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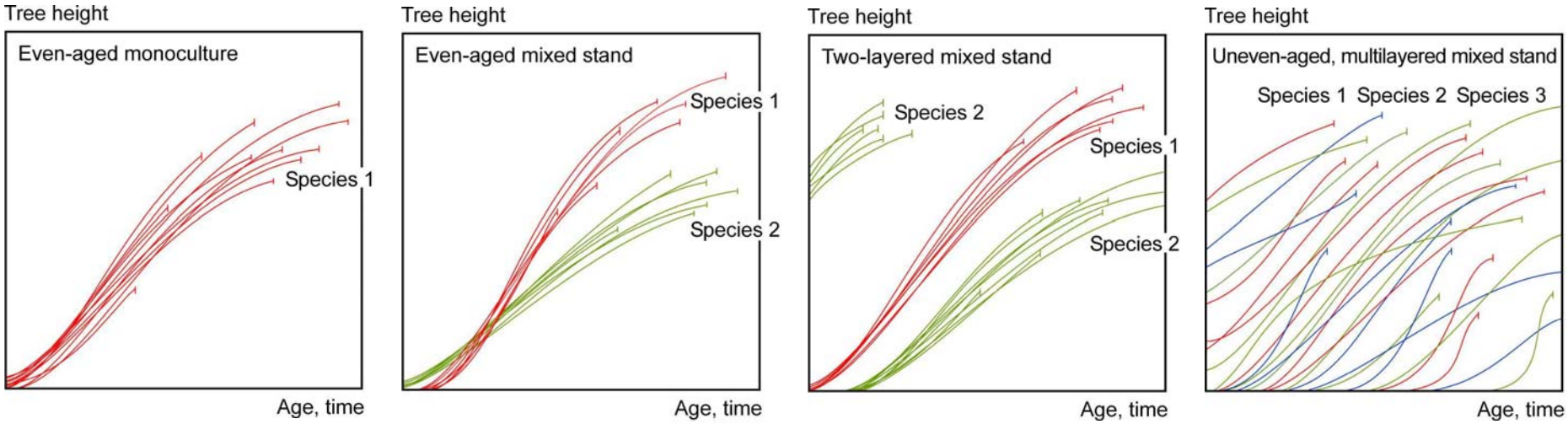
The continuum from even-aged monocultures to uneven-aged mixed-species stands. Representation by the height growth trajectories



Mixed European beech forest in Central European lowlands

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

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Criteria for sustainable forest ecosystem management

Criteria for sustainable forest management	Indicators
Forest resources	timber resources, area of forest, extension of area
Health and vitality	stability, fitness, elasticity
Productive functions	growth, yield, net return
Biological diversity	habitat quality, richness flora/fauna, conservation
Protective functions	soil, water, climate, noise, protection
Socio-economic functions	employment, recreation, esthetics, proximity to nature

according to MCPFE, 2000

The Romans 1. - 3. Century

Clearings in medieval times 12. – 13. Century

Industrialisation 18. – 19. Century

World War I. und II. 20. Century


human made Norway spruce monocultures in the lowlands

Norway spruce stands damaged by bark beetle
Rachel und Lusen, Bavarian Forest, 2010


Storm damage by Gudrun
>75 million m³ Småland,
Schweden, 2005


Summary 1:
• ice ages reduced tree species richness
• humans reduced and simplified the forest
• postwar forestry favoured risky conifer monocultures
Storm damage by Gudrun >75 million m³ Småland, Schweden, 2005

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Mixed species forestry

Hans Pretzsch
Chair for Forest Growth and Yield Science
Technical University of Munich

http://waldwachstum.wzw.tum.de/index.php?id=presentations

1 Short story of human made monocultures in Europe

2 Ecology and growth of mixed compared to mono-specific stands

3 Silvicultural prescriptions for mixed-species stands

Perspectives

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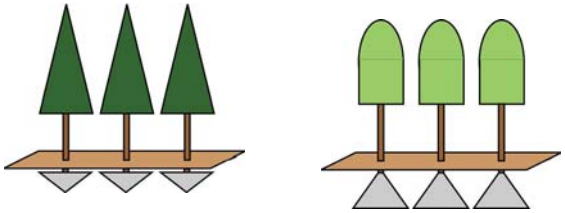
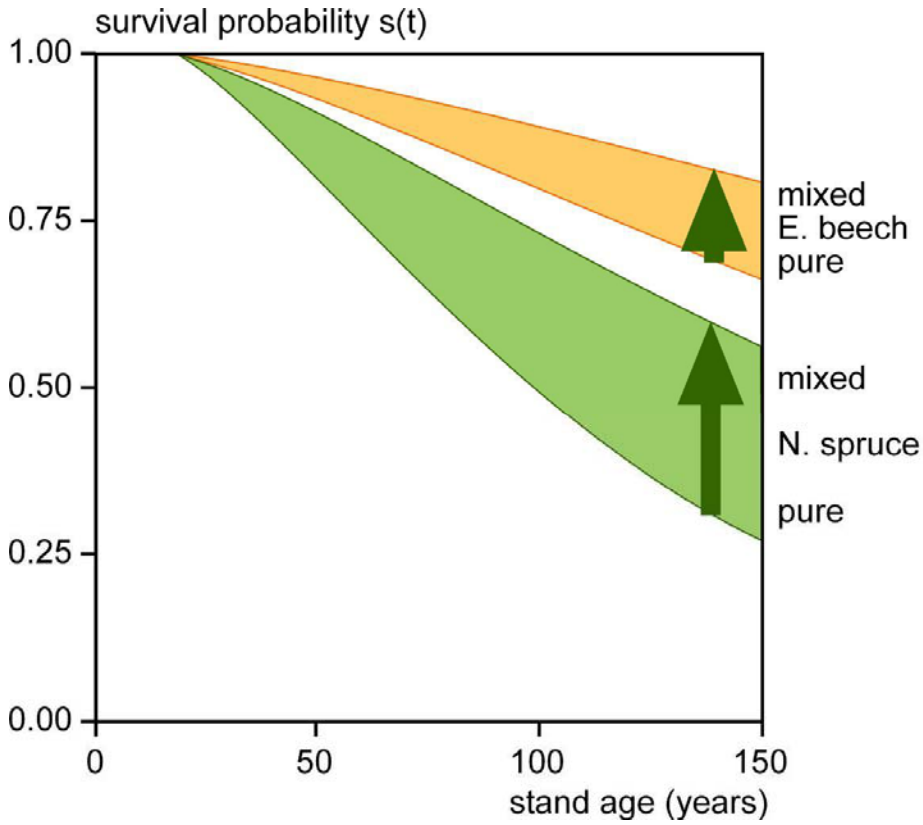
Systemanalyse

Stability by mixing shallow and deep rooting species



wind stability: oak > beech > pine > spruce



Brandl et al. (2018)
Griess and Knoke (2011)

