University of Natural Resources and Life Sciences - Vienna
Department of Forest and Soil Sciences

Simulated effects of tree species diversity and species pattern on biomass production at stand level

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Managing Forests in the 21st Century
03.03.2020
Potsdam

diversity and ecosystem productivity relationships (PDRs)

state of knowledge

Mischung und Produktivität von Wa
Ergebnisse langfristiger ertragskundli

Aus dem Lehrstuhl für Waldwachstumskunde der Technisch

(Mit 9 Abbildungen und 1 Tabelle)

H. Pretzsch[2]), K. Bielak, A.

esa ECOSPHERE

Relationships between tree biomass productivity and local species diversity

Juan Wang,[1] Yanxia Cheng,[1] Chunyu Zhang,[1,†] Yazhou Zhao,[2] Xiuhai Zhao,[1] and Klaus Von Gadow[3,4]

China

Journal of Ecology

Standard Paper | Free Access

Overyielding in mixed fo

Maude Toïgo, Patrick Vallet, Thoma Courbaud

First published:24 November 2014 | https://doi.org/10.11

Nova Acta Leopoldina NF *114*, Nr. 391, 239–254 (2013)

Mixing Patterns of Tree Species and their Effects on Resource Allocation and Growth in Forest Stands

Thomas Rötzer (München)

-0248.2011.01691.x

erate ecies

in the context of for forests, and no

RESEARCH PAPER

The effect of productivity: boreal forest

Alain Paquette* and Ch

Journal of Ecology

BRITISH ECOLOGICAL SOCIETY

Free Access

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

Yu Zhang, Han Y. H. Chen, Peter B. Reich

First published:12 January 2012 | https://doi.org/10.1111/j.1365-2745.2011.01944.x | Citations: 267

state of knowledge

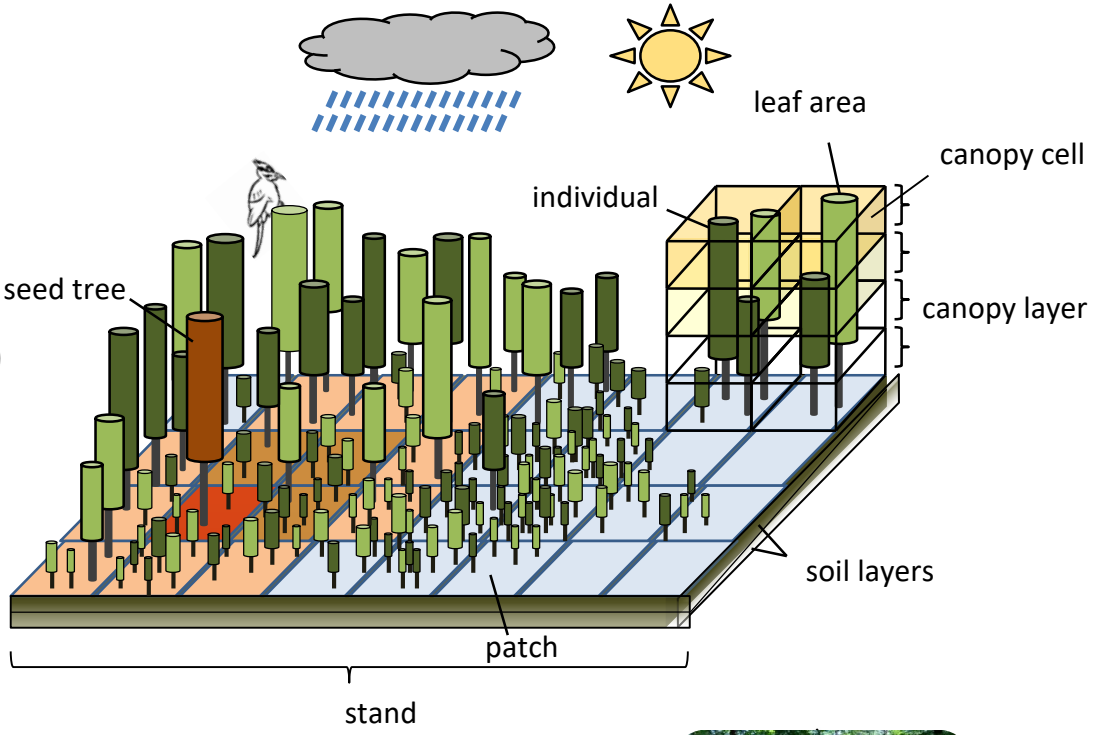
- **overall PDR means are positive, but no universal rules**
- **known factors that may have an influence:**
  - species richness
  - species identity effect (traits)
  - complementarity effect
  - site quality
  - …

questions

- **Q1: How is productivity related to tree species diversity when simulated with a forest ecosystem model?**
- **Q2: Can simulated biomass production be explained by species identity effect and complementarity effect?**
- **Q3: What is the effect of mixture in patches versus random mixture?**

