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# Integrative ecosystem management through the diversification of structure and tree species

Hans Pretzsch

1 Diversification can provide more holistic functions and services

2 New tools, new knowledge are needed for the design of diversity

3 Diversification paves the way for integrative system management

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*Lectio Magistralis* given on April 26th, 2024 on the occasion of the Doctor honoris causa award ceremony at the University of Valladolid, Spain

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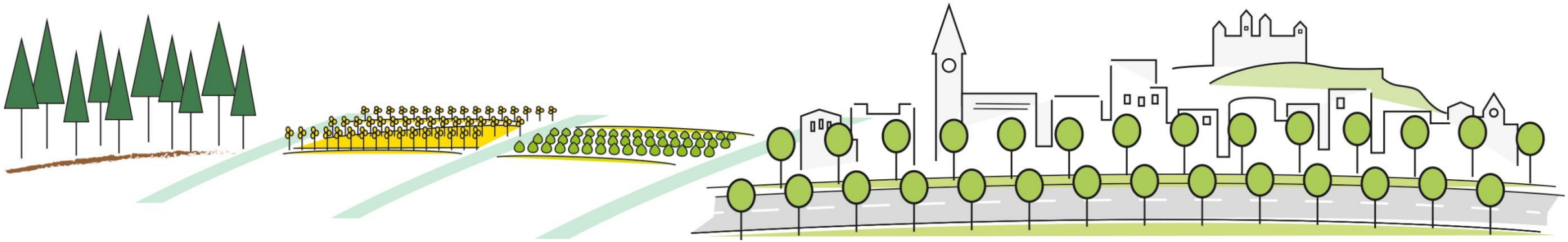
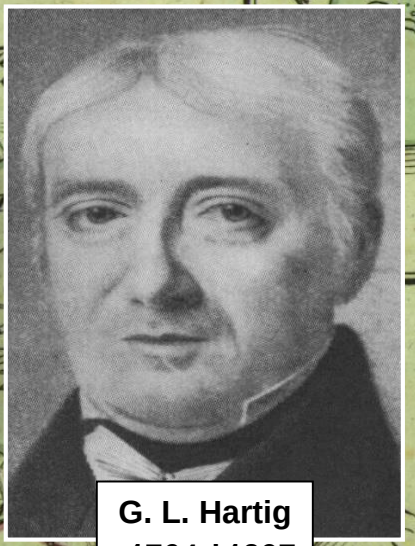
# Segregation between forestry, agriculture, and urban systems according to von Thünen (1783-1850)



C. v. Carlowitz
*1645 †1714



G. L. Hartig
*1764 †1837

Regulation by areas of age classes „Dianenburger Forst“ nach Hartig, G. L. (1804)

Neerdar, Sauerland, 1959

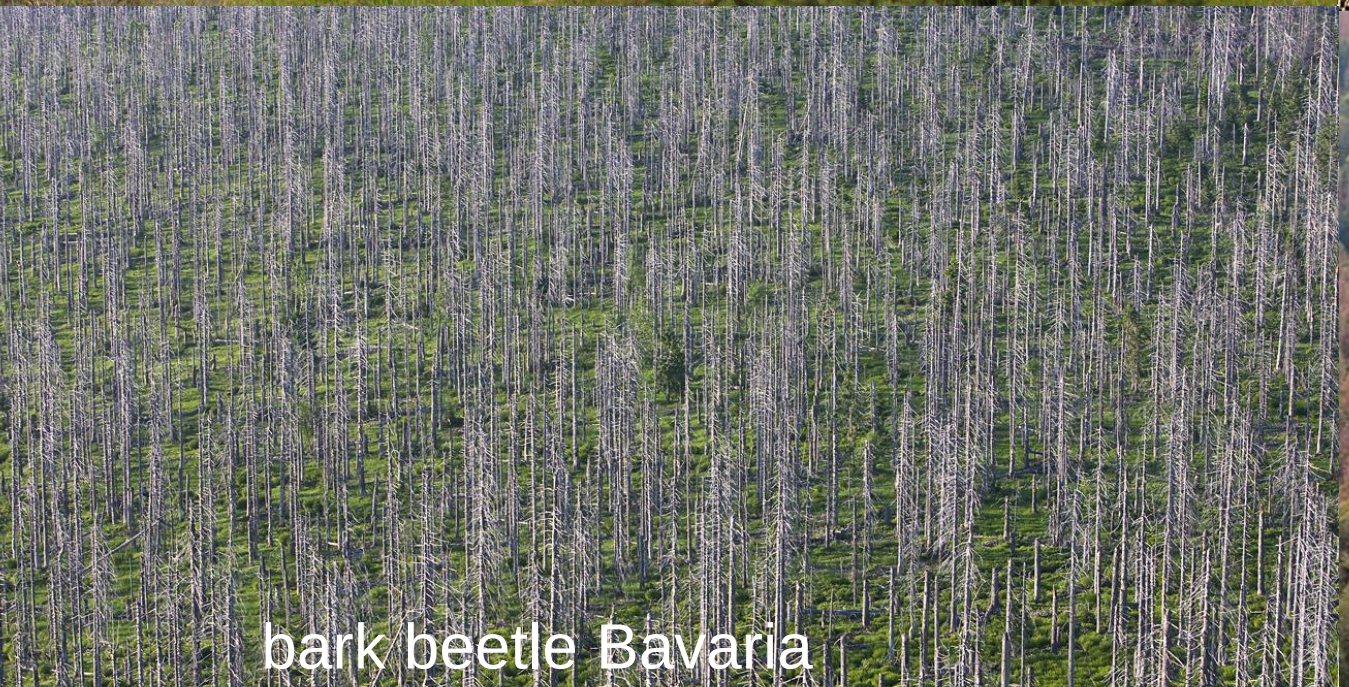
# Criteria (and indicators) for sustainable forest ecosystem management

- **Maintenance of the forest area and stock (e.g. volume stock, carbon stock…)**
- **Health and vitality (e.g. resistance against drought, storm, pathogen…)**
- **Forest growth, wood production (e.g. wood for building, refinery, energy…)**
- **Biological diversity (e.g. speceis richness…)**
- **Protective functions (e.g. water, climate protection…)**
- **Socio-economic functions (e.g. income, recreation, health…)**

For integrative management 50 European states agreed on these 6 criteria (Helsinki-Warsaw-Geneva process, MCPFE 2006)


acid rain CZ


storm Sweden


bark beetle Bavaria

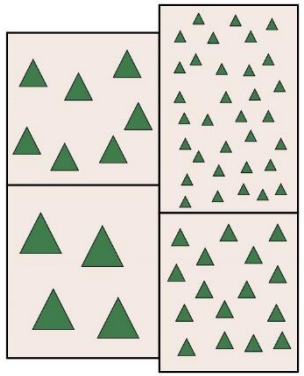

drought Germany


Segregation of unmanaged *versus* managed forest areas

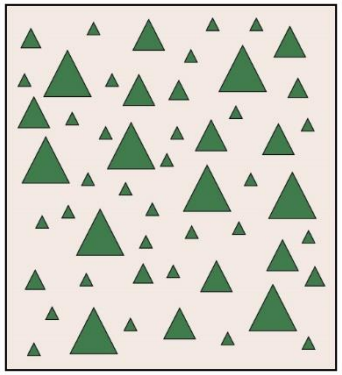

mono-specific
even-aged
mixed-species
even-aged
mixed-species
uneven-aged

# Diversification of structure and species at the tree and stand level

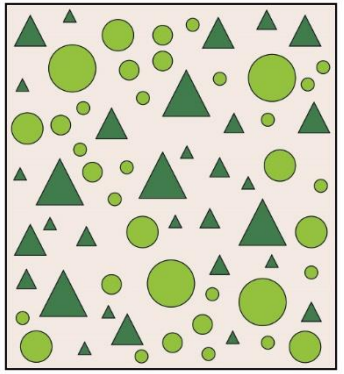
## Diversification at the tree level



(a)

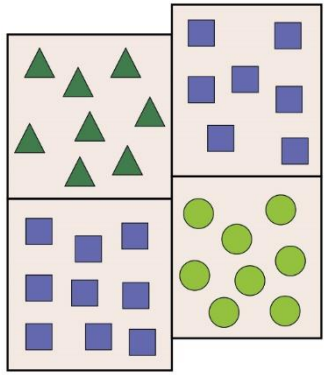


(b)

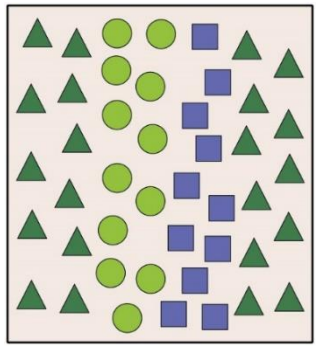


(c)

