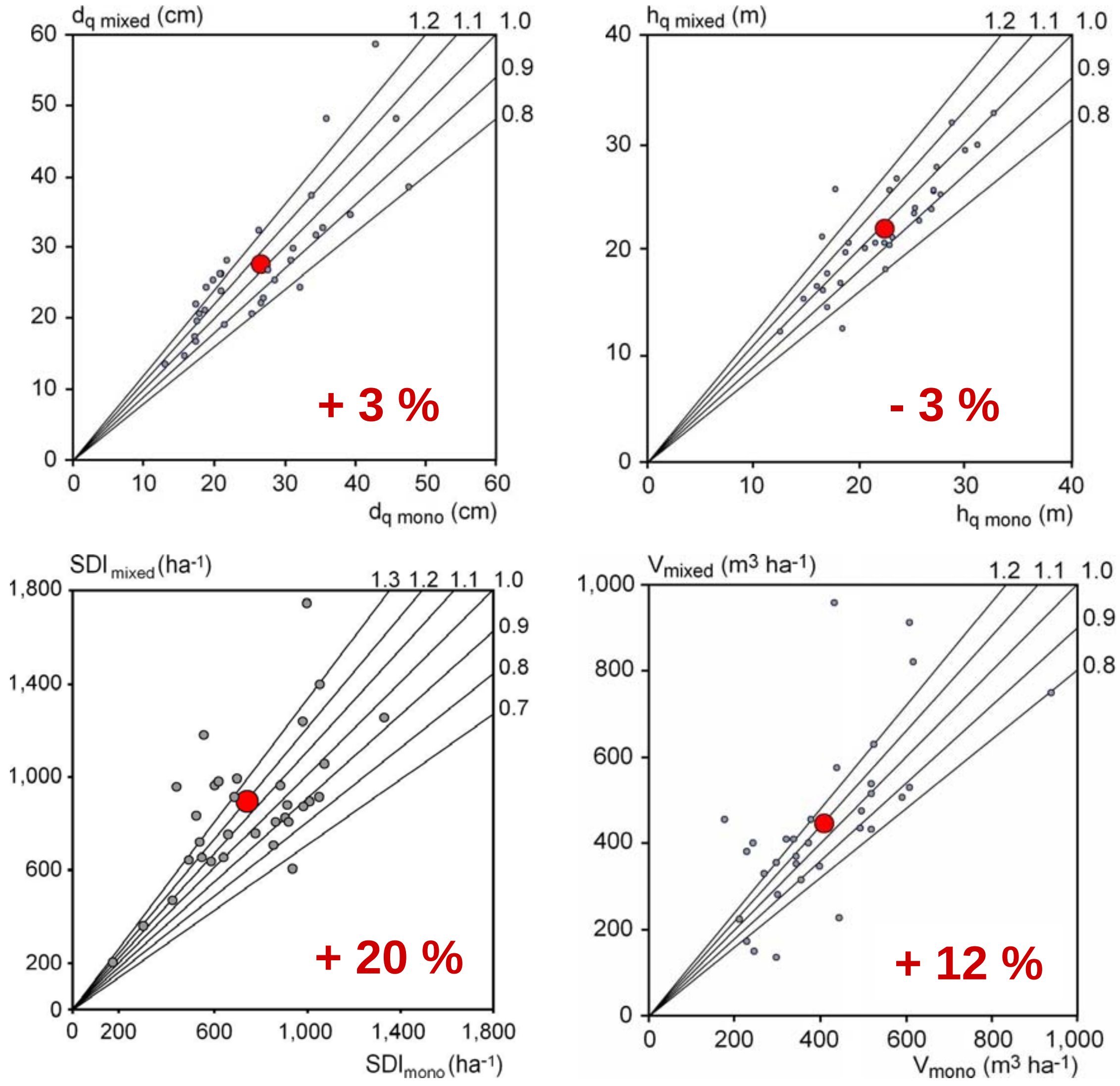
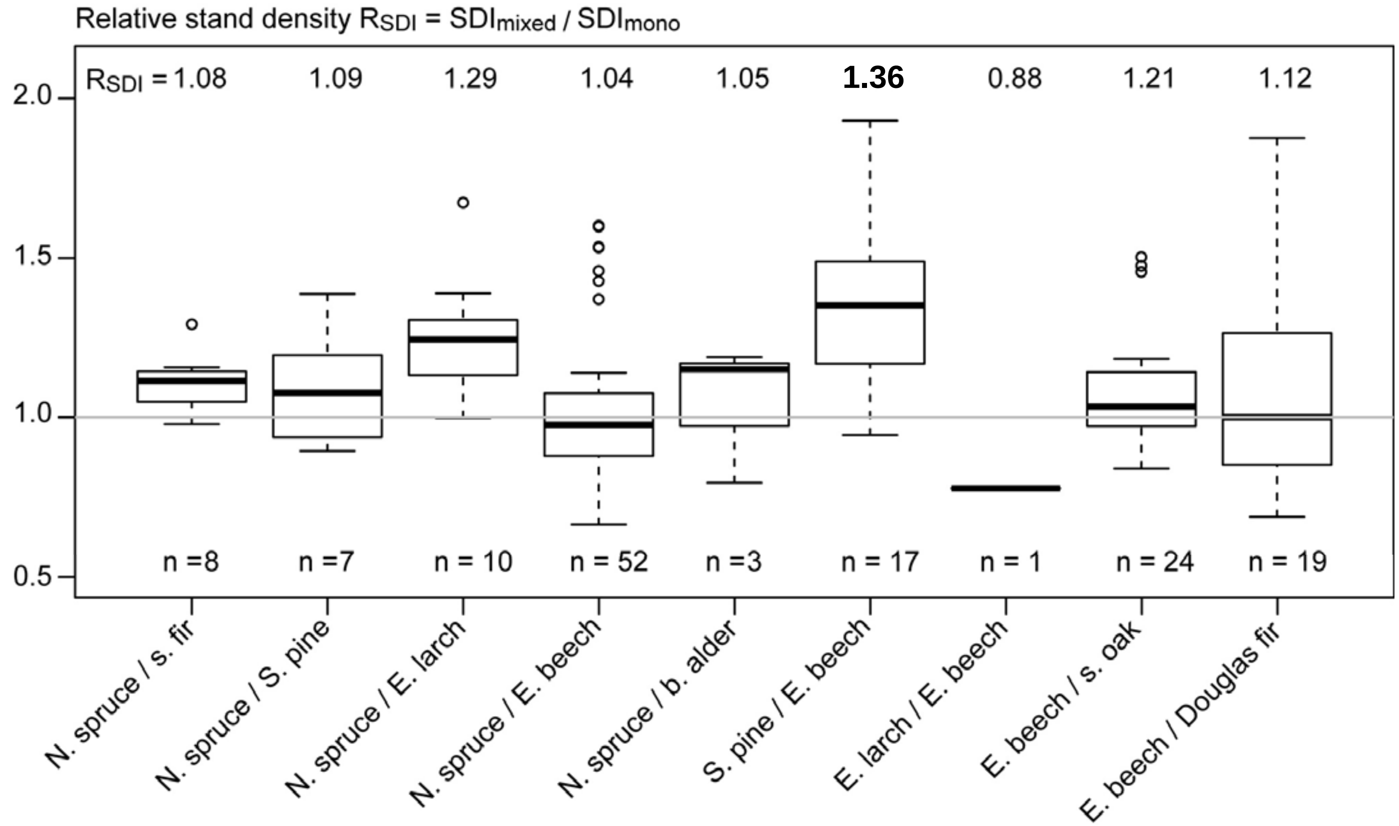
Pretzsch (2016) Ertragstafel-Korrekturfaktoren für Umwelt- und Mischunsgeffekte, AFZ Der Wald, 14/2016: 47-50