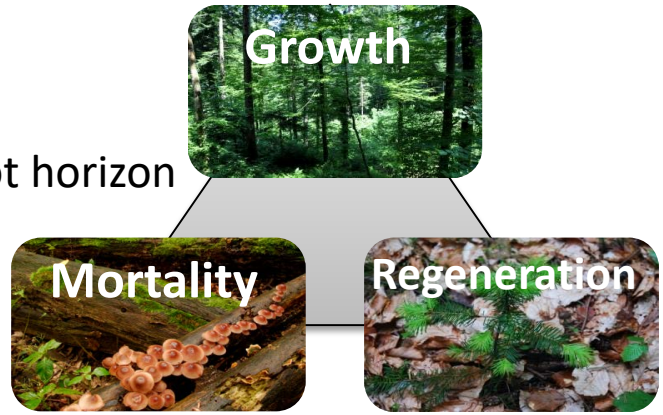
the experimental setup

PICUS v1.6



main features

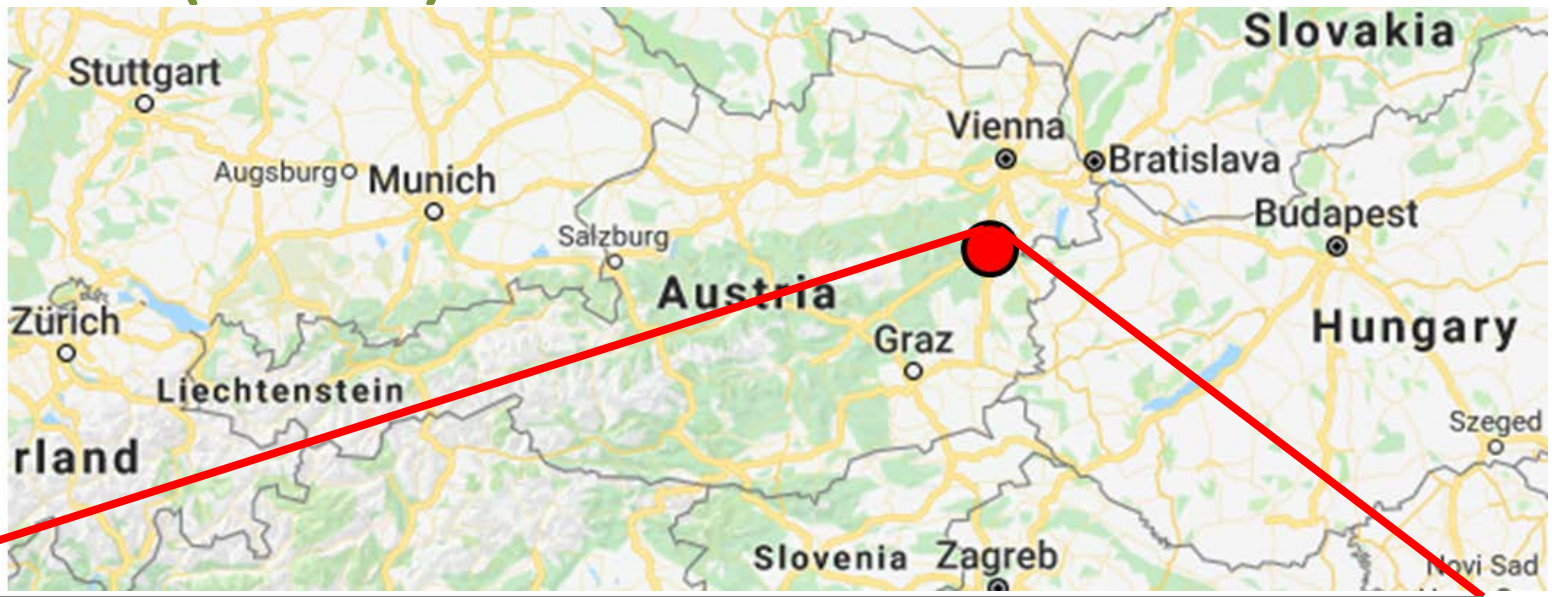
- hybrid forest gap model (3PG)
- individual tree growth
- on patches (10x10m)
- 3D canopy structure
- trees compete for light
- tree population dynamics
- watercycle module with detailed water balance and physiological water relations of vegetation
- individual trees & species compete for water in the root horizon
- requires daily weather data (rad., temp., precip., vpd)