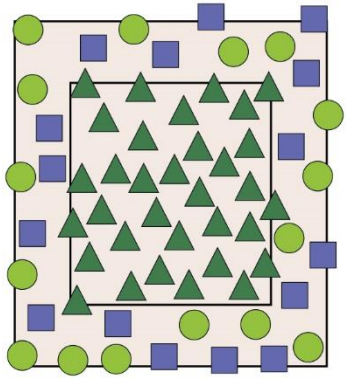
## Diversification at the patch or stand level



(d)



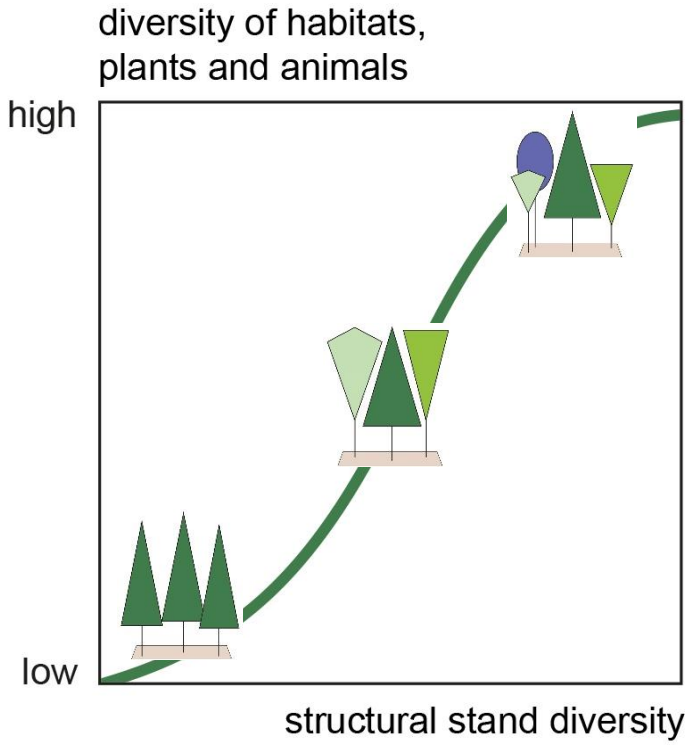
(e)



(f)

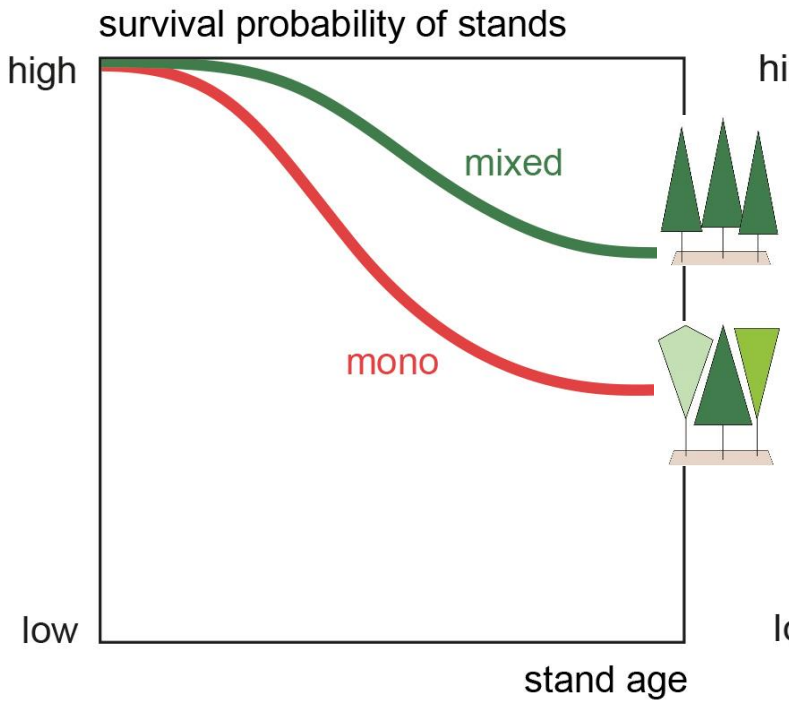
del Río et al. (2016)

# Effects of the diversification of structure or tree species



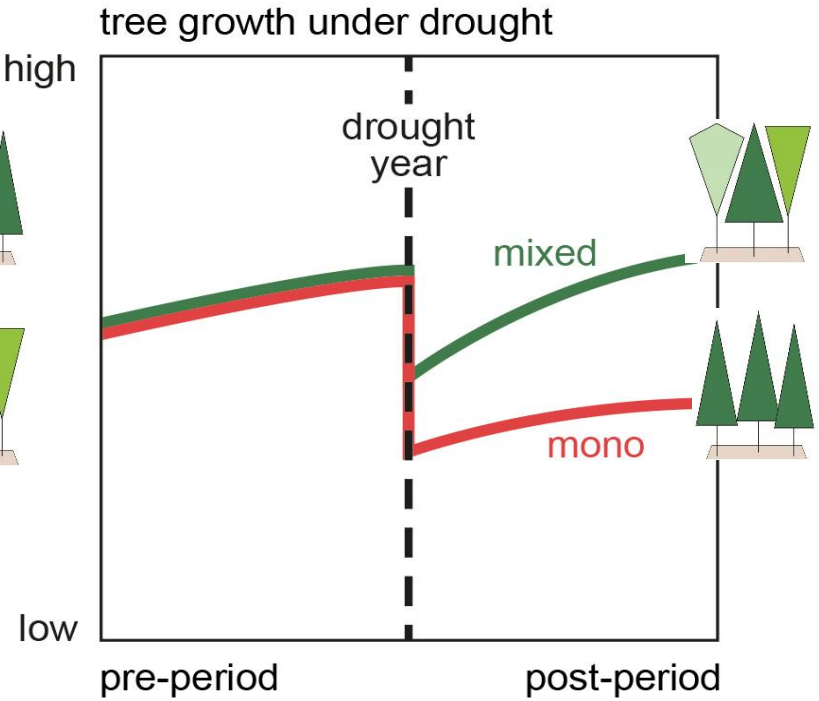

(a)

Begon et al. (1998)
Dieler et al. (2017)




(b)

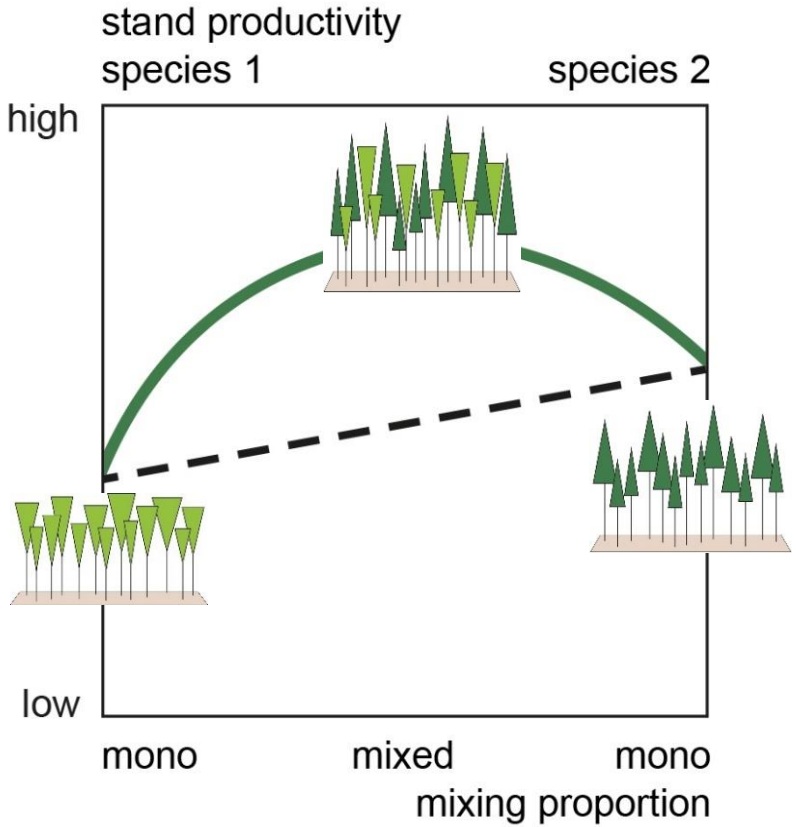
Paul et al. (2019)
Brandl et al. (2020)




(c)