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



# Stand density (SDI) of mixed-species stands versus monocultures on long-term experiments in Central Europe





Pretzsch, H., Biber, P. (2016) Tree species mixing can increase maximum stand density. Canadian Journal of Forest Research, DOI: 10.1139/cjfr-2015-0413

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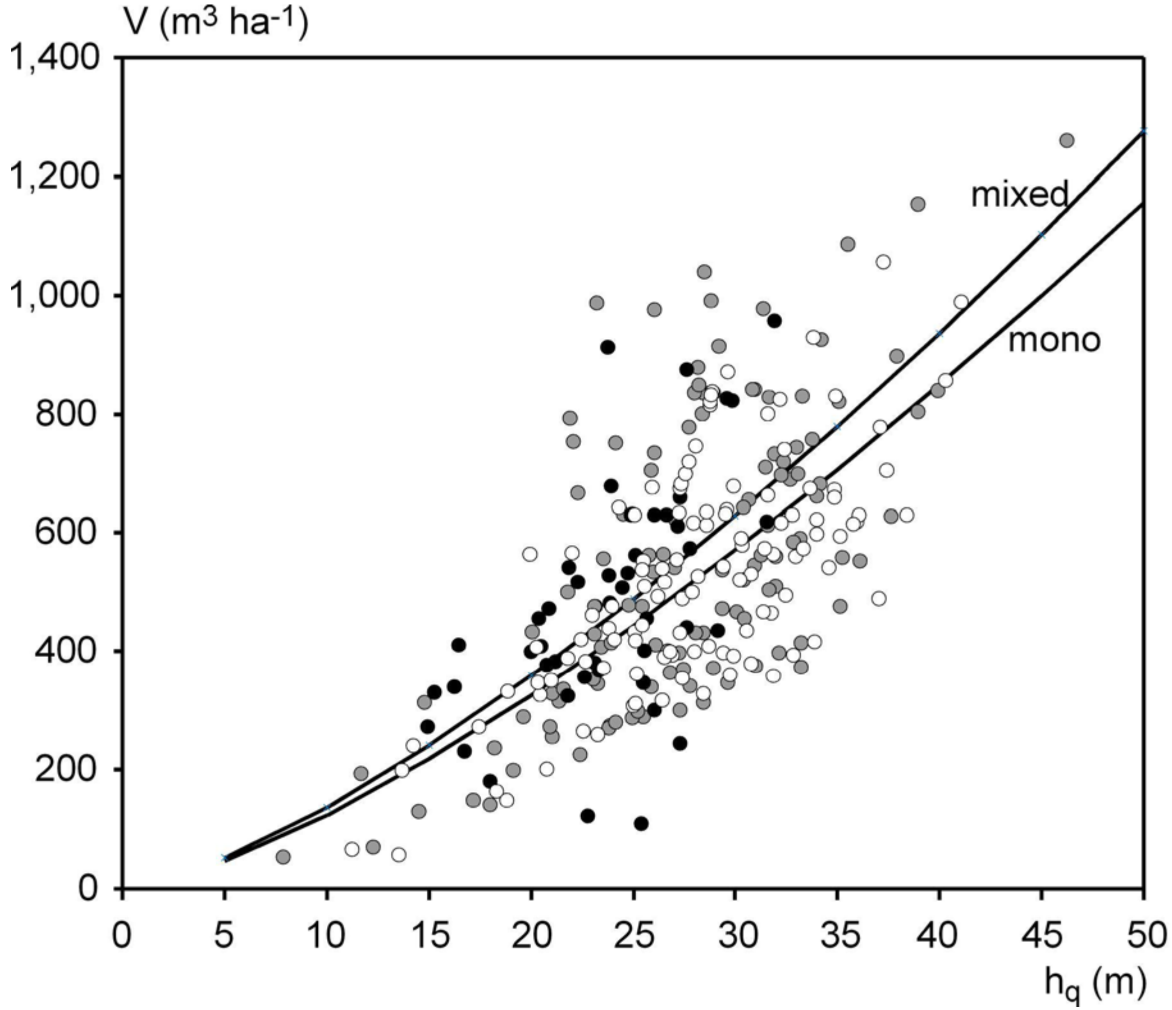
# Eichhorn‘s rule (common yield level) in mixed stands on average + 10-15 %, in S. pine and E. beech + 30% compared with monocultures