- management module (>>not active)
- disturbance modules for storm and bark beetles (>> not active)

the experimental setup

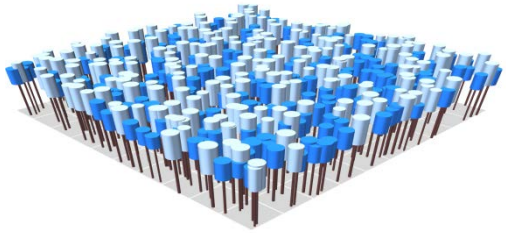
site: Rosalia (Austria)

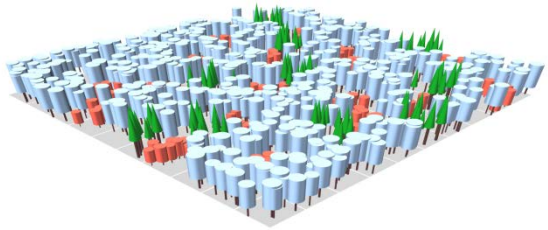


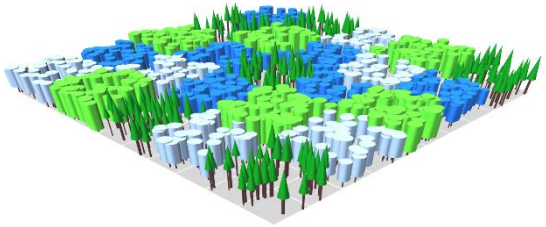
- **site**
  - altitude: 450 m a.s.l.
  - soil type: Cambisol
  - soil depth: 100cm
  - pH: 4.17
  - WHC: 155mm
  - Ø annual temp.: 8.8°C
  - annual precip.: 774mm

source: Catalin Petritan

experimental setup







random	patches		
trees randomly distributed in the simulated forest	patch size 10x10m	patch size 20x20m	patch size 30x30m

- **initialisation**
  - 8 species in all combinations (PA, AA, LD, PS, FS, AP, QP, BP)
  - minimum share per species 10%
  - juvenile stand (80 – 130cm tree height)
- **settings**
  - 100 years simulation period
  - no management
  - no regeneration
  - no disturbances

analysis approach (1)

- **relative yield (RY) & overyielding (OY)** (Pretzsch & Schütze, 2009)

$$\mathbf{RY} = \frac{\textbf{actual absolute yield mixed stand}}{\textbf{expected absolute yield of pure stand shares}}$$

RY > 1 → OY

RY < 1 → UY

RY = 1 → no PDR

- **transgressive OY**

  actual absolute yield (AY) mixed stand > AY of pure stand of each species

- **tree species diversity via Shannon Index**

$$\textbf{Shannon Index} = -\sum \mathbf{S_{Sp\ i} * \ln S_{Sp\ i}}$$

$S_{Sp\ i}$ = species share of species i

analysis approach (2)

- **species identity & complementarity effect** (Loreau & Hector, 2001)
  - mean & CV of the species traits
    - light response
    - potential max. height at the age of 100 [m]
    - leaf area allometric exponent
- **statistical analysis**
  - Pearson correlations
  - uni & multivariate OLS regressions