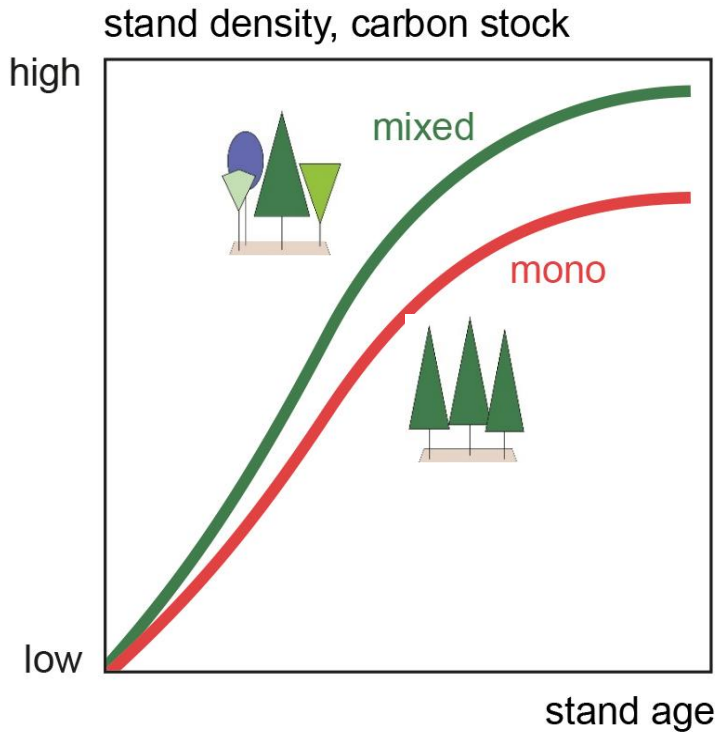
del Río et al. (2017, 2022)
Pardos et al. (2021)
Pretzsch et al. (2013)

# Effects of the diversification of structure or tree species



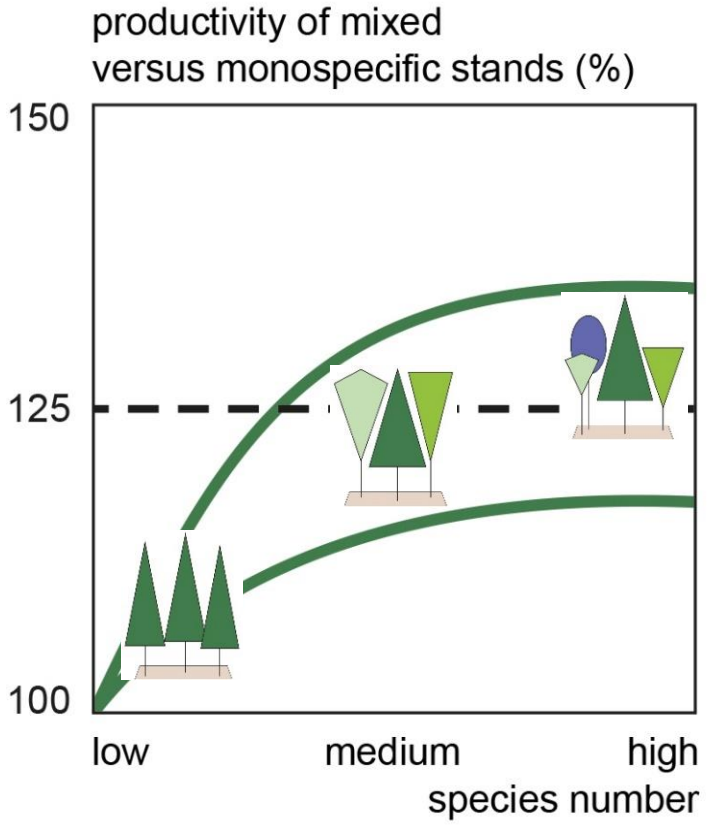

(a)

Forrester & Pretzsch (2017)
del Río et al. (2022)




(b)

Pretzsch and Biber (2016)




(c)

Liang et al. (2016)

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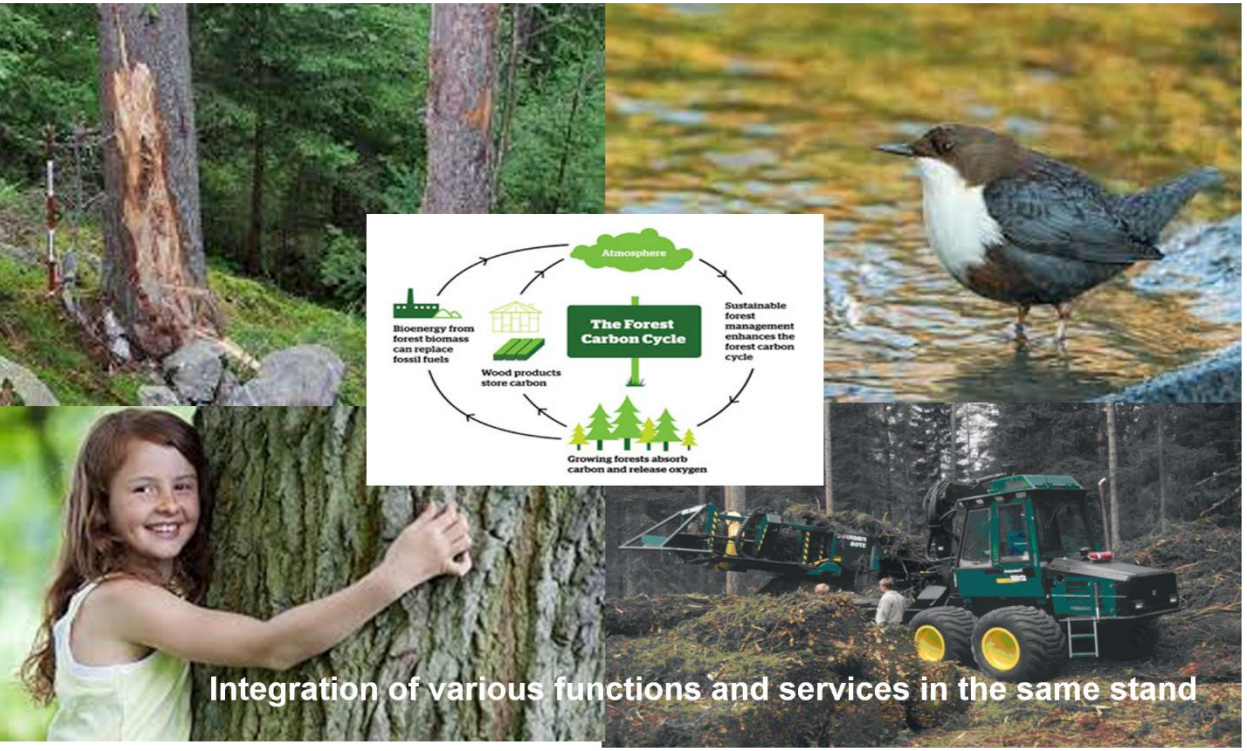
# Integrative versus segregated forest ecosystem management




Integration of various functions and services in the same stand

Segregation of unmanaged *versus* managed forest areas

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# Integrative versus segregated forest ecosystem management



*Summary 1:*

- The extended demands for ecosystem services and functions are not achievable by artificial monocultures
- Diversification of structure and species can enrich ecosystem functions & services
- Diversification supports integrative forest ecosystem management

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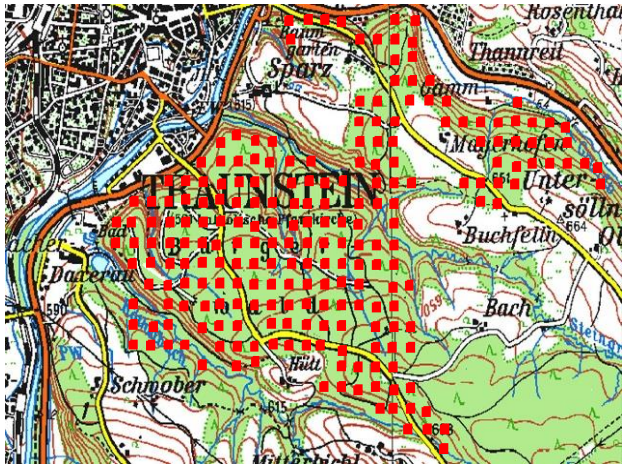
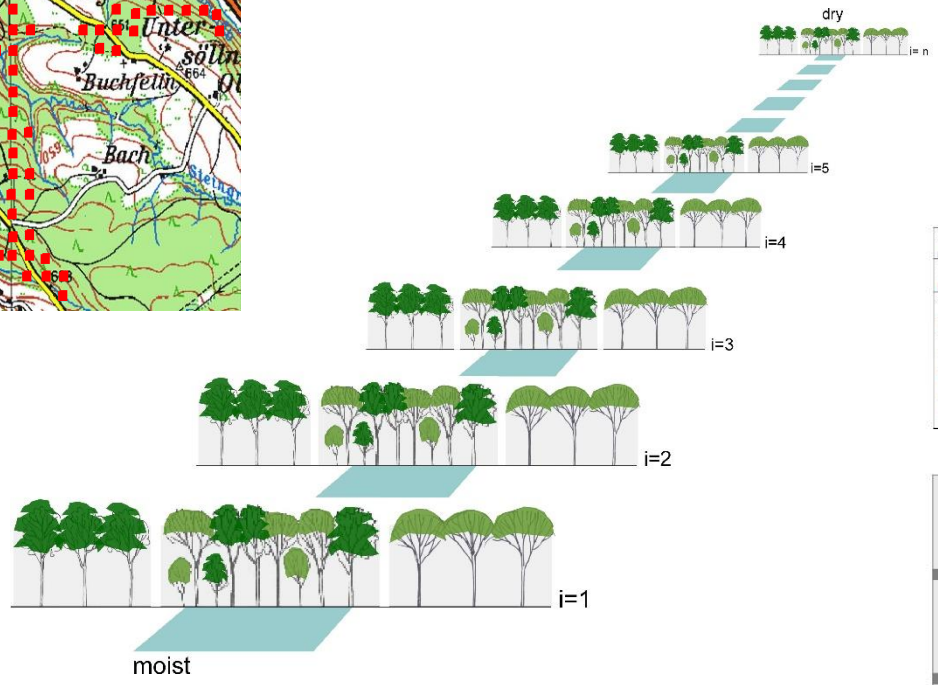
# Experiments and data for complex forests