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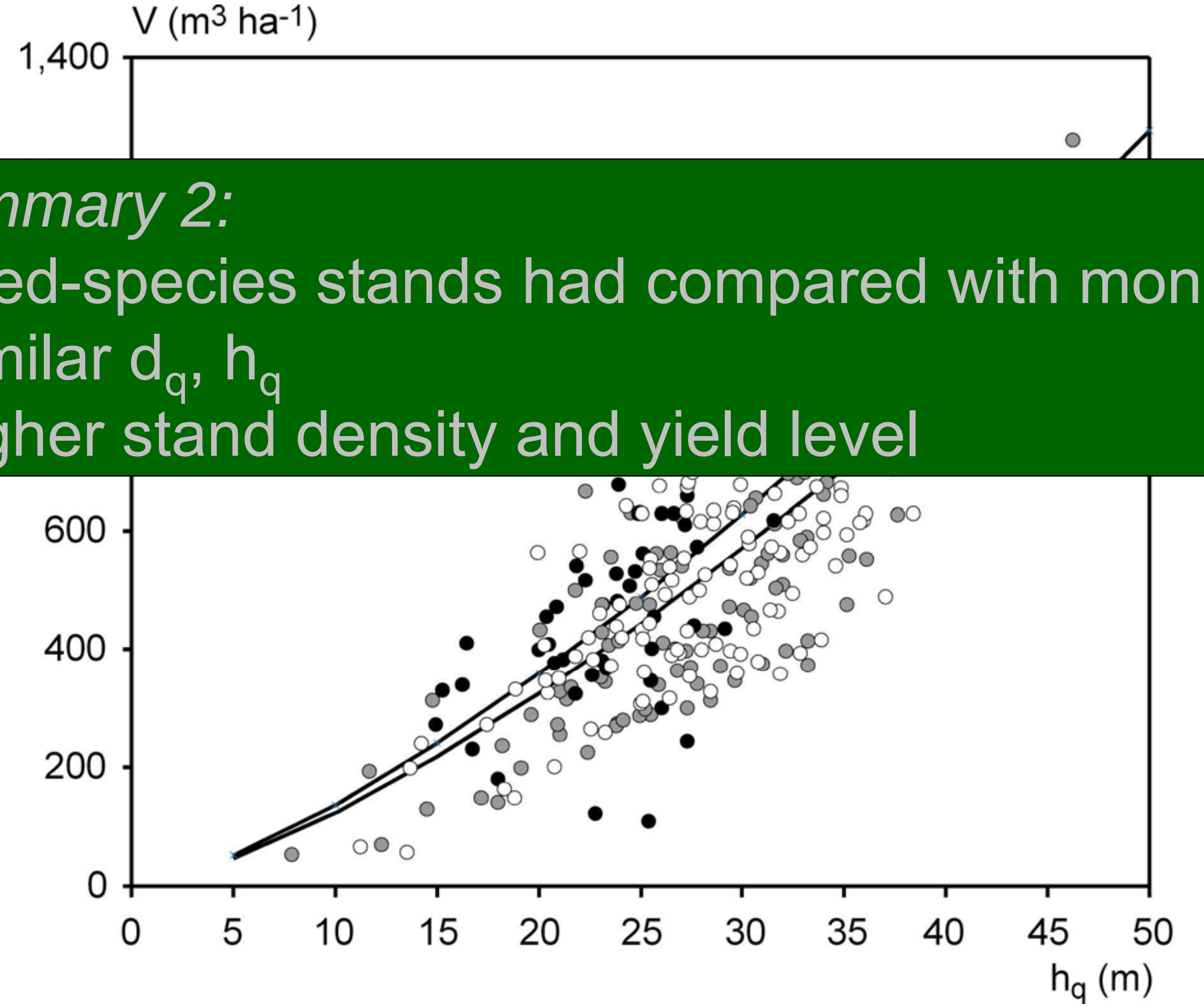


*Summary 2:*
Mixed-species stands had compared with monocultures:
- similar $d_q$, $h_q$
- higher stand density and yield level

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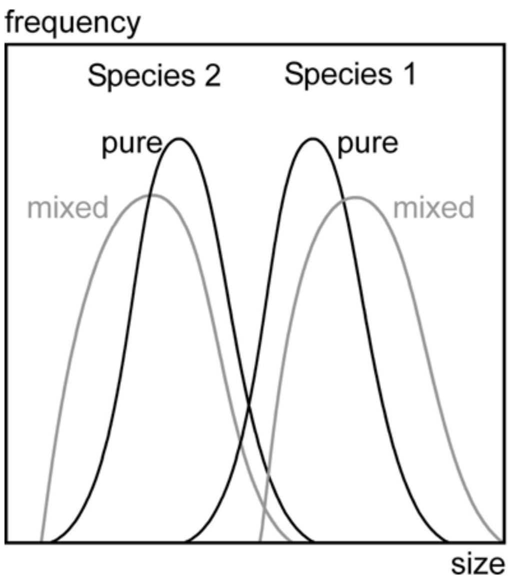
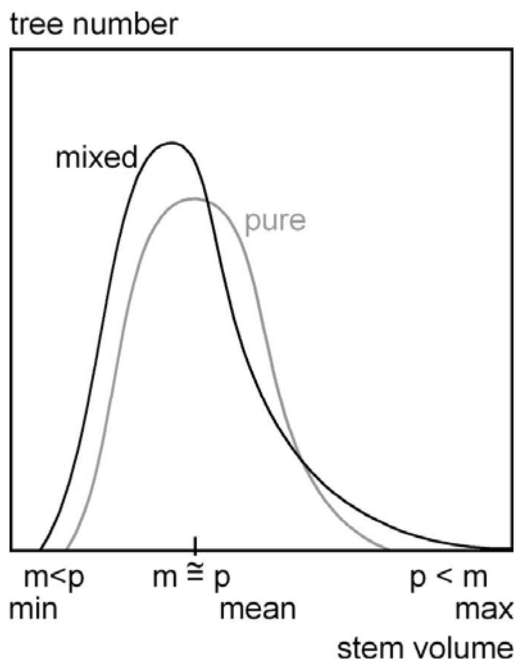
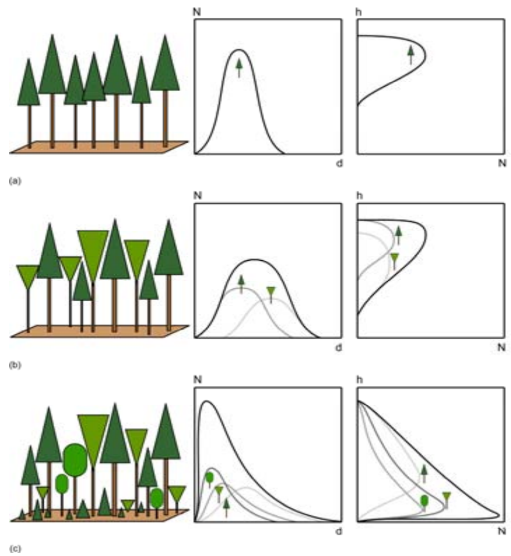
# More trees, wider size range, stronger right-skewness in mixed stands; often species 1 ahead, species 2 behind the monoculture