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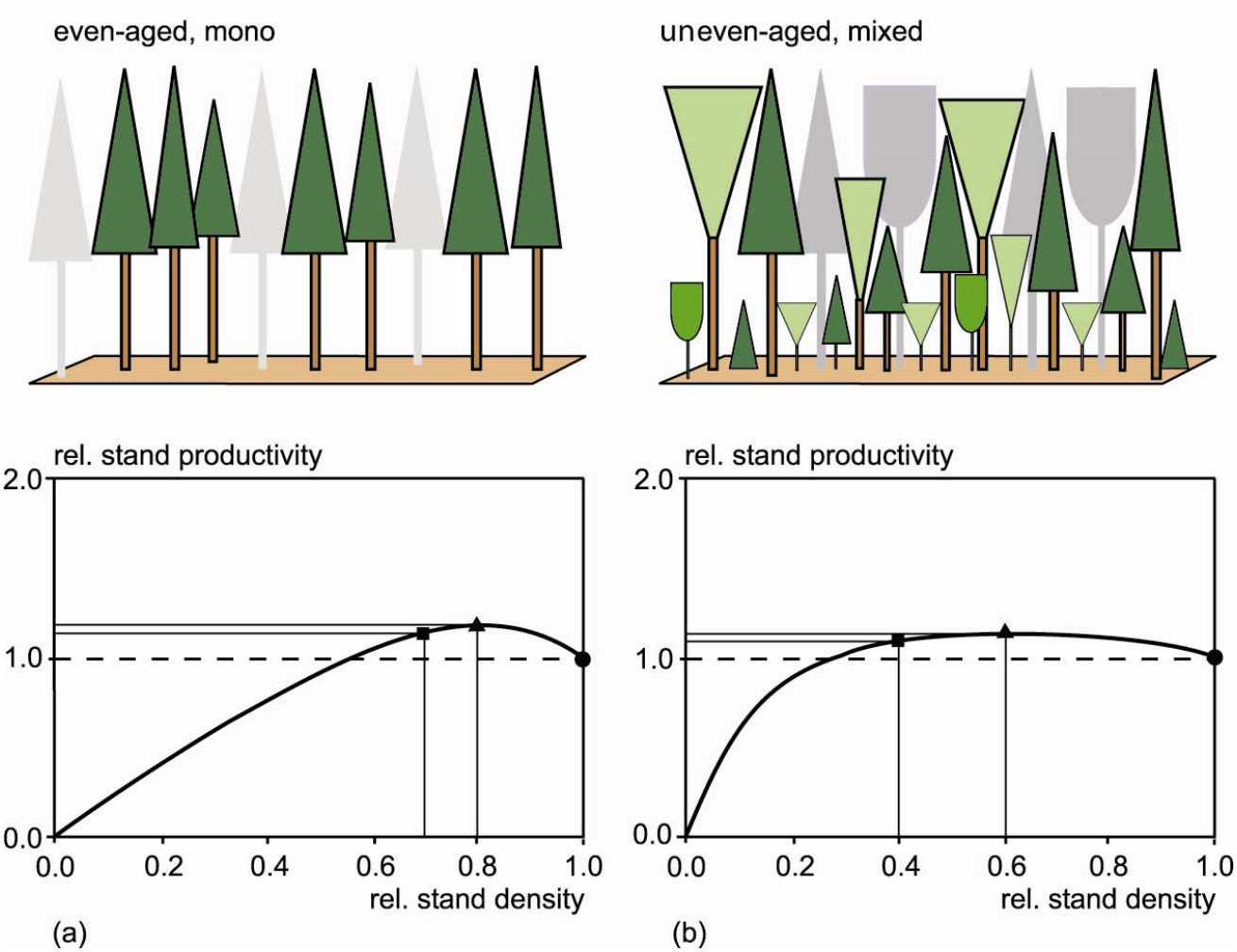
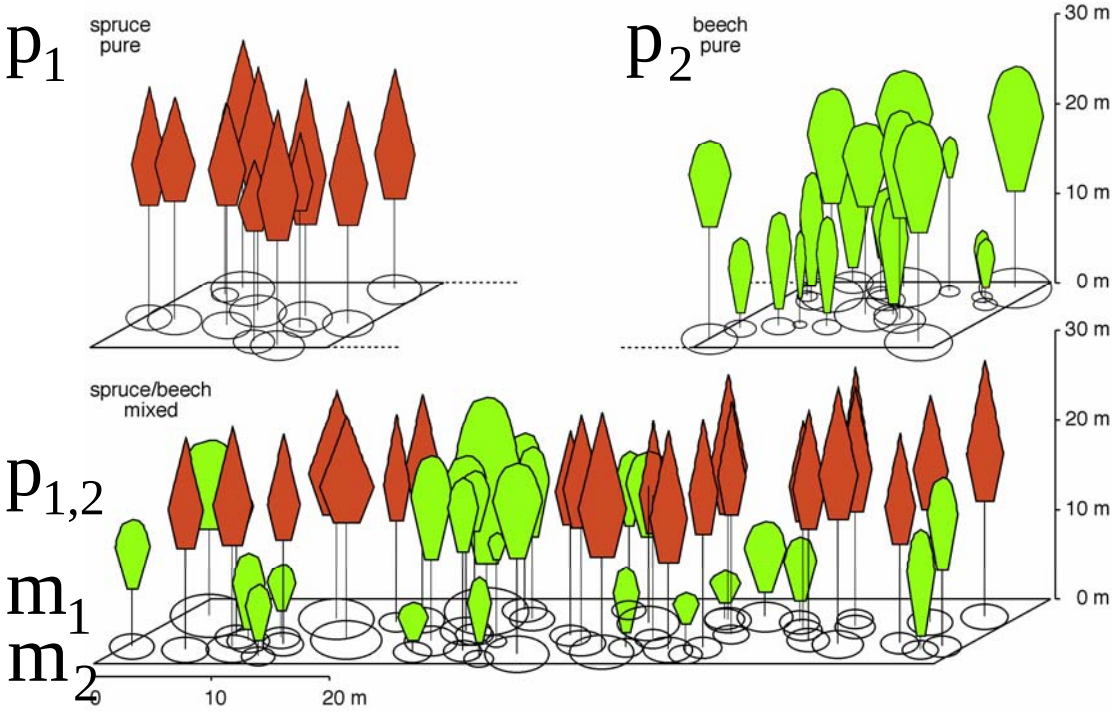
Growth resilience by multi-storey stand structure



Overyielding by mixing complementary tree species.



$$\text{relative productivity} = p_{1,2}/(p_1 \times m_1 + p_2 \times m_2)$$

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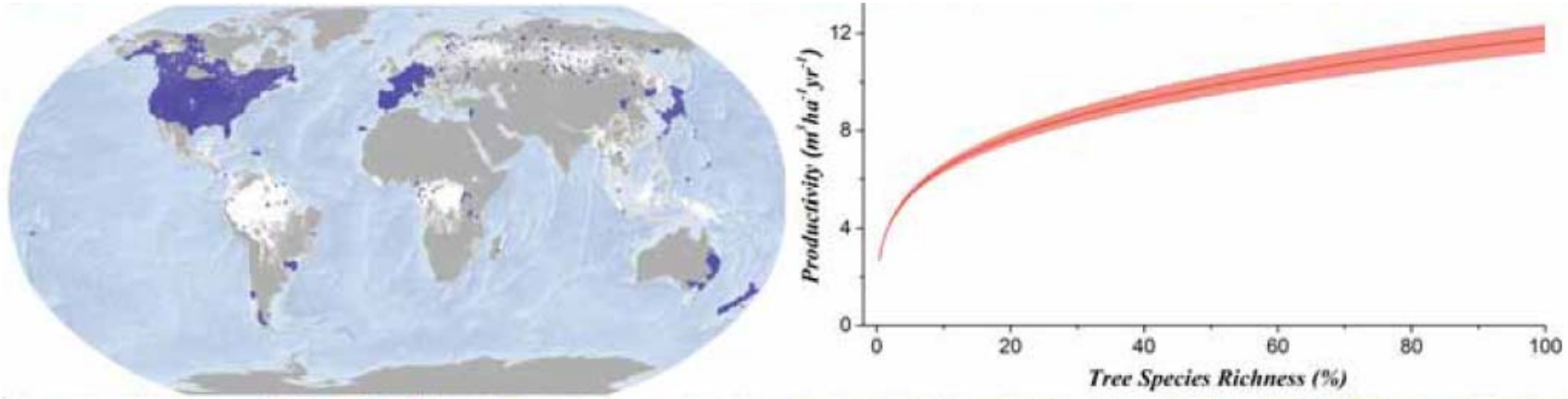
Mixing effects on productivity of forests worldwide and in Central Europe