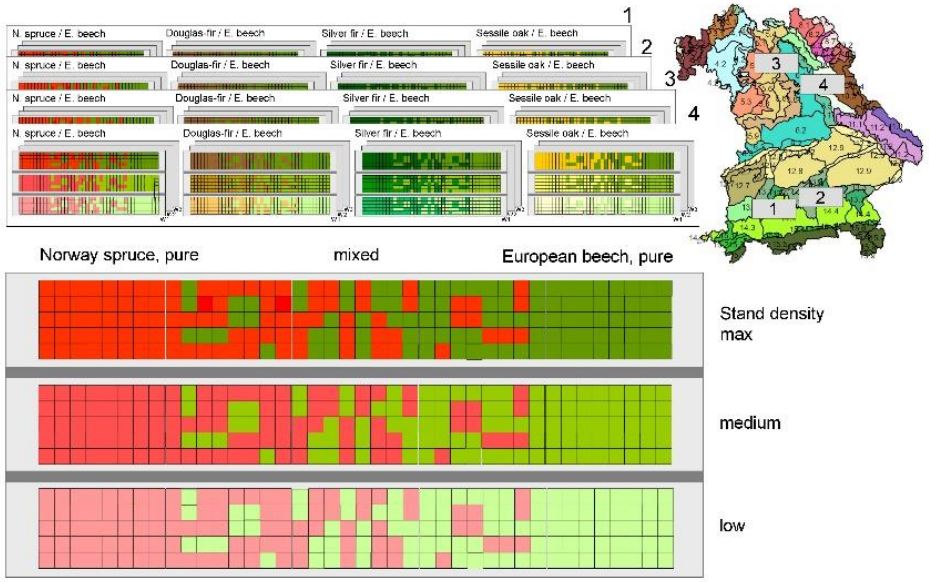
## (a) Forest inventories




## (b) Triplets along ecological gradients

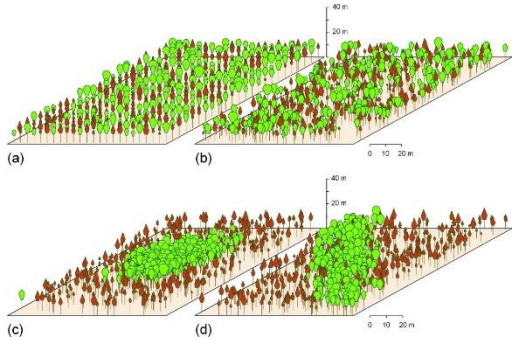


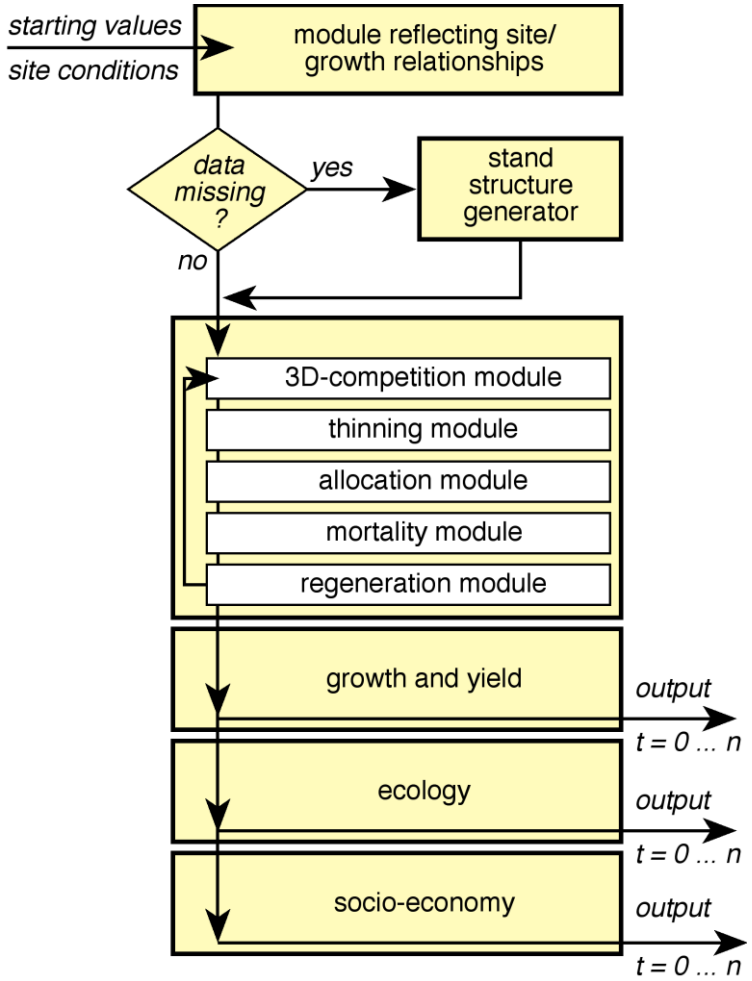

## (c) Long-term experimental plots

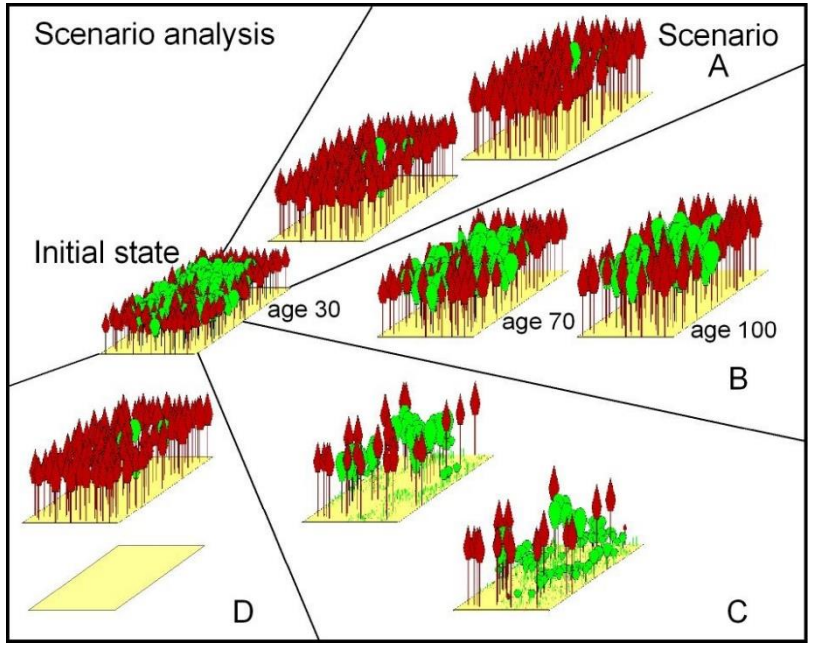



Pretzsch (2019), Bravo-Oviedo, A. et al. (2018), Uhl et al. (2024)