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

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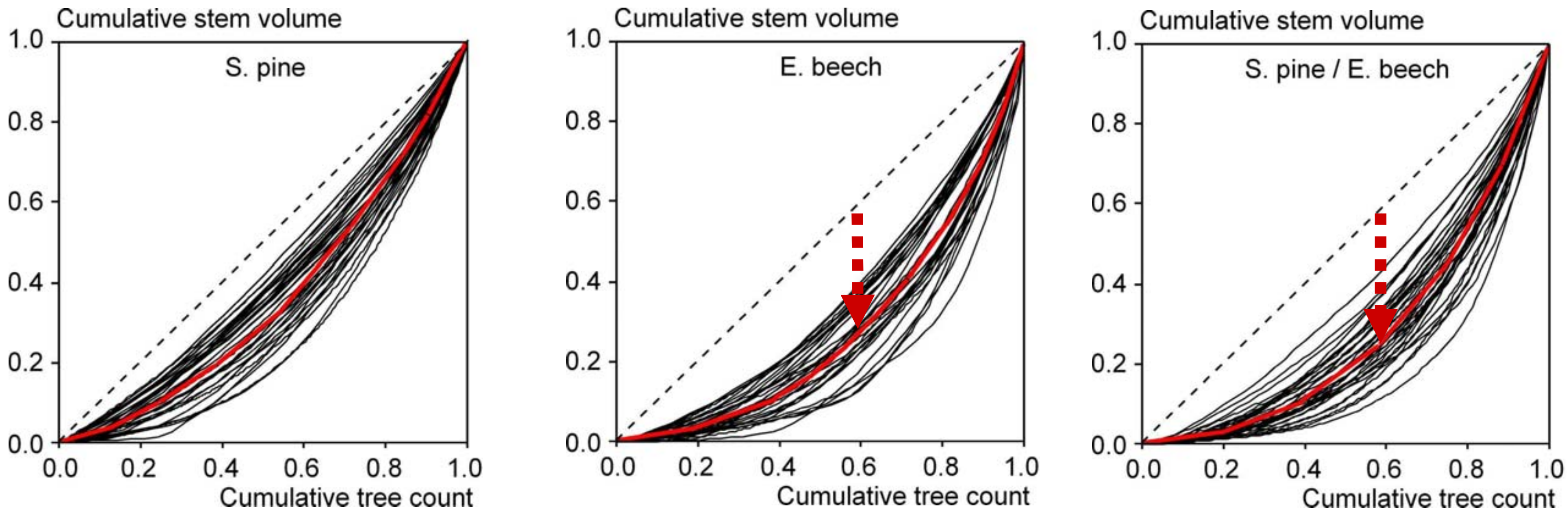
# Cumulative distribution of stem volume over tree count (Lorenz-curve, Gini-coefficient)




Pretzsch, H., … Bravo-Oviedo, A. (2016): Mixing of Scots pine and European beech enhances structural heterogeneity, and the effect increases with water availability. Forest Ecology and Management 373: 149-166.

# Higher structural heterogeneity in mixed stands especially on moist sites


Compared with the monoculture:
similar mean tree height and diameter
but
higher density, higher yield level, more heterogeneous structure,
heterogeneity increases with water supply

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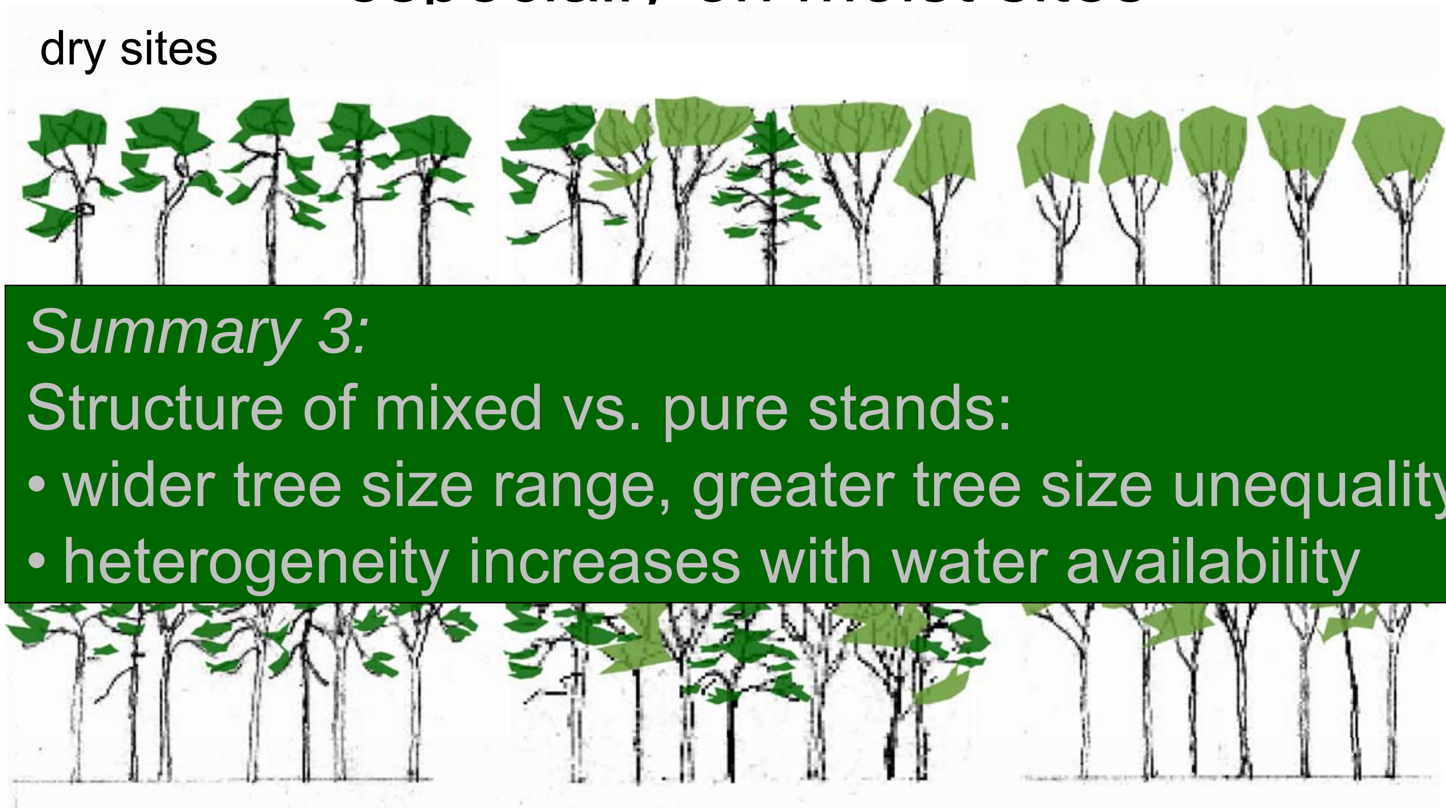
# Higher structural heterogeneity in mixed stands especially on moist sites