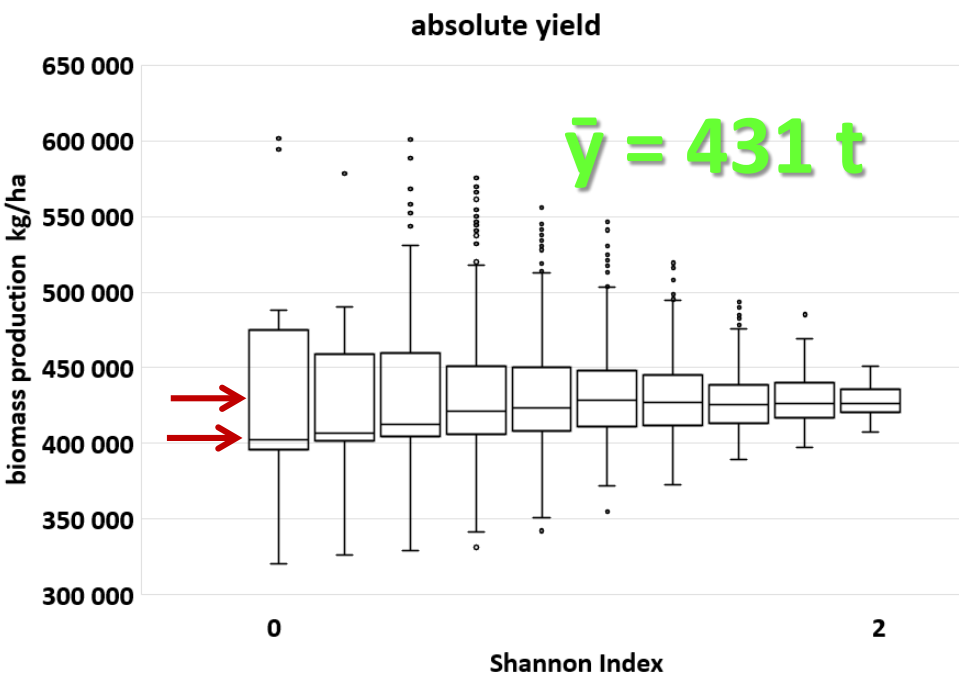
$$\mathbf{RY = a + b * x_1 + c * x_2 + d * x_3 + \ ...}$$

x_1 ... x_i = mean & CV of the species traits

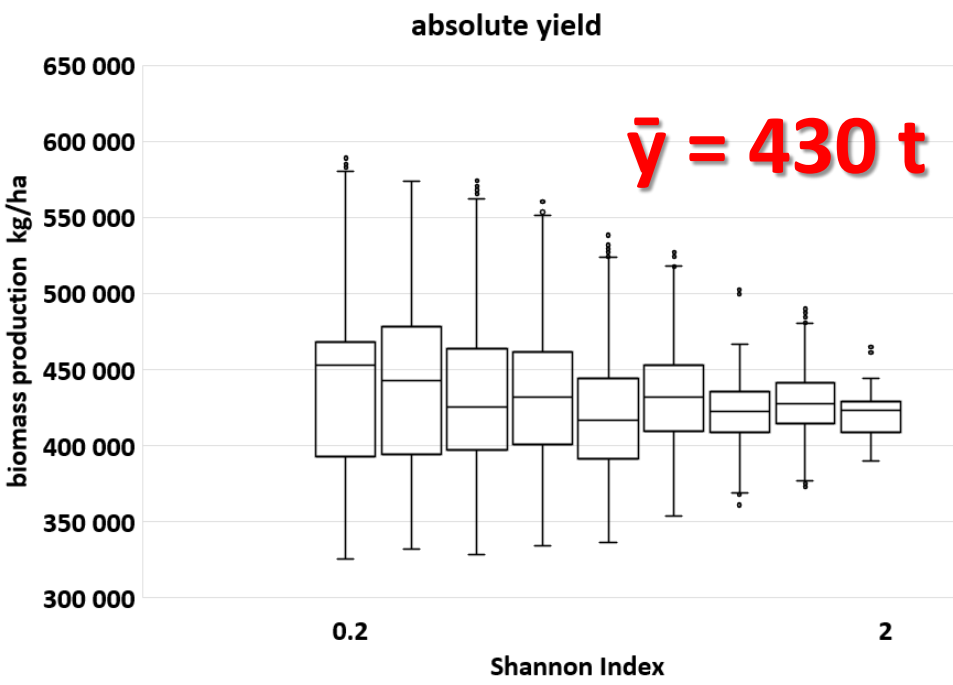
  - multicollinearity (VIF)