# Models and simulators for complex forests



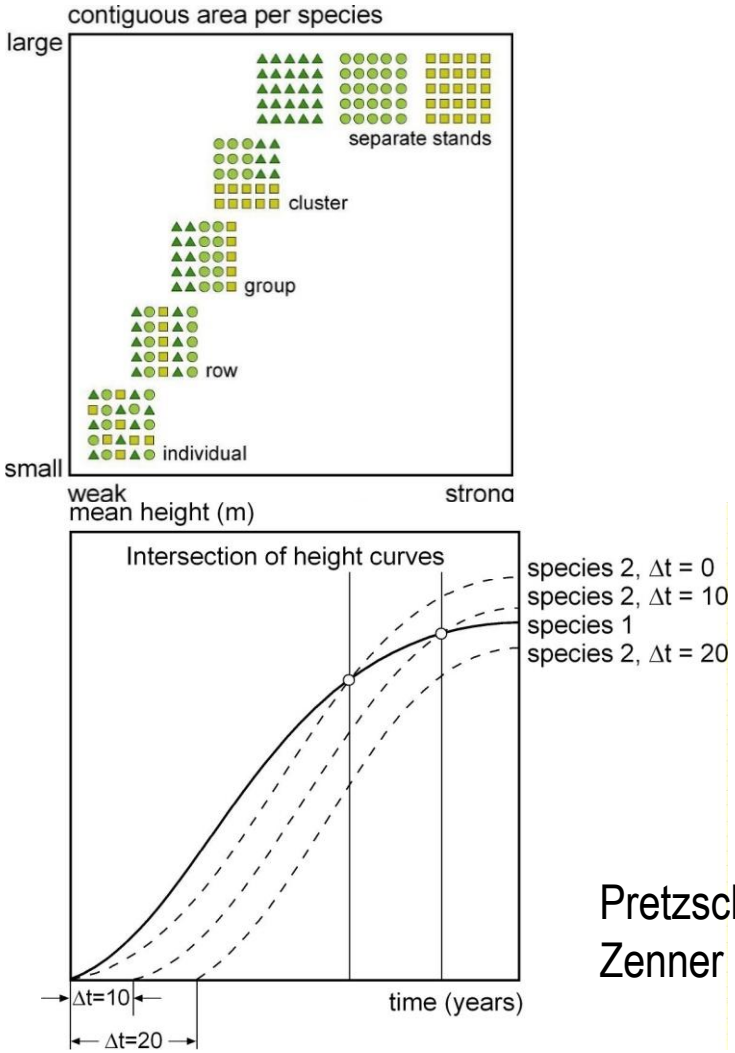




Bravo-Oviedo, F. et al. (2019), Pretzsch and Zenner (2017), Pretzsch, Calama et al. (2021)

# Silvicultural guidelines and training plots for complex forests

## (a) Silvicultural prescriptions how to mix in space and time



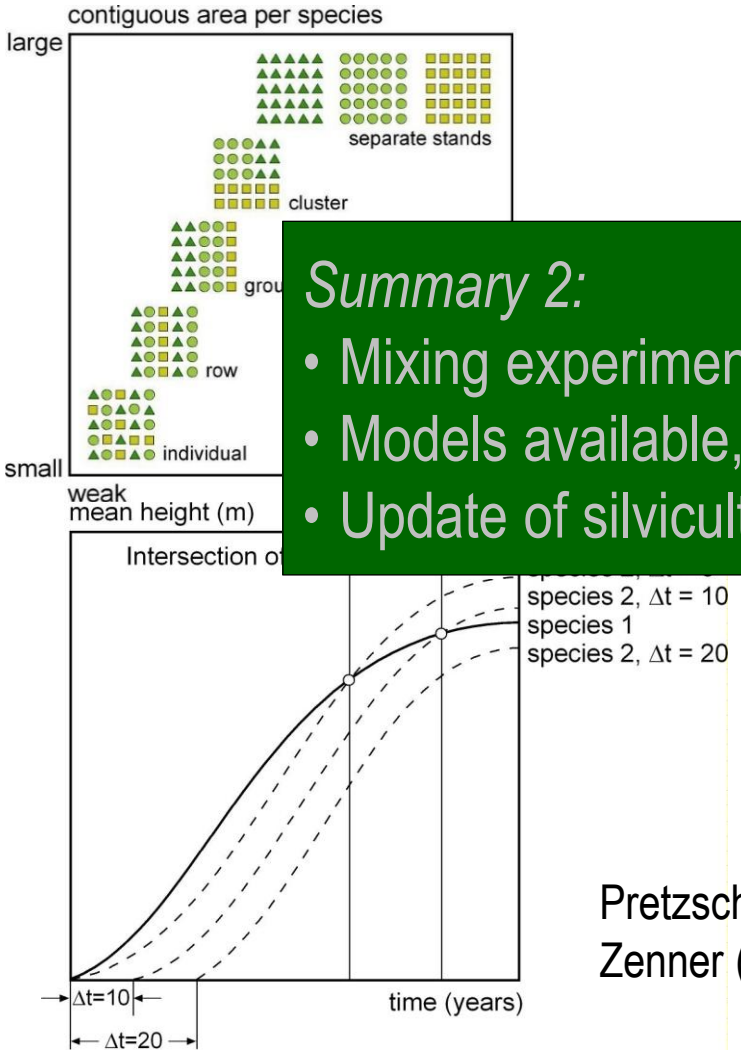

Pretzsch and Zenner (2017)

## (b) Marteloscopes in Germany and Spain for teaching and training

Fotos:
L. Steinacker
F. Bravo-Oviedo

# Silvicultural guidelines and training plots for complex forests

## (a) Silvicultural prescriptions how to mix in space and time




Pretzsch and Zenner (2017)

## (b) Marteloscopes in Germany and Spain for teaching and training

Fotos:
L. Steinacker
F. Bravo-Oviedo

*Summary 2:*

- Mixing experiments needed
- Models available, but lacking data for their parameterization
- Update of silvicultural prescriptions, training and teaching plots required