*Summary 3:*

Structure of mixed vs. pure stands:

- wider tree size range, greater tree size unequality
- heterogeneity increases with water availability

Compared with the monoculture:
similar mean tree height and diameter
but
higher density, higher yield level, more heterogeneous structure,
heterogeneity increases with water supply

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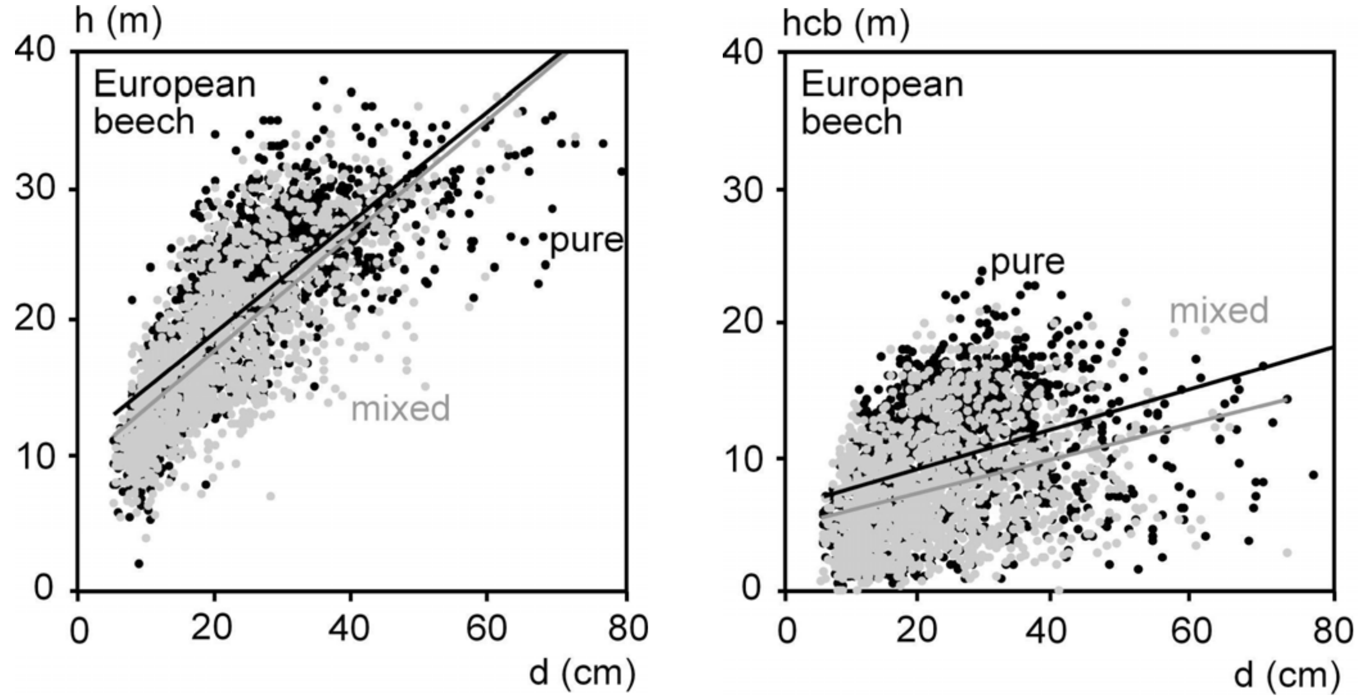
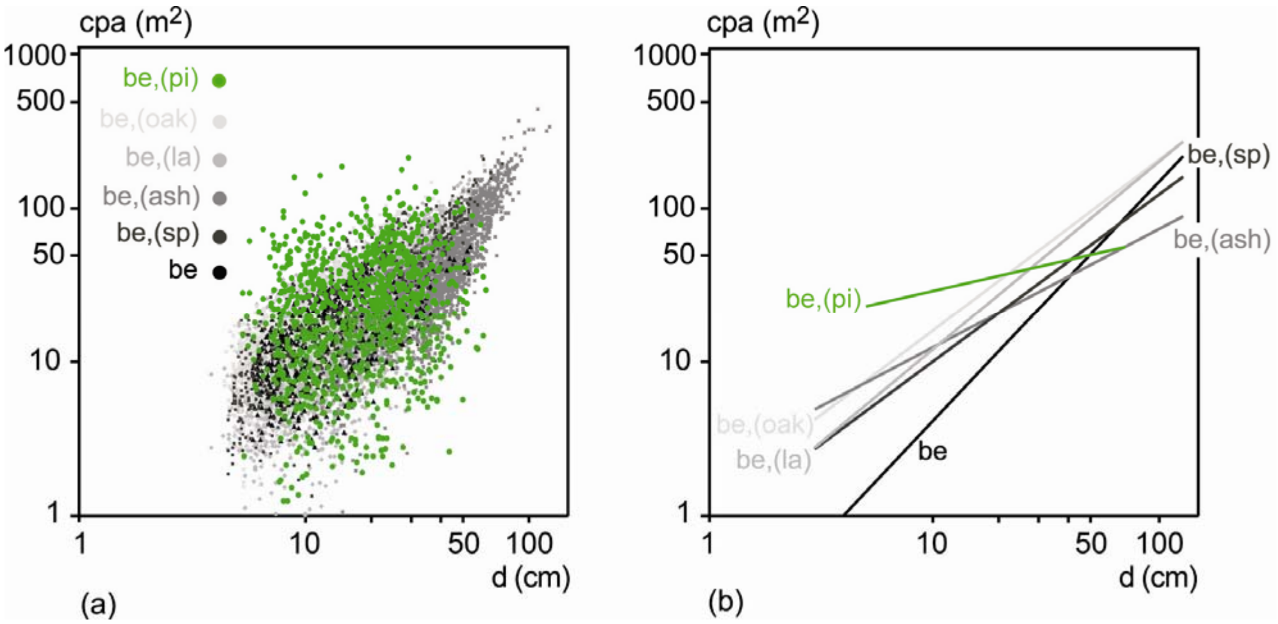
# Tree height and height to crown base of E. beech in mixed versus pure stands