Liang, J. et al. (2016) Positive Biodiversity-Productivity Relationship Predominant in Global Forests, Science, 354 (6309), aaf8957

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	21	30	20	11	21	25	13	
(± SE) in %	(± 3)	(± 9)	(± 3)	(± 8)	(± 11)	(± 6)	(± 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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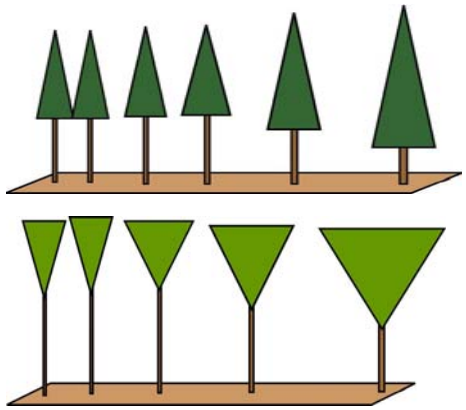
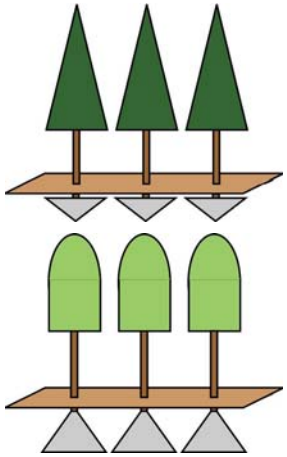
Systemanalyse

Some structural and functional complementarities

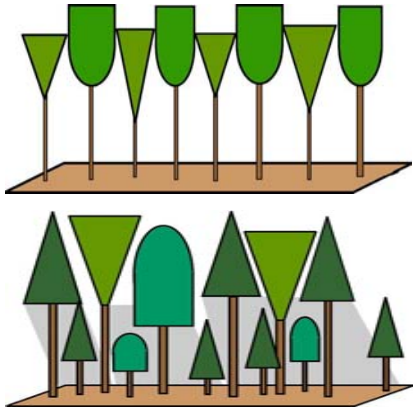
inplastic - plastic



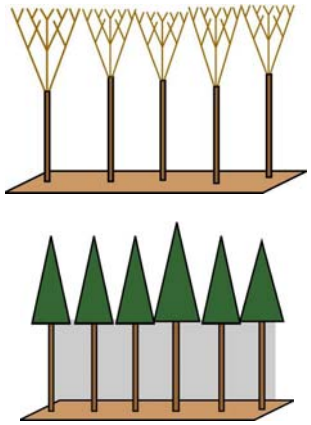
shallow – deep rooting



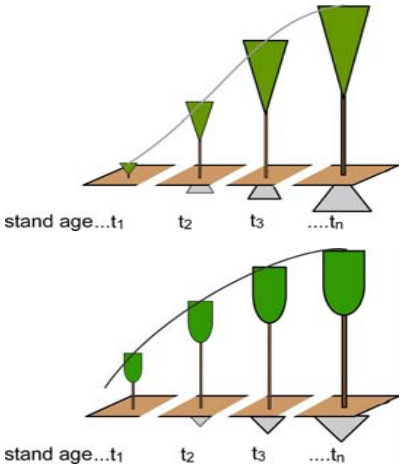
light demanding - shade tolerant



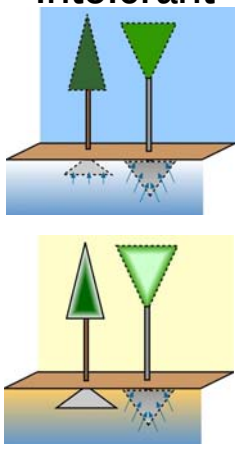
seasonal - evergreen



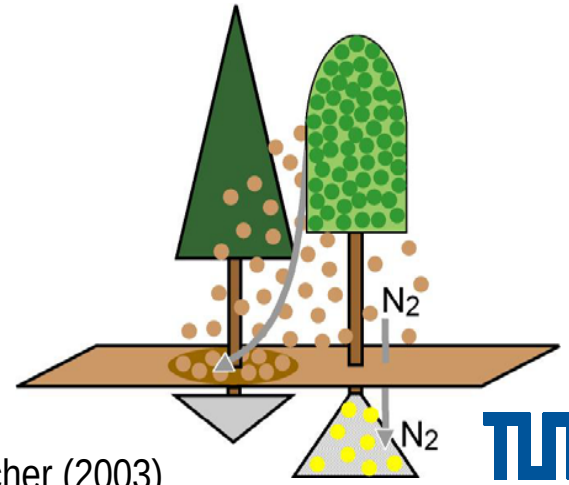
slow - fast growing



drought tolerant-intolerant

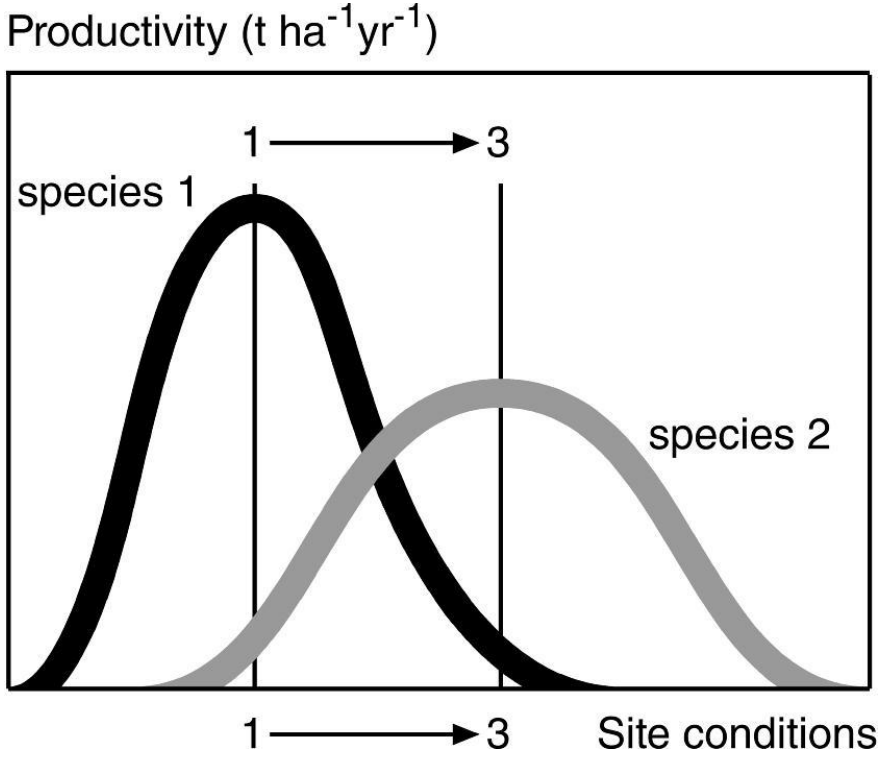


N-fixing - non N-fixing



Ammer (2018), Pretzsch et al. (2017), Ellenberg and Leuschner (2010), Larcher (2003)