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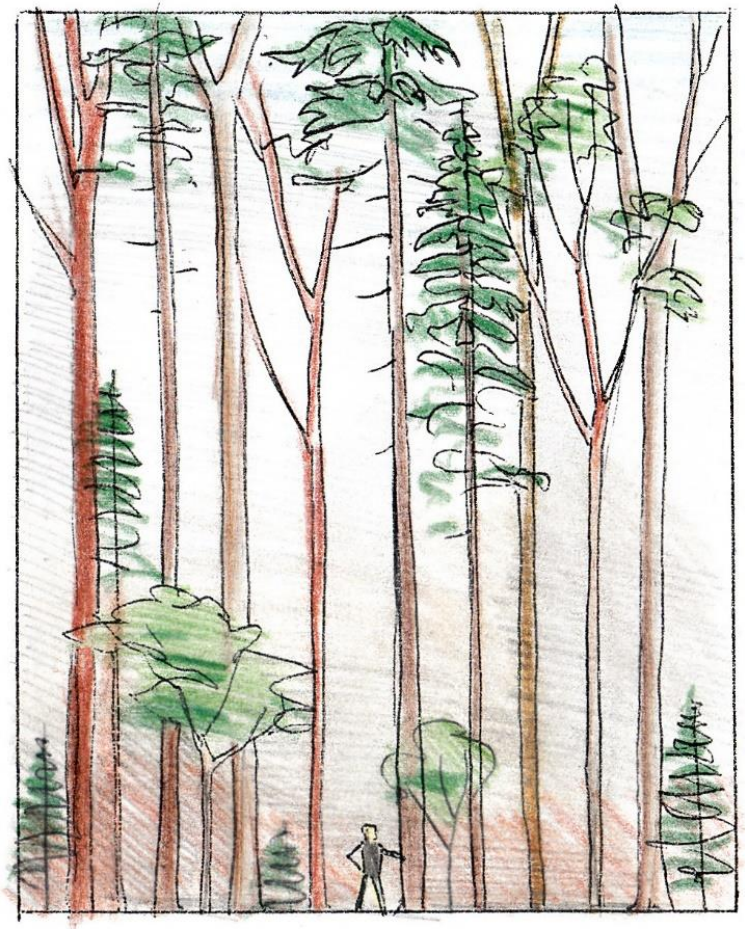
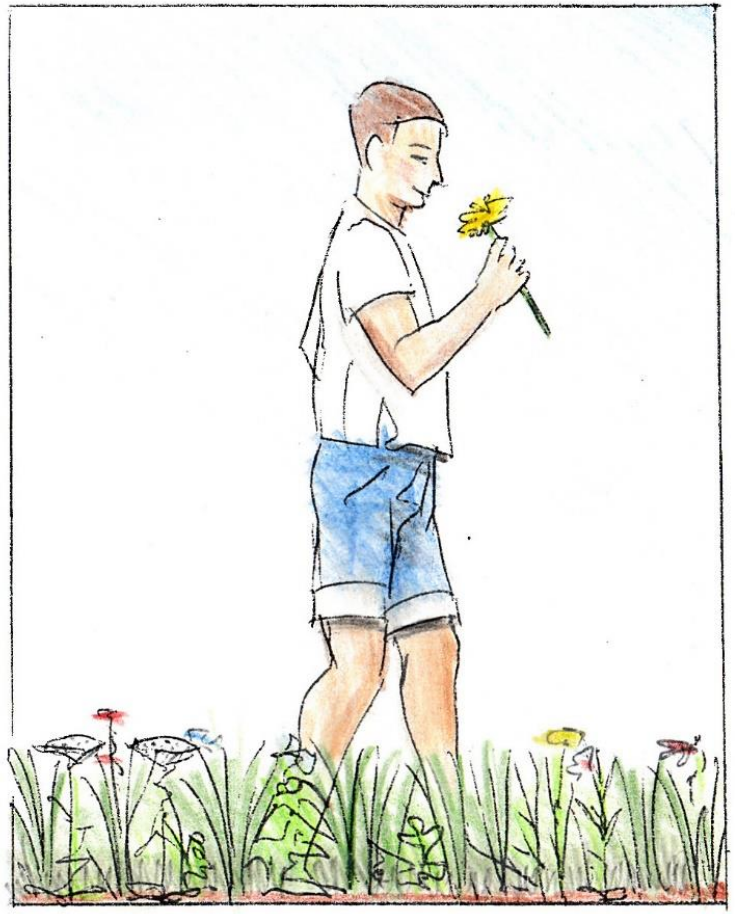
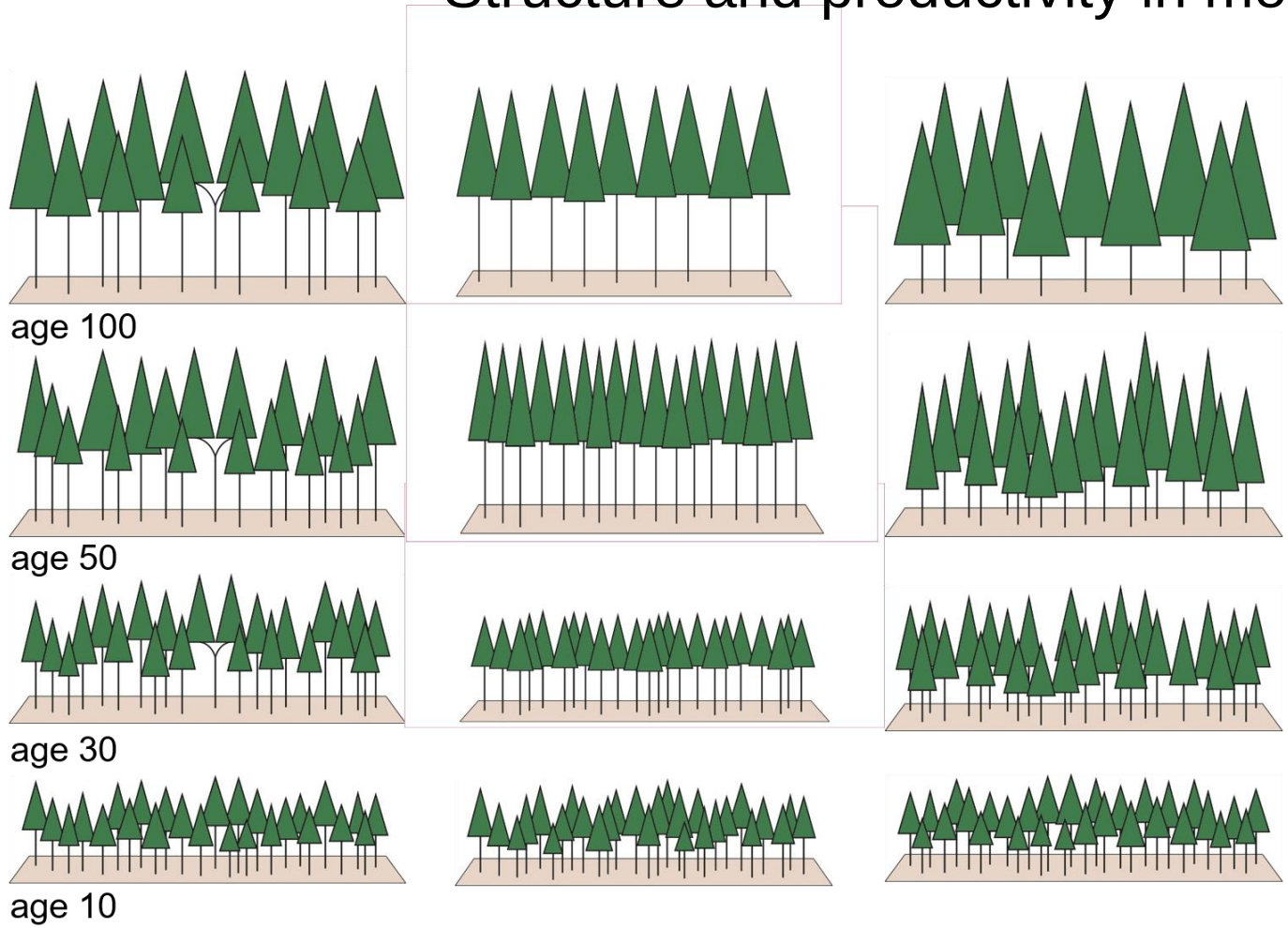
# Size ratio between plants and humans in forest science versus agricultural science