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 when growing in mono-specific versus mixed stands




S. pine
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.

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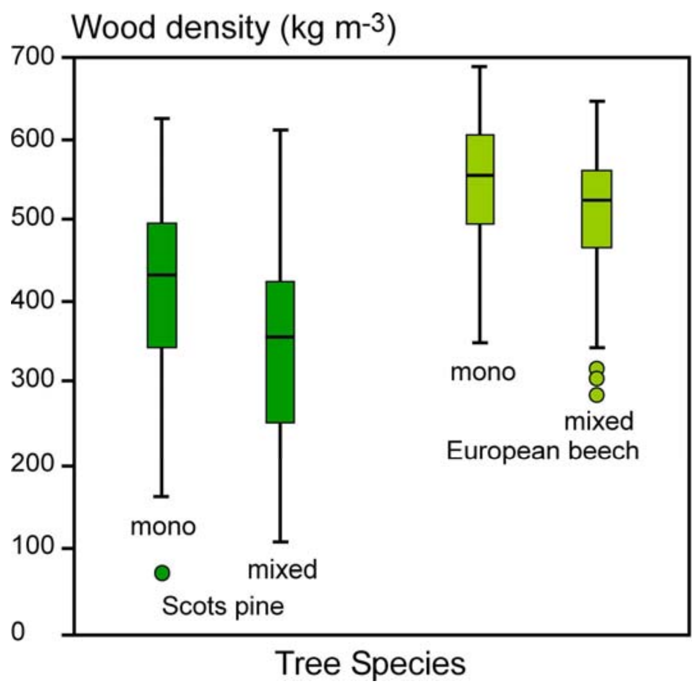
# Wood density in mixed-species stands of S. pine and E. beech compared with monocultures




Zeller et al. in prep.
Pretzsch and Rais 2016

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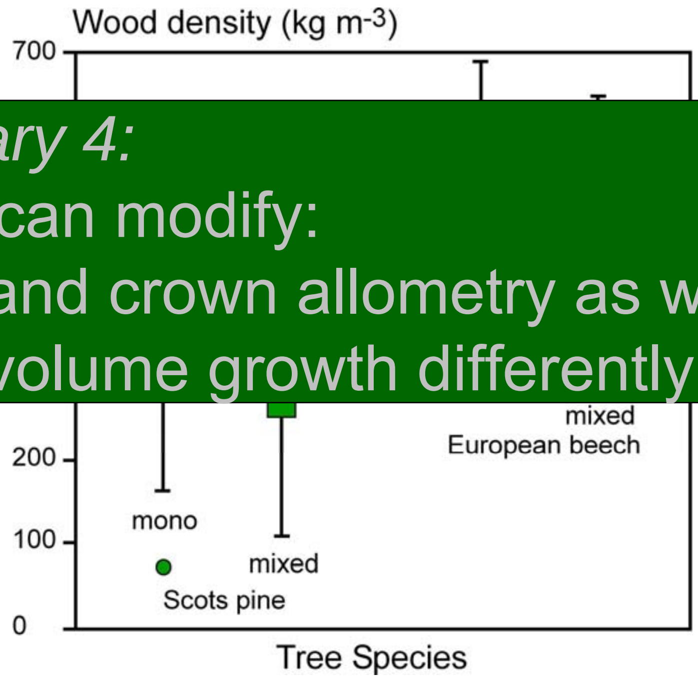
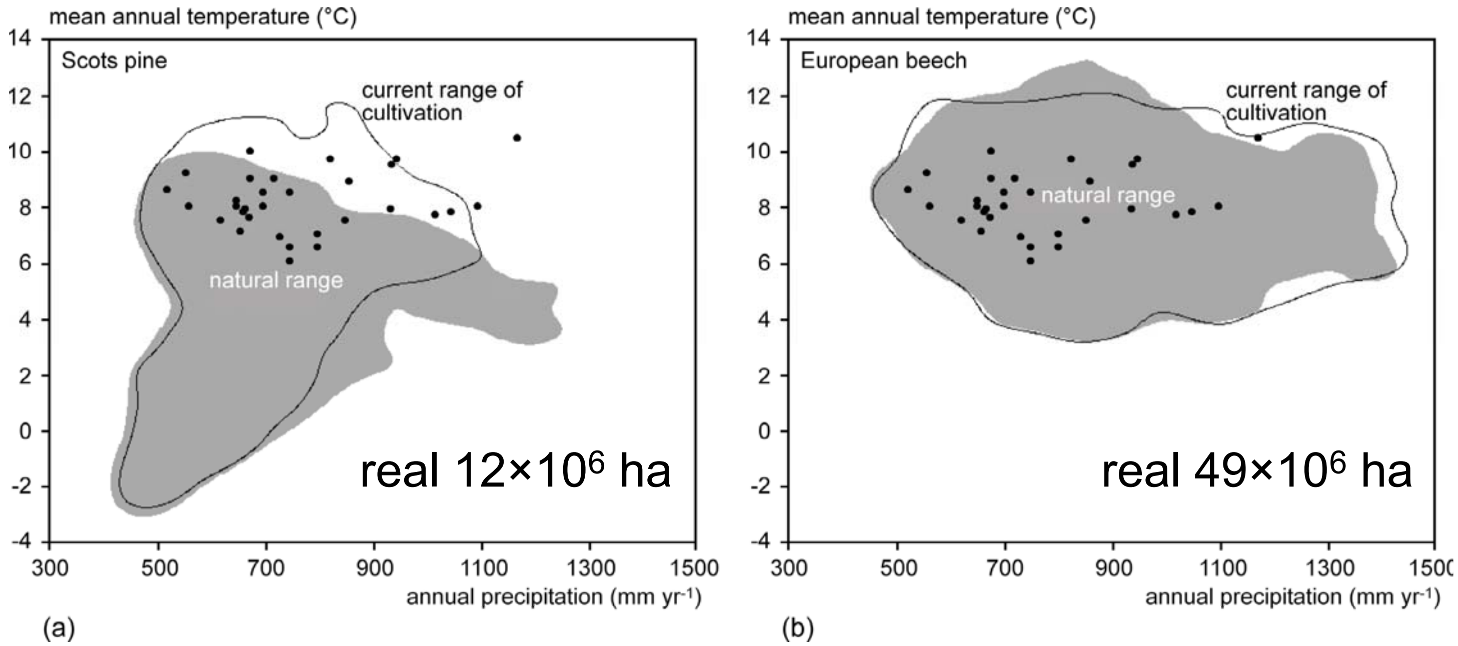
# Wood density in mixed-species stands of S. pine and E. beech compared with monocultures