Preparation for change of site conditions: species mixing for risk distributiuon



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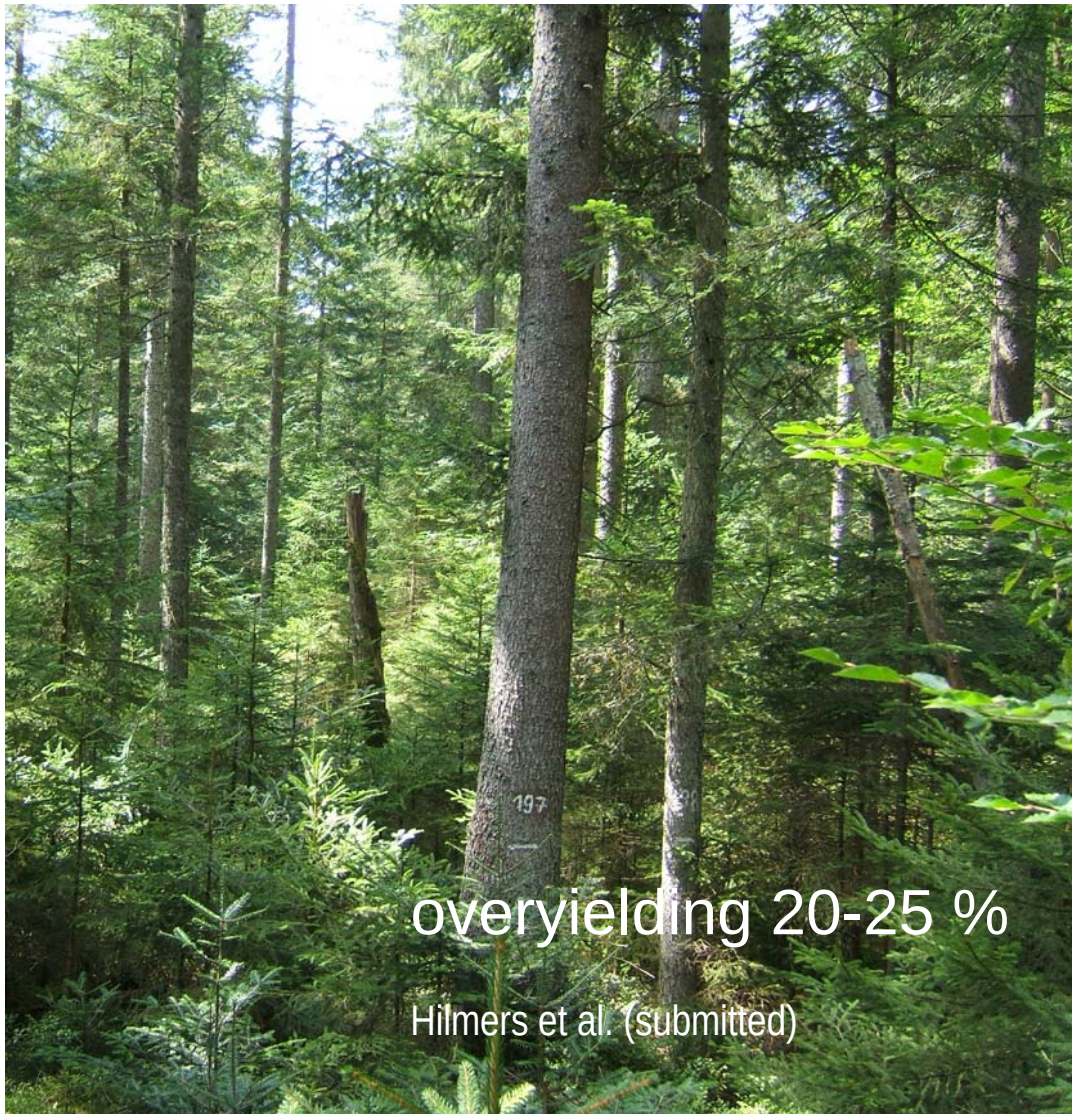
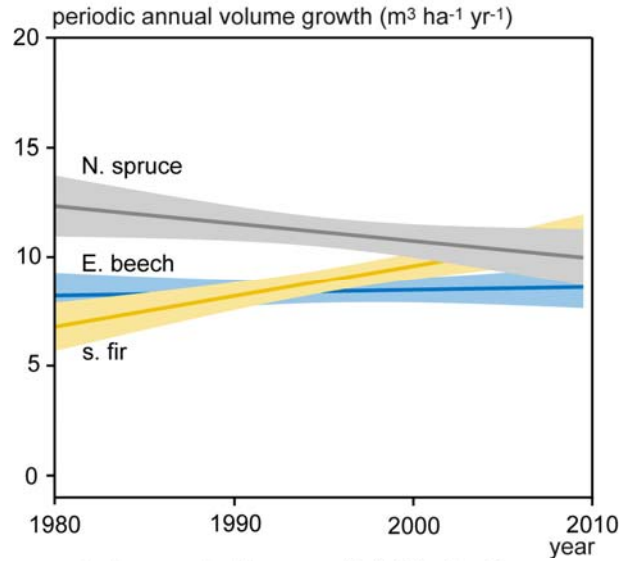
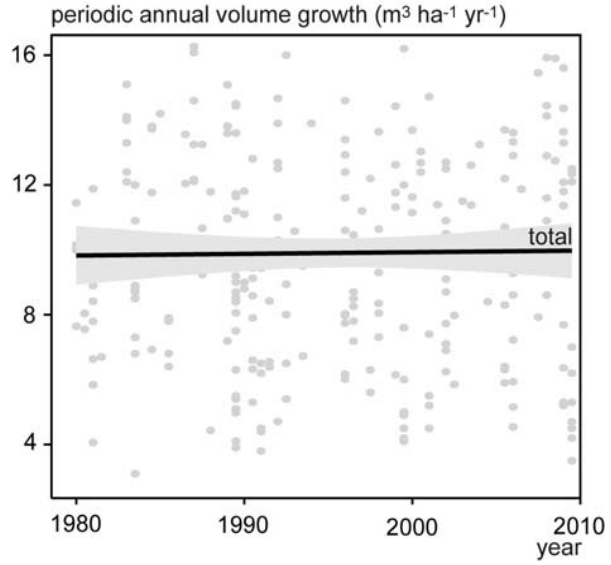
Growth stability by risk distribution. Growth on n=105 CLIMO study # 1 spruce-fir-beech stands