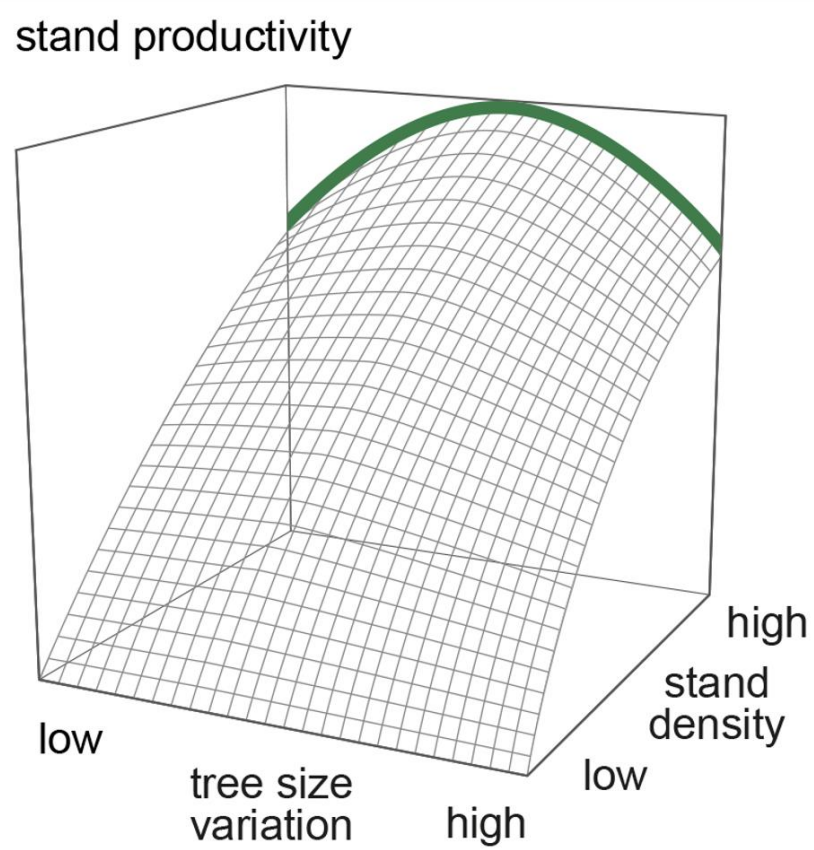




# Structure and productivity in monospecific stands



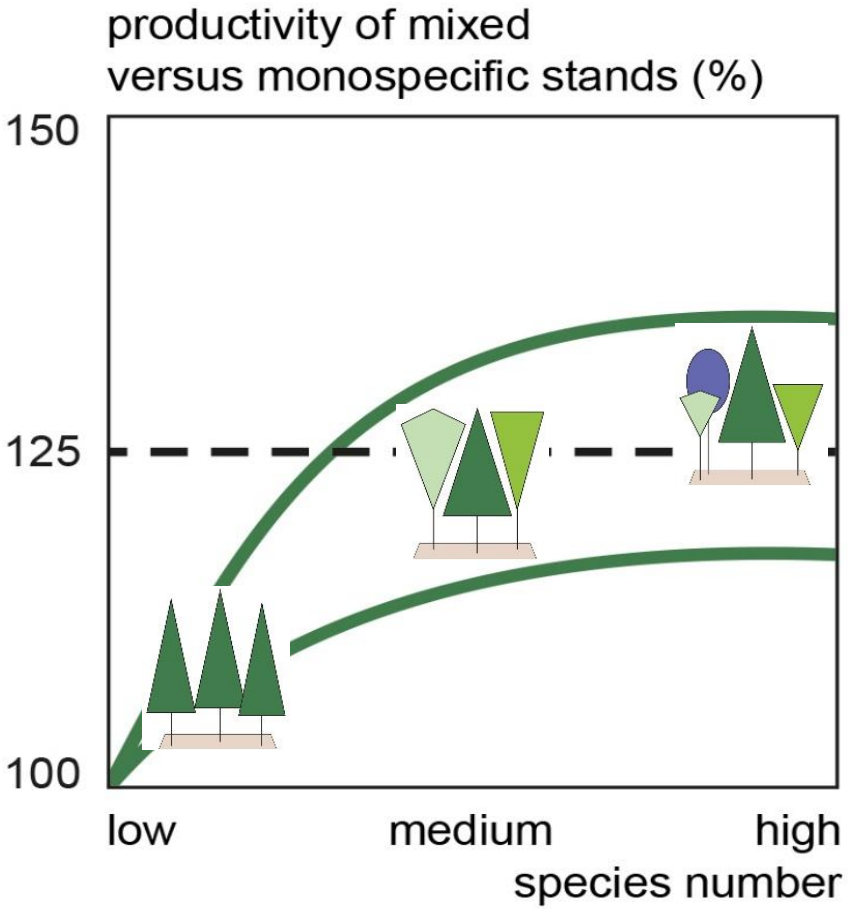

(a) unthinned (b) homogenized (c) structured

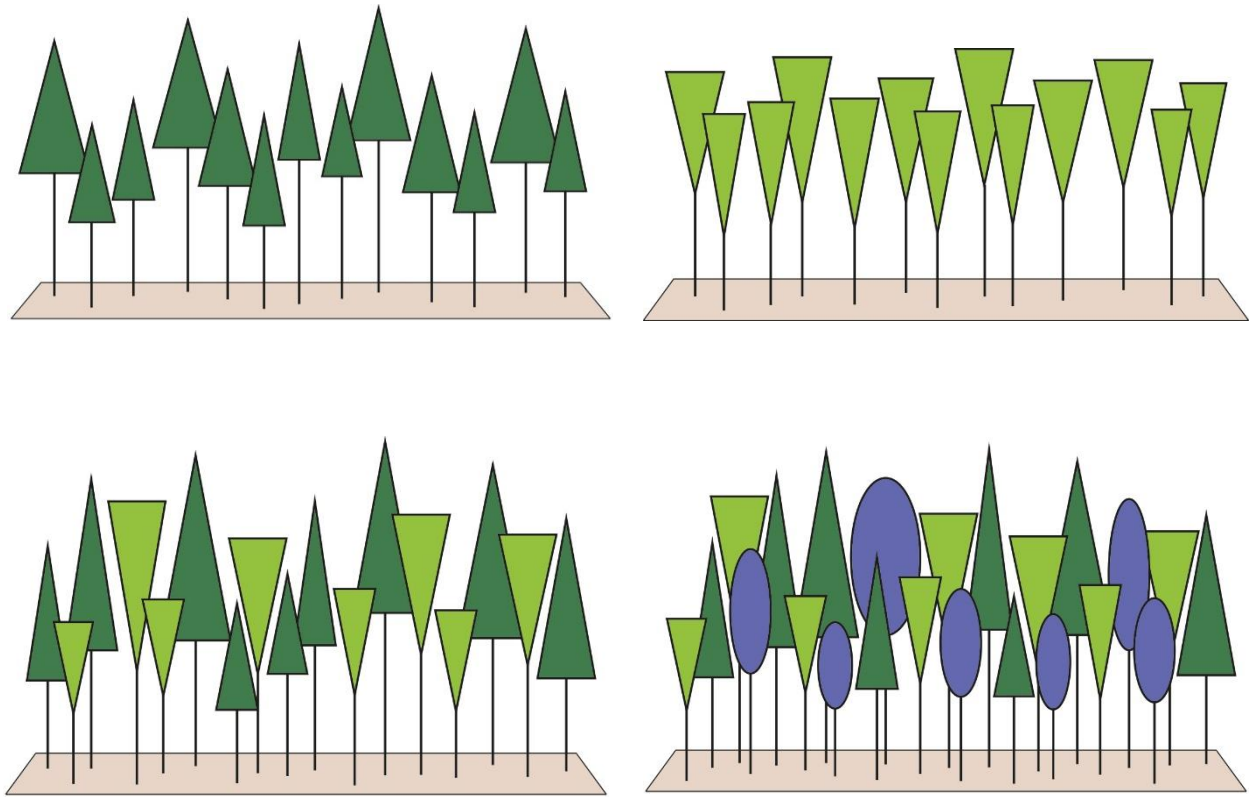



(d) structure-density-growth relationship

Pretzsch, Hilmers, del Río (2024)

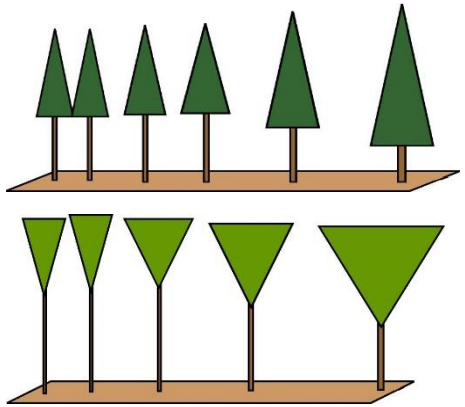
# Diversity and productivity in mixed-species stands



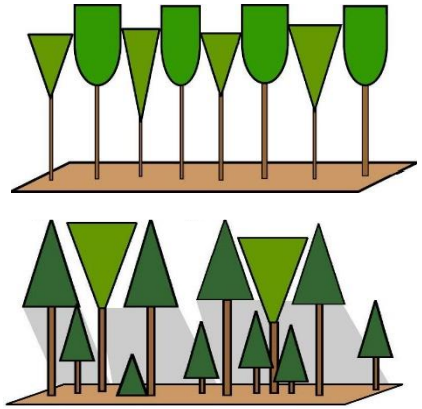



# Causes for complementarity, facilitation, and the overyielding

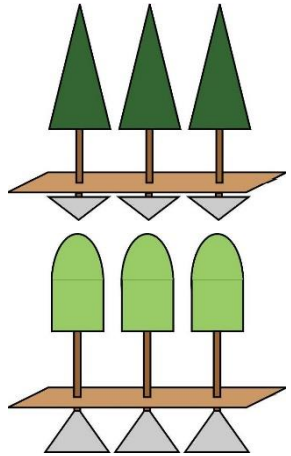
**non-plastic - plastic**



**light demanding - shade tolerant**

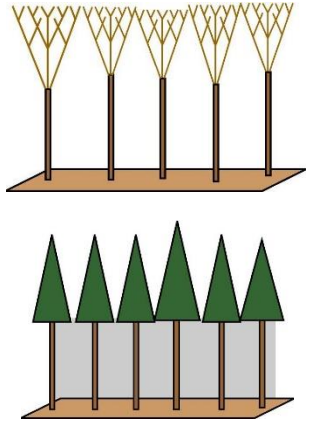


**shallow – deep rooting**

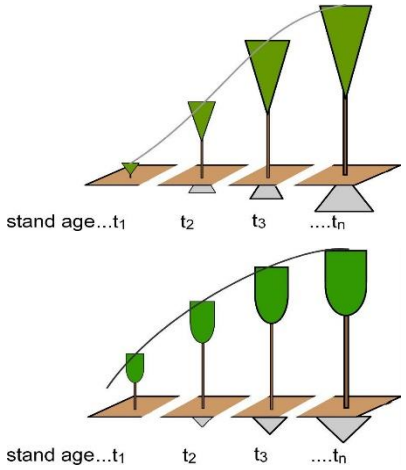


Ammer (2019)
Pretzsch, Forrester, Bauhus, J (2017)

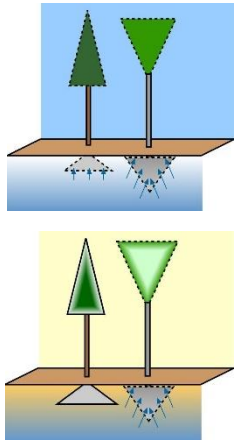
**seasonal - evergreen**



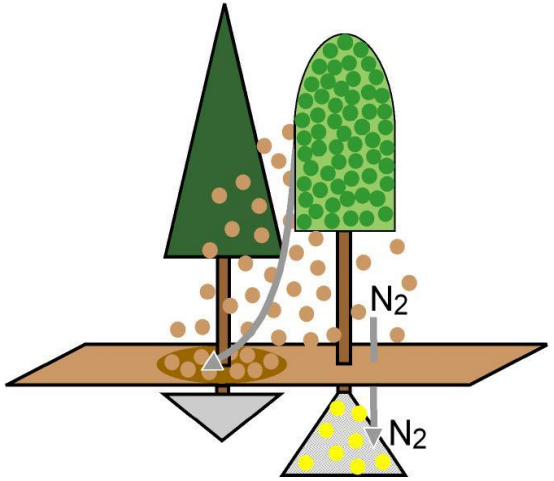
**slow - fast growing**




**drought tolerant-intolerant**



**$N_2$-fixing - non $N_2$-fixing**



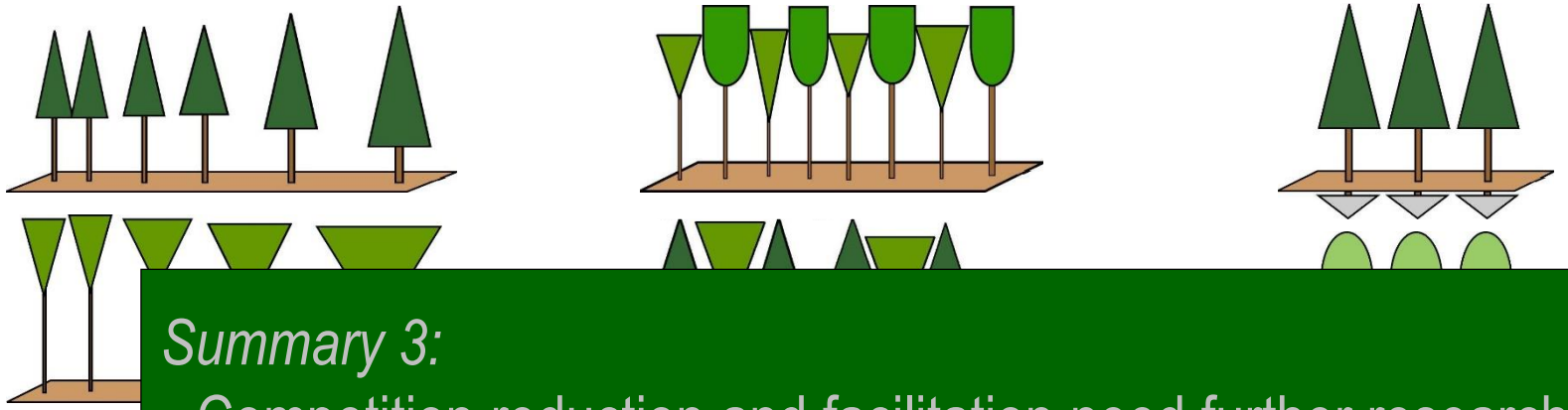

Rothe, Binkley (2001)
Prieto et al. (2012)
Forrester et al. (2007)

# Causes for complementarity, facilitation, and the overyielding

**non-plastic - plastic**

**light demanding - shade tolerant**

**shallow – deep rooting**

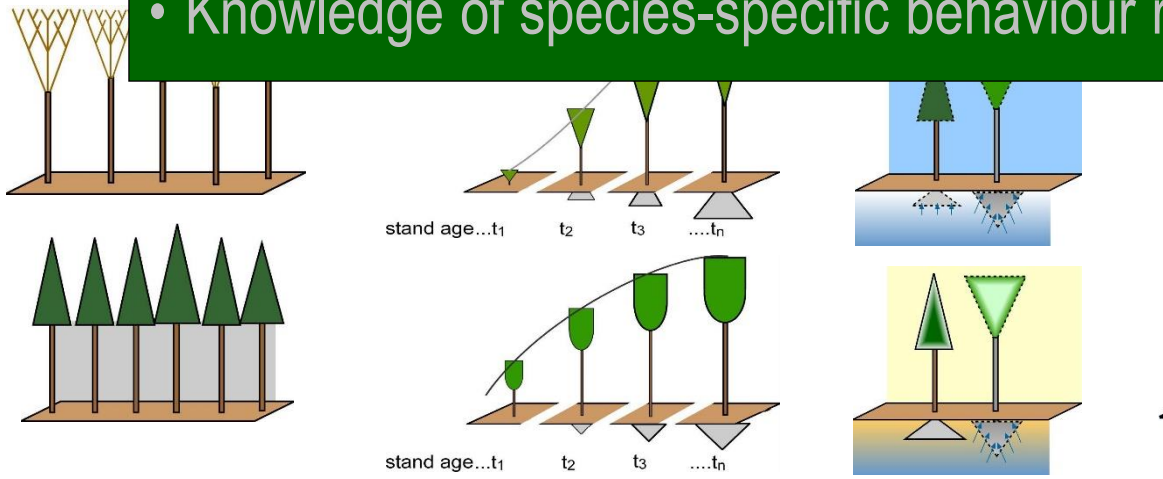


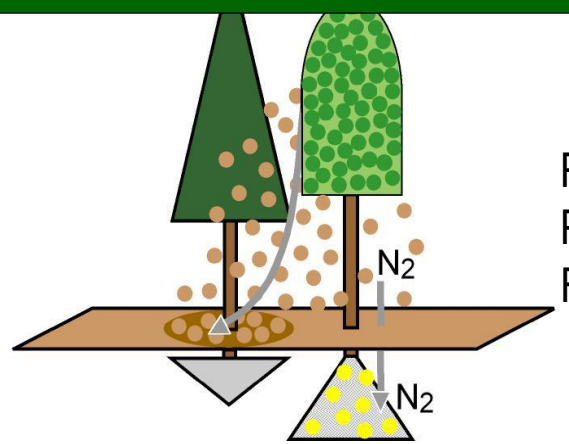
Ammer (2019)

*Summary 3:*

- Competition reduction and facilitation need further research
- Proportion between human and tree size enables insights into tree-tree interactions
- Knowledge of species-specific behaviour required for models, planning, guidelines

**seasonal**

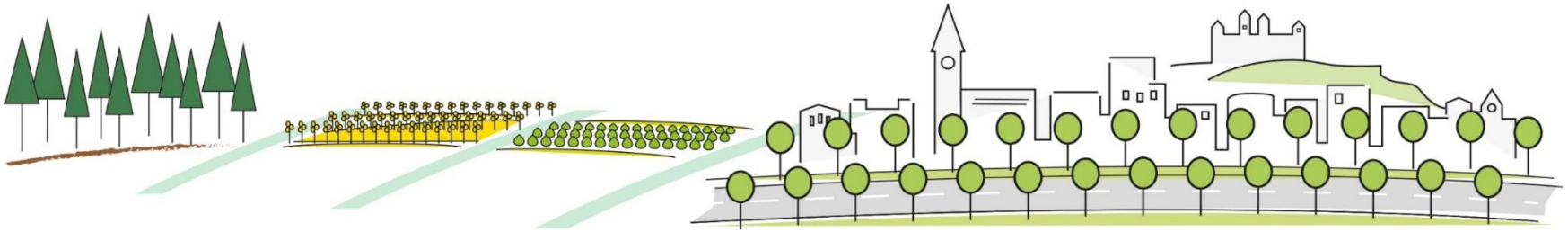


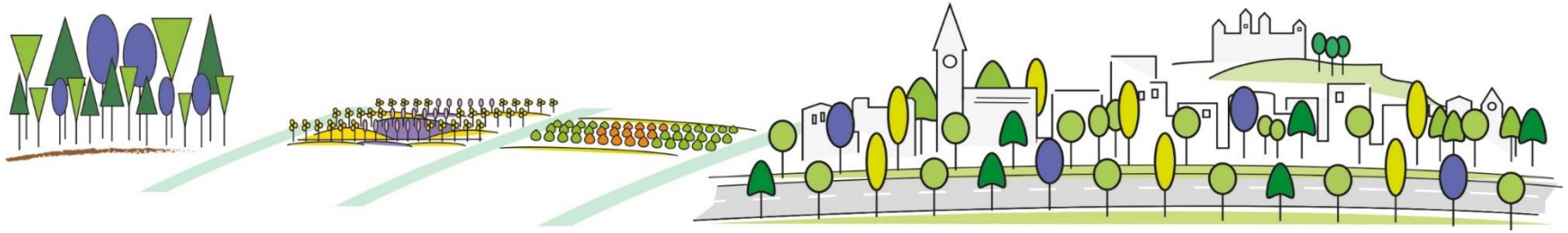

Rothe, Binkley (2001)
Prieto et al. (2012)
Forrester et al. (2007)

# Perspective: „One Carbon, One biodiversity, One health, One sustainability“

(a) Segregated, homogenized sectors



(b) Within-sector diversification



(c) Cross-sector diversification

*Thanks for discussions and advice are due to*

*Urban greening*:
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Niels P. R. Anten
Maria-Victora Piazza
Noemi Mazia
Hans Schnyder
Ulrich Lüttge

*Forest science:*
Felipe Bravo-Oviedo
Roberto Tognetti
Enrico Tomelleri

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Cotta von H (1828) Anweisung zum Waldbau. Arnoldische Buchhandlung, Dresden, Leipzig

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Waldwachstumskunde
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