*Summary 4:*
Mixing can modify:
- stem and crown allometry as well as wood density
- stem volume growth differently from total mass growth

Zeller et al. in prep.
Pretzsch and Rais 2016

# Natural range of Scots pine and European beech regarding temperature and precipitation. Range of the triplets




Triplets reach from the atlantic to the continental climate:

| | |
|---|---|
| mean temperature: | 6-10.5 °C |
| annual precipitation: | 520-1,175 mm $J^{-1}$ |
| Martonne index: | 28-67 mm $°C^{-1}$ |

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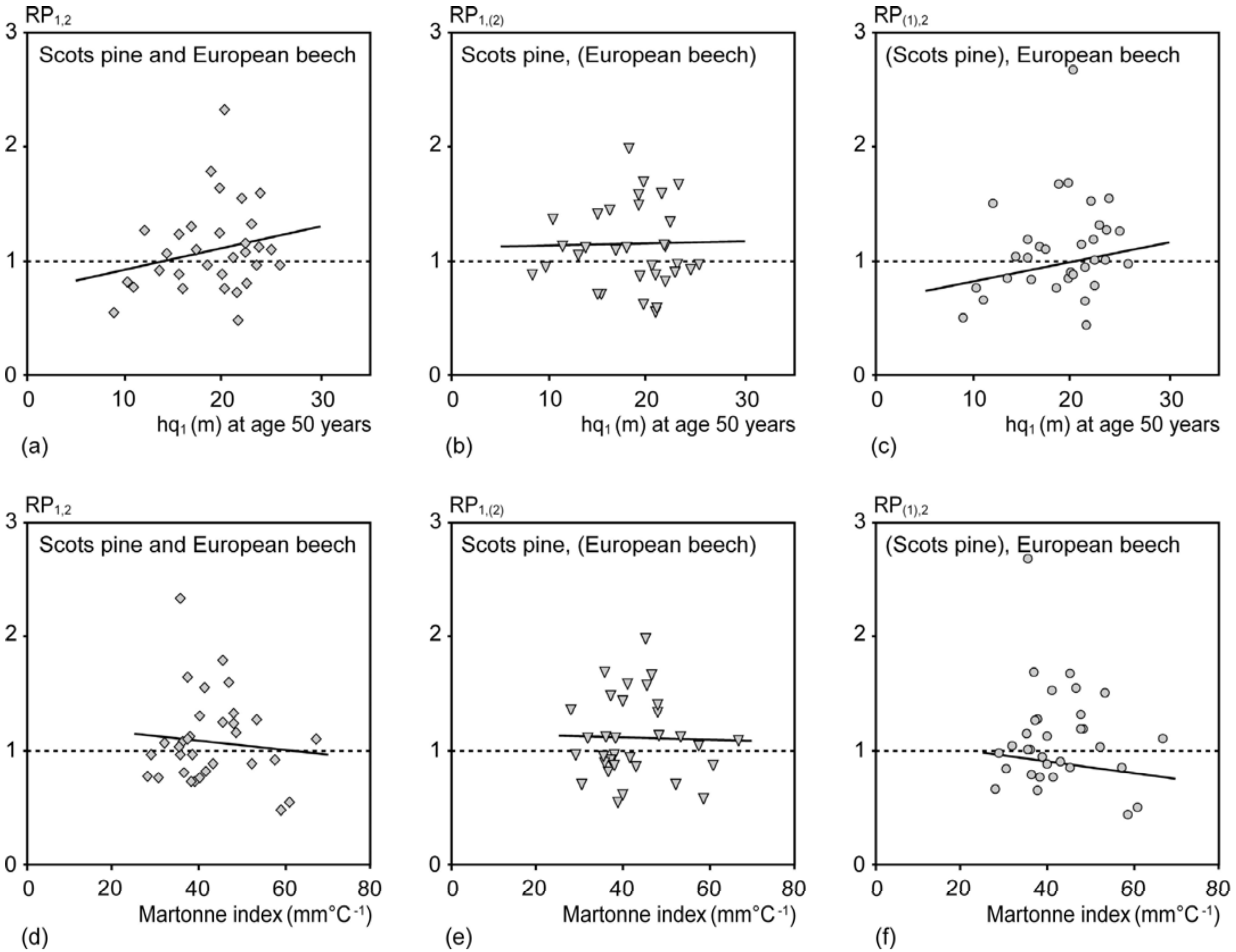
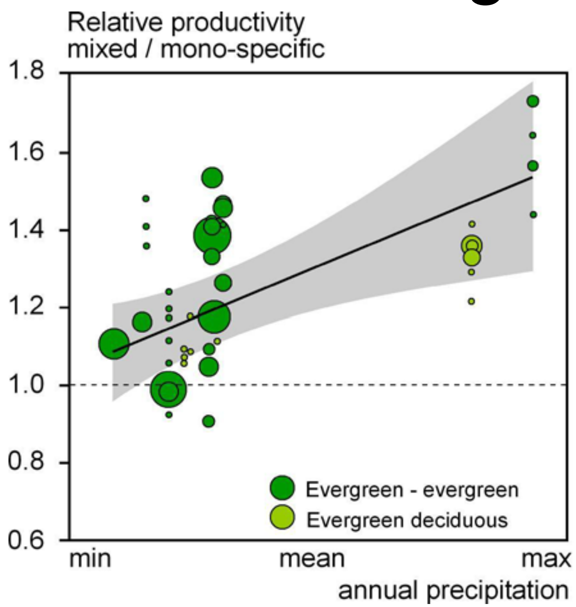
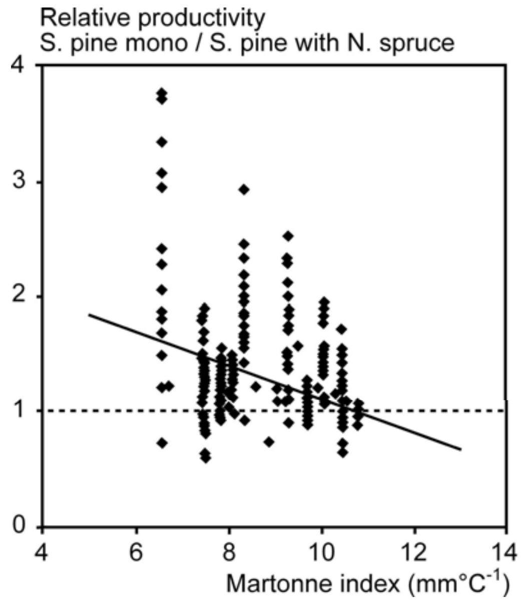
# No statistical relationship between overyielding and site characteristics (6-10.5 °C, 520-1,175 mm yr$^{-1}$)