effects of diversity on absolute yield

random mixture

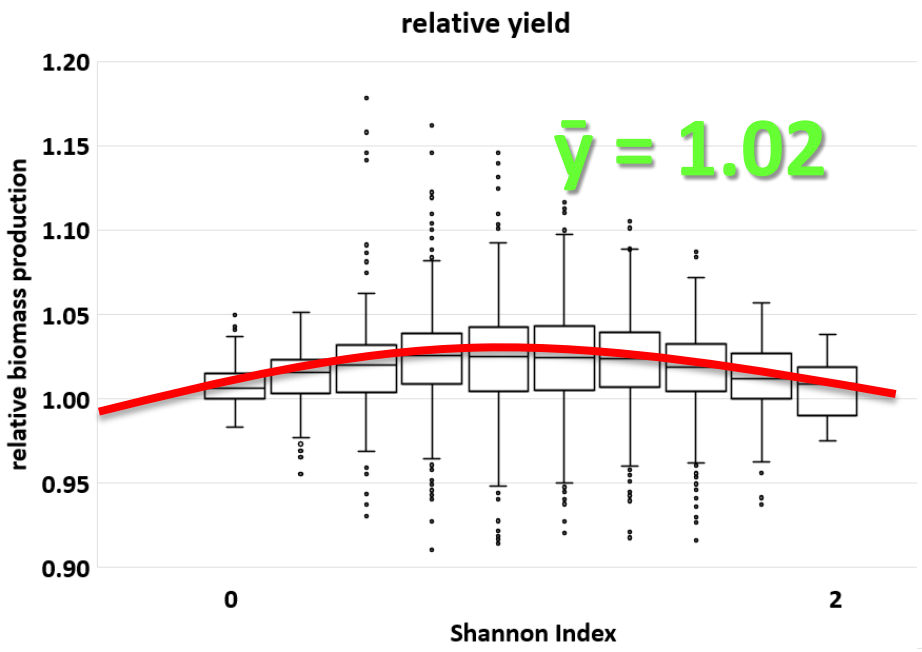


patches

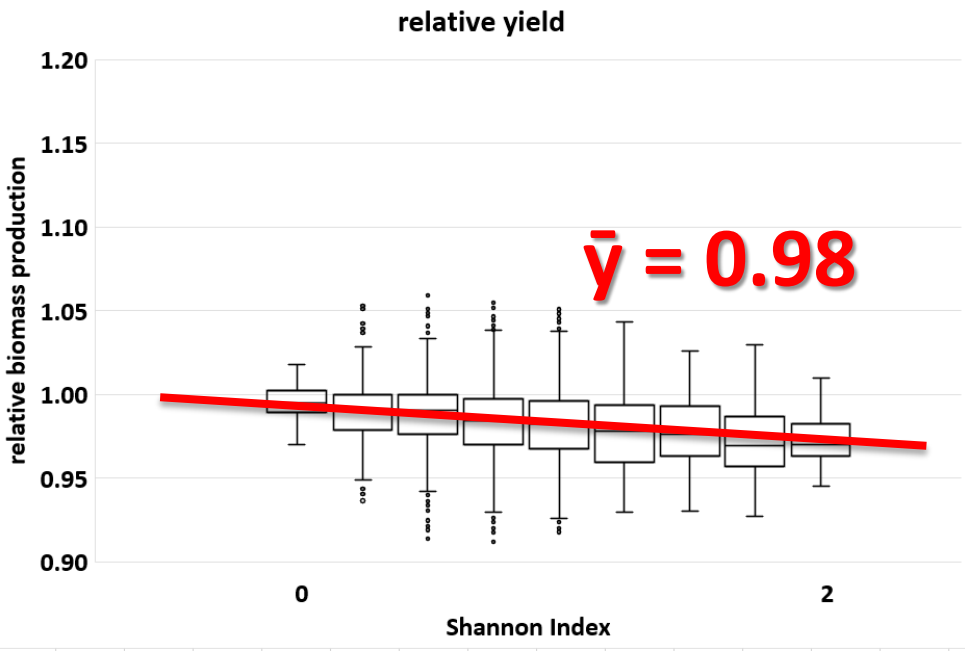


effects of diversity on relative yield

random mixture



patches



% of stands	random mix	patches
overyielding	80%	18%
transgressive OY	6%	0.6%

species identity and complementarity explain variation in RY

Standardised Regression Coefficients (SRC)

	mean light response	mean max. height	mean LA exponent	CV light response	CV max. height	CV LA exponent	R^2
random mix	-0.17***	-0.35***	-0.41***	na	0.24***	-0.24***	0.23
10x10 patches	0.21***	-0.15***	na	-0.19***	na	-0.14***	0.34
20x20 patches	0.26***	na	0.13***	-0.24***	na	-0.13***	0.33
30x30 patches	0.29***	na	0.15***	-0.22***	na	-0.12***	0.35

R^2 = coefficient of determination
* level of significance $\alpha = 0.05$
** $\alpha = 0.01$
*** $\alpha = 0.001$

influence

conclusions

- **diversity has positive influence in random mixture, effect is lost in patch mixtures** (also Morin et al., 2011; Vila et al., 2007)
- **80% of simulated random mixed stands show OY and 6% show transgressive OY** (similar in Morin et al., 2011)
  - reveals the importance of this topic
- **diversity optimum for OY in random mixture** (see Paquette & Messier, 2011)
  - 3 to 4 species may be enough diversity?
- **species identity and complementarity effect explain 23-35% of variation in RY, 21% in meta analysis by Zhang et al.(2012)**

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Thank you!

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