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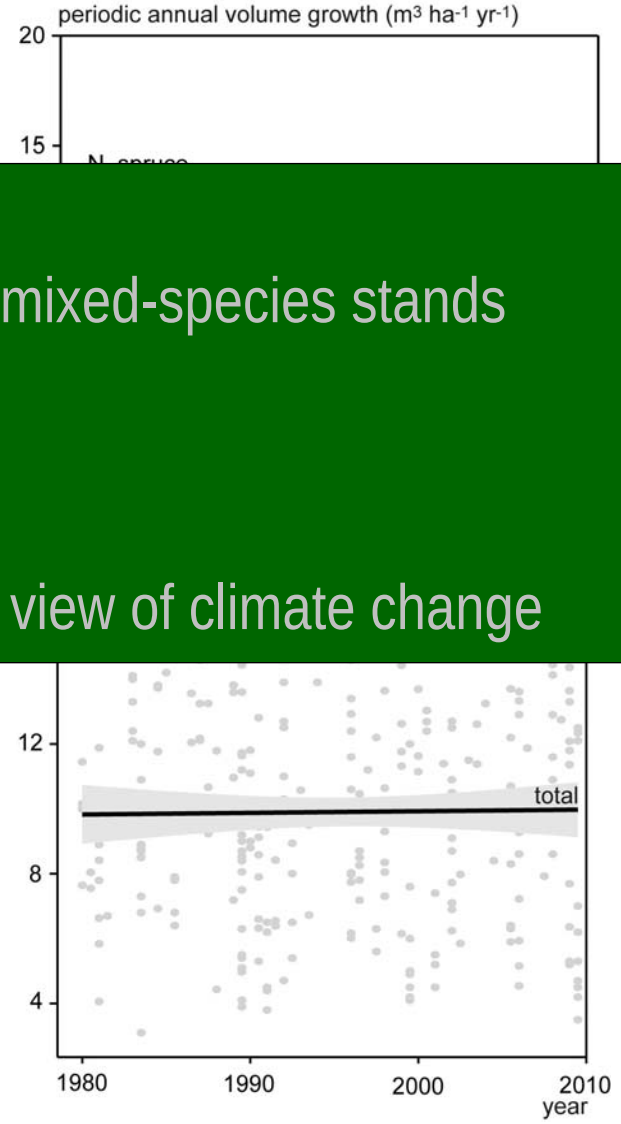
Overyielding and growth stability of the n=105 CLIMO study # 1 spruce-fir-beech stands

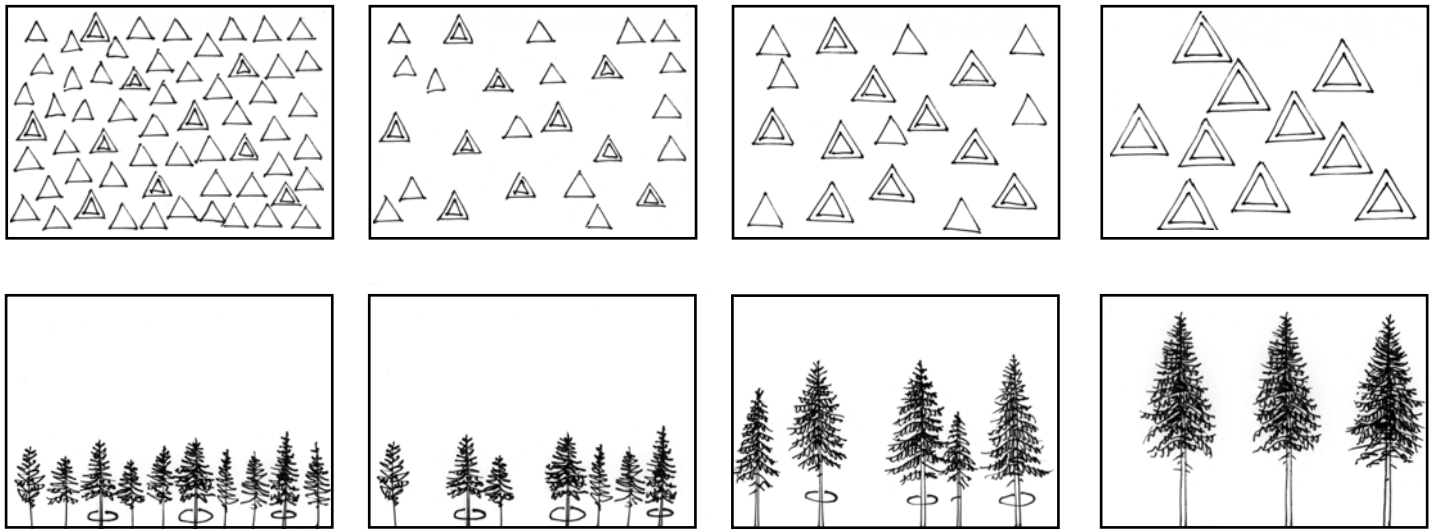
Summary 2:

Potential advantages of mixed-species stands

- stability
- resilience
- overyielding
- risk distribution, e.g. in view of climate change



Future crop tree thinning in monocultures. Schematic representation



future tree selection when mean height 10-12 m

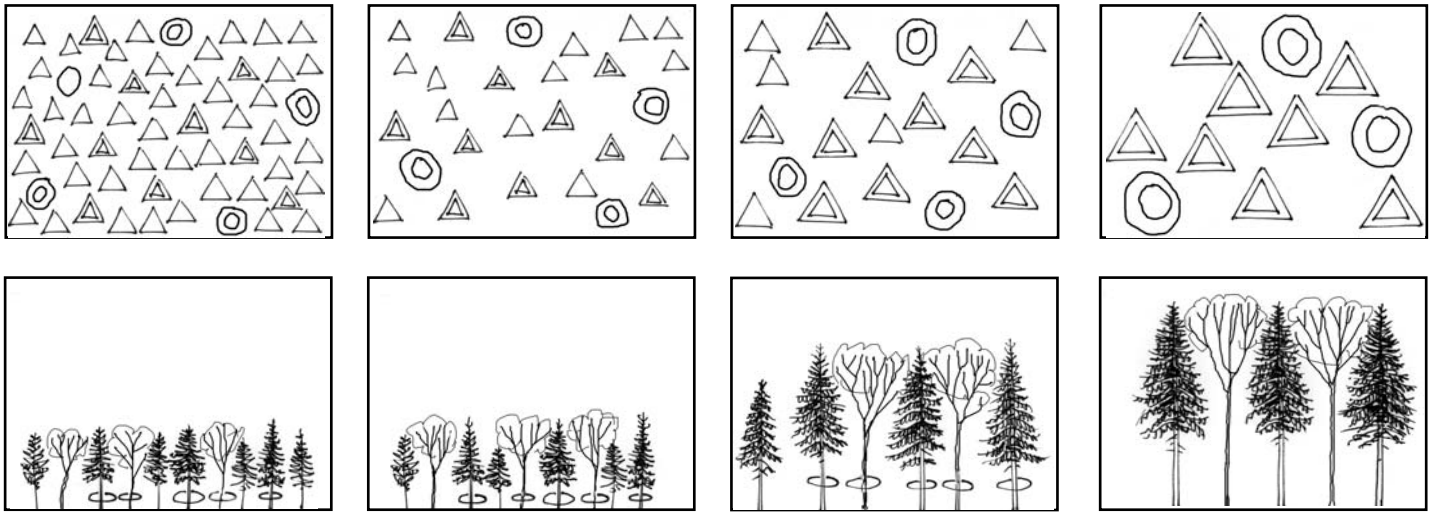
elimination of competitors

permanent release of future crop trees

homogeneous mature stand


161
160

Future crop tree thinning in mixed-species stands. Schematic representation



future tree selection when mean height 10-12 m

elimination of competitors

permanent release of future crop trees

homogeneous mature stand

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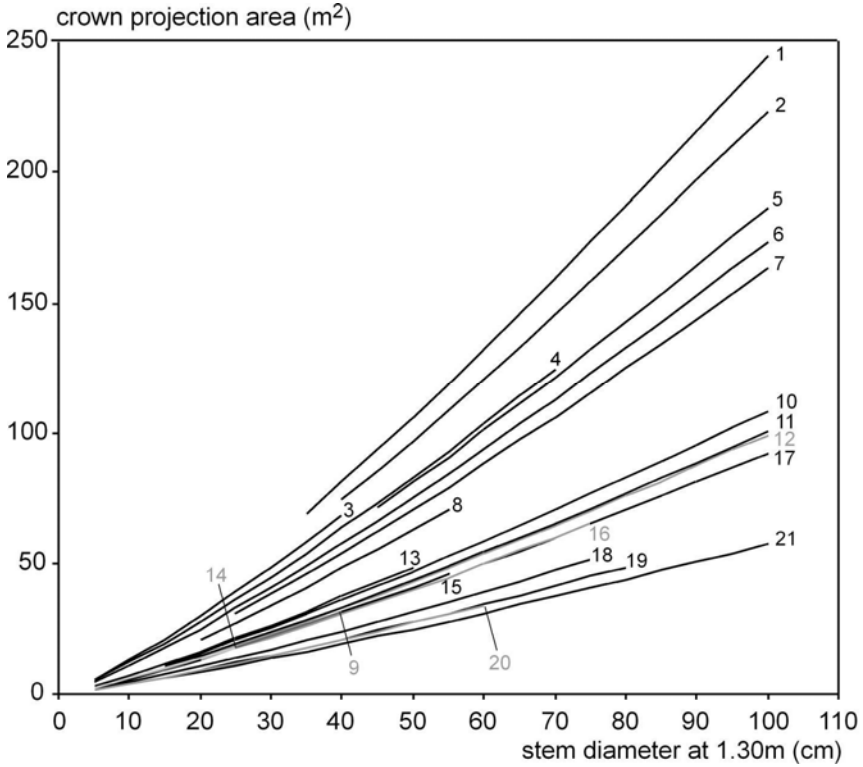
Systemanalyse

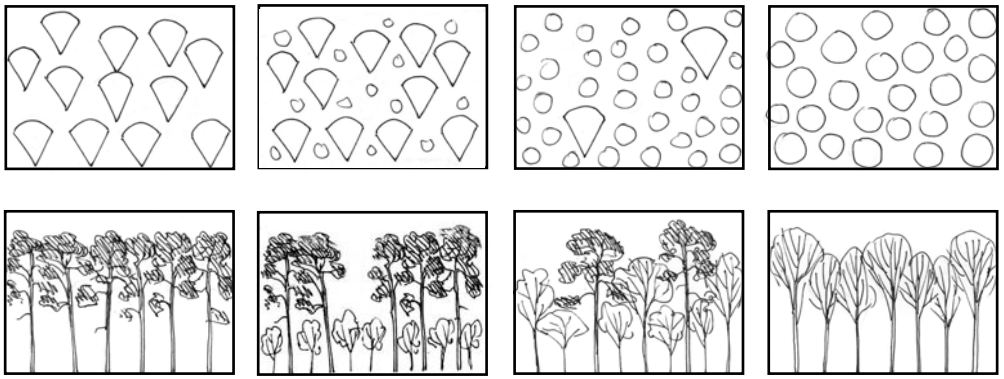
Species-specific growing space requirement. maximum stand density increases by mixture



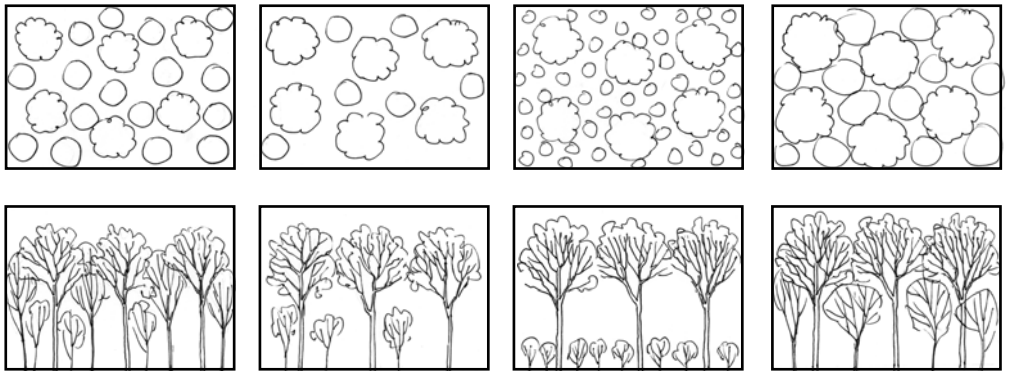
Tree species	Nor. spruce	Silver fir	Douglas fir	Scots pine	Eur. larch	Eur. beech	Sessile oak
Number of future trees (trees ha^{-1})	400	300	100	200	100	110	60
Norway spruce	5.7 (4.0)						
Silver fir	6.2 (5.0)	6.6 (4.0)					
Douglas fir			11.5 (8.0)				
Scots pine	7.0 (6.0)	7.3 (6.0)		8.1 (5.0)			
European larch		9.0 (7.0)		9.8 (8.0)	11.5 (5.0)		
European beech	8.5 (7.0)	8.7 (7.0)		9.5 (7.0)	11.2 (8.0)	11.0 (5.0)	
Sessile/ Common oak				11.4 (8.0)	13.1 (9.0)	12.9 (9.0)	14.8 (6.0)

[1] *Quercus nigra* L., [2] *Platanus x hispanica* Münchh., [3] *Carpinus betulus* L., [4] *Tilia cordata* Mill.,
[5] *Khaya senegalensis* (Desr.) A.Juss., [6] *Fagus sylvatica* L., [7] *Aesculus hippocastanum* L.,
[8] *Robinia pseudoacacia* L., [9] *Alnus glutinosa* [L.] Gaertn., [10] *Araucaria cunninghamii* Aiton ex. D.Don,
[11] *Pseudotsuga menziesii* [Mirb.], [12] *Abies alba* Mill., [13] *Sorbus aucuparia* L., [14] *Betula pendula* Roth,
[15] *Acer pseudoplatanus* L., [16] *Abies sachalinensis* Mast., [17] *Quercus petraea* [Matt.] Liebl.,
[18] *Pinus sylvestris* L., [19] *Larix decidua* Mill., [20] *Fraxinus excelsior* L., [21] *Picea abies* [L.] Karst.

Two-cohort systems with generation overlap

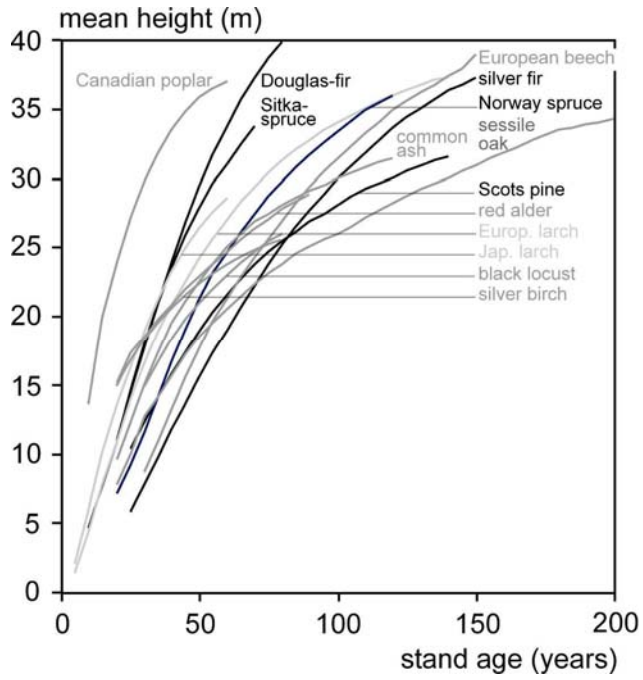


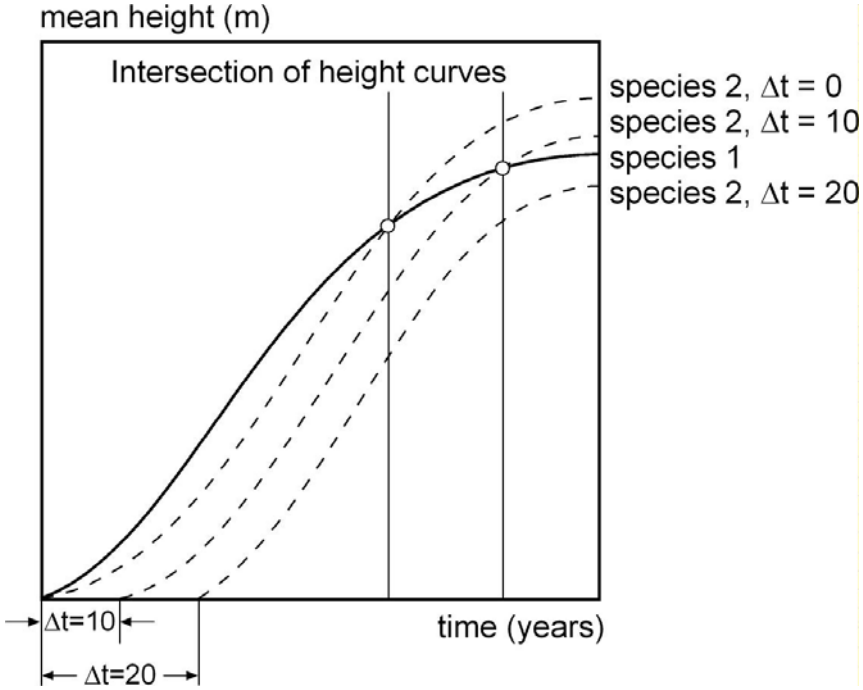
E. beech
under S. pine



E. beech
under sessile oak

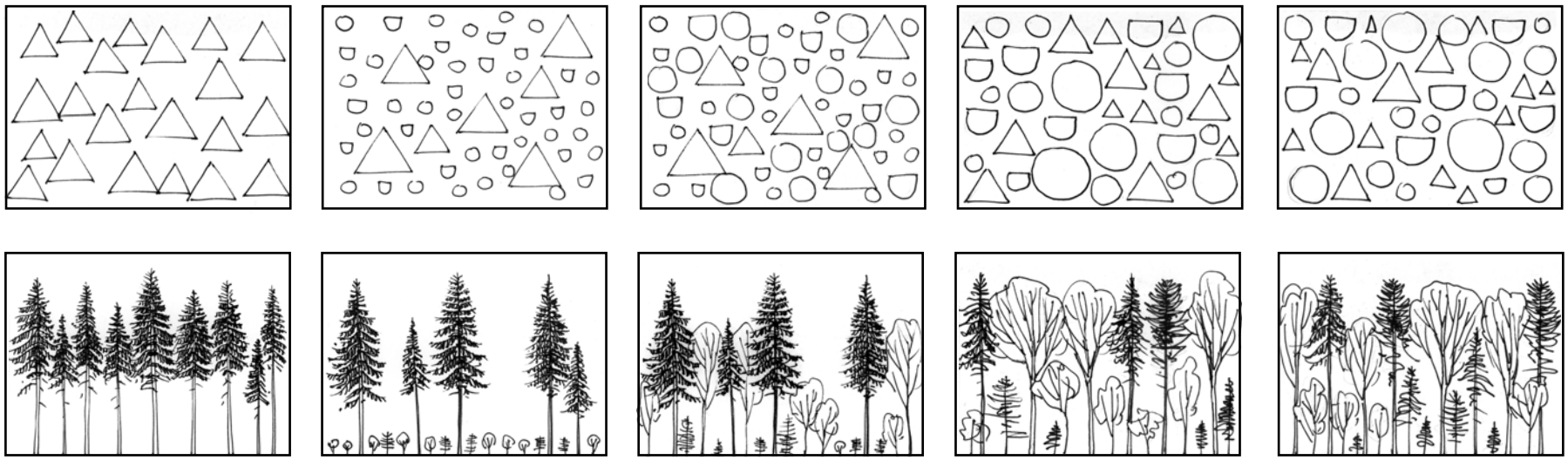
Regulation of competition by temporal separation





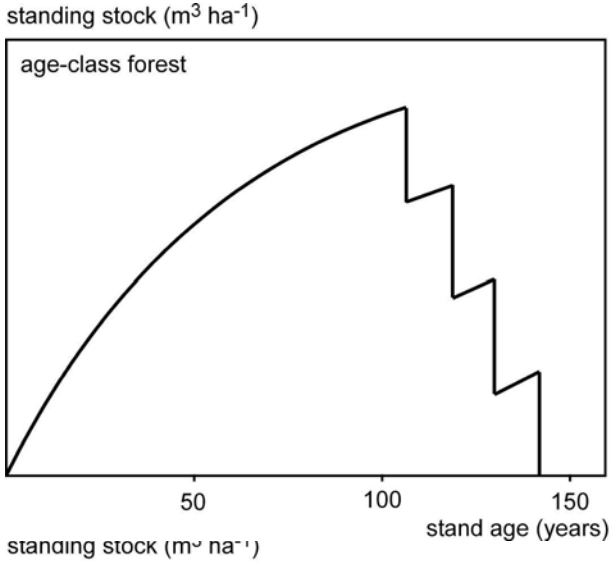
Pretzsch H, Forrester D, Bauhus J (2017) Mixed-species forests. Ecology and Management, Springer, Berlin, 653 p

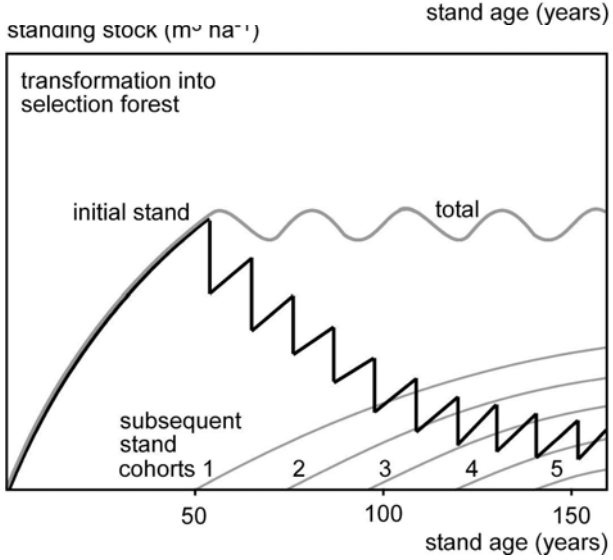
Conversion of artifical pure spruce or pine stands to more natural stands. Schematic representation

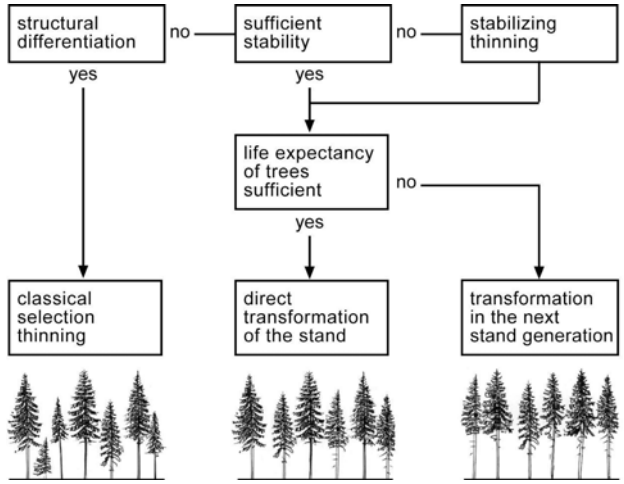


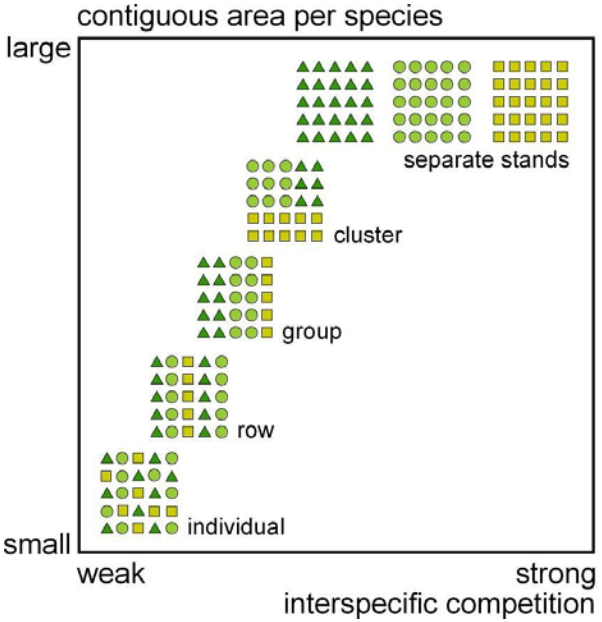
monoculture | underplanting | multi-layered | selection forest | selection forest

Conversion of artifical pure spruce or pine stands.





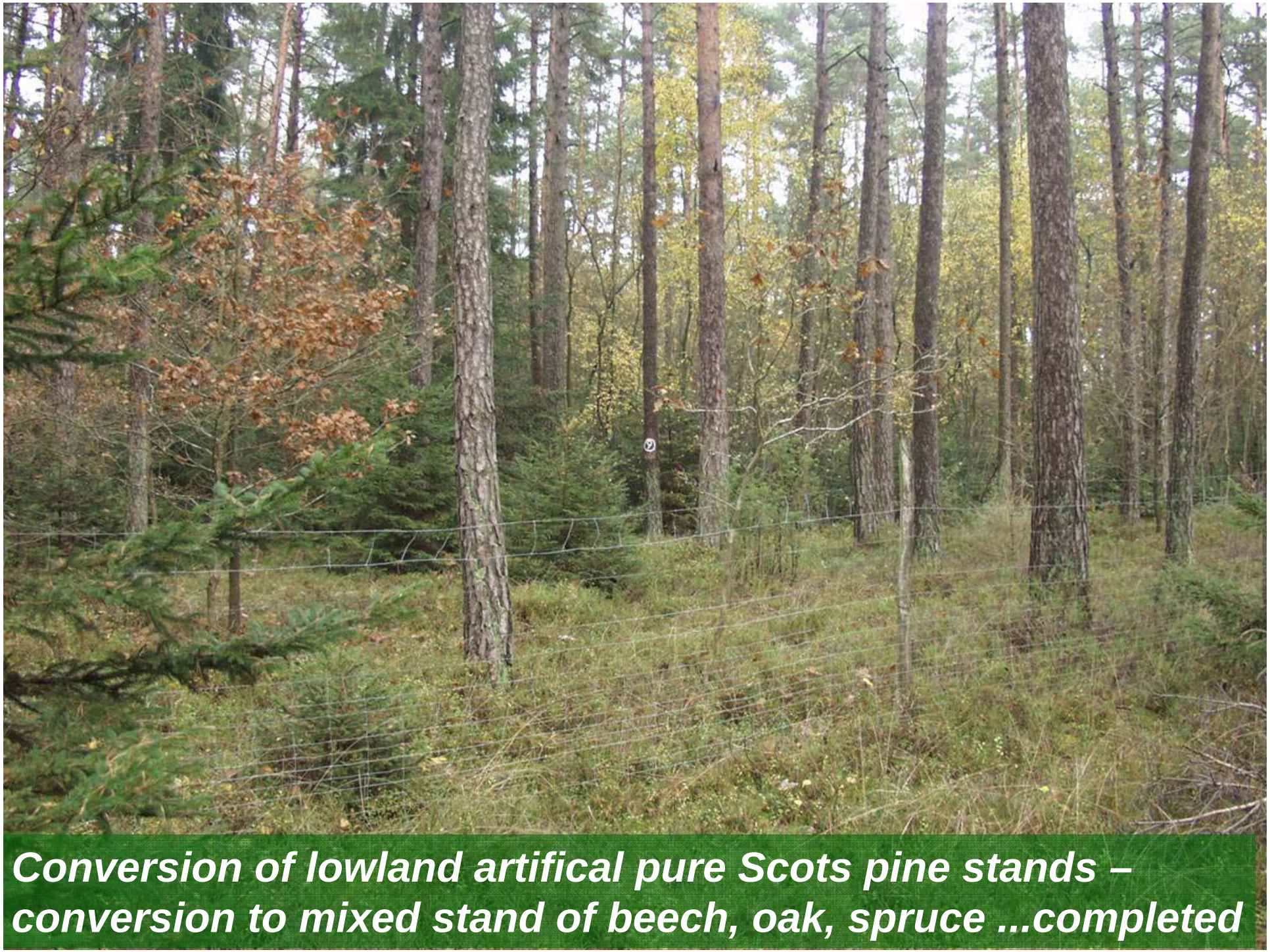




Pretzsch et al. (2018)

Conversion of lowland artifical pure Norway spruce stands – underplanting by E. beech and s fir

Conversion of lowland artifical pure Norway spruce stands – conversion to mixed stand of spruce, fir, beech completed



Conversion of lowland artifical pure Scots pine stands – conversion to mixed stand of beech, oak, spruce ...completed

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