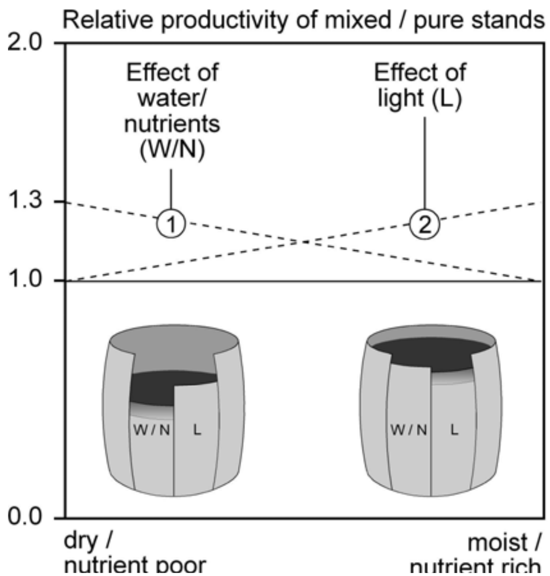
# Mixing effects and site conditions




Gritti E. S. ...
Jactel H. et al. (2016)




Bielak et al. (2015)




*remedy of the limiting factor*

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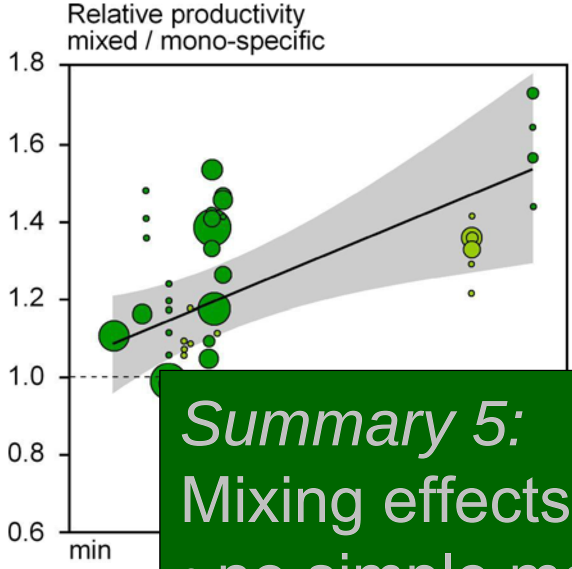
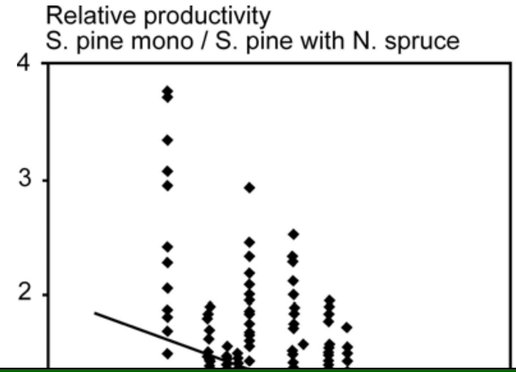
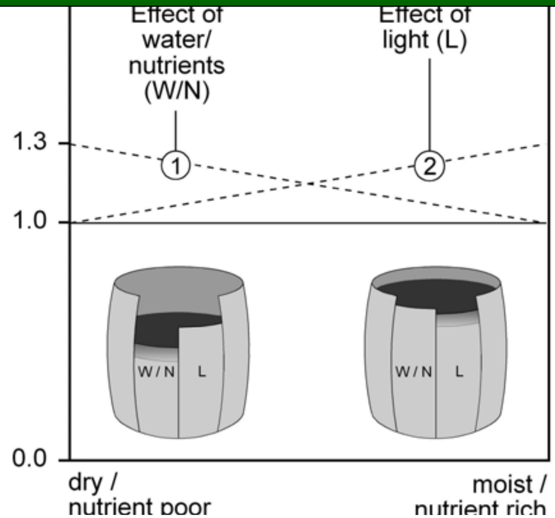
# Mixing effects and site conditions




*Summary 5:*
Mixing effects depending on site conditions:
- no simple mono-causal relationships
- rather a function of the respective limiting factor




*remedy of the limiting factor*

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# Further results of the triplet initiative

- standard for measurement and evaluation of mixed species stands
- characterization of mixed species stands
- platform for further research (e.g., drought stress, tree allometry, resource-productivity relationship, model parameterisation)
- free accessible dataset
- platform for further applications for funding

Thanks to all contributors to the triplet initiative, in particular to
del Río M, Ammer Ch, Avdagic A, Barbeito I, Bielak K, Brazaitis G, Coll L, Dirnberger G, Drössler L, Fabrika M, Forrester D I, Godvod K, Heym M, Hurt V, Kurylyak V, Löf M, Lombardi F, Matović B, Mohren F, Motta R, den Ouden J, Pach M, Ponette Q, Schütze G, Schweig J, Skrzyszewski J, Sramek V, Sterba H, Stojanović D, Svoboda M, Vanhellemont M, Verheyen K, Wellhausen K, Zlatanov T, and Bravo-Oviedo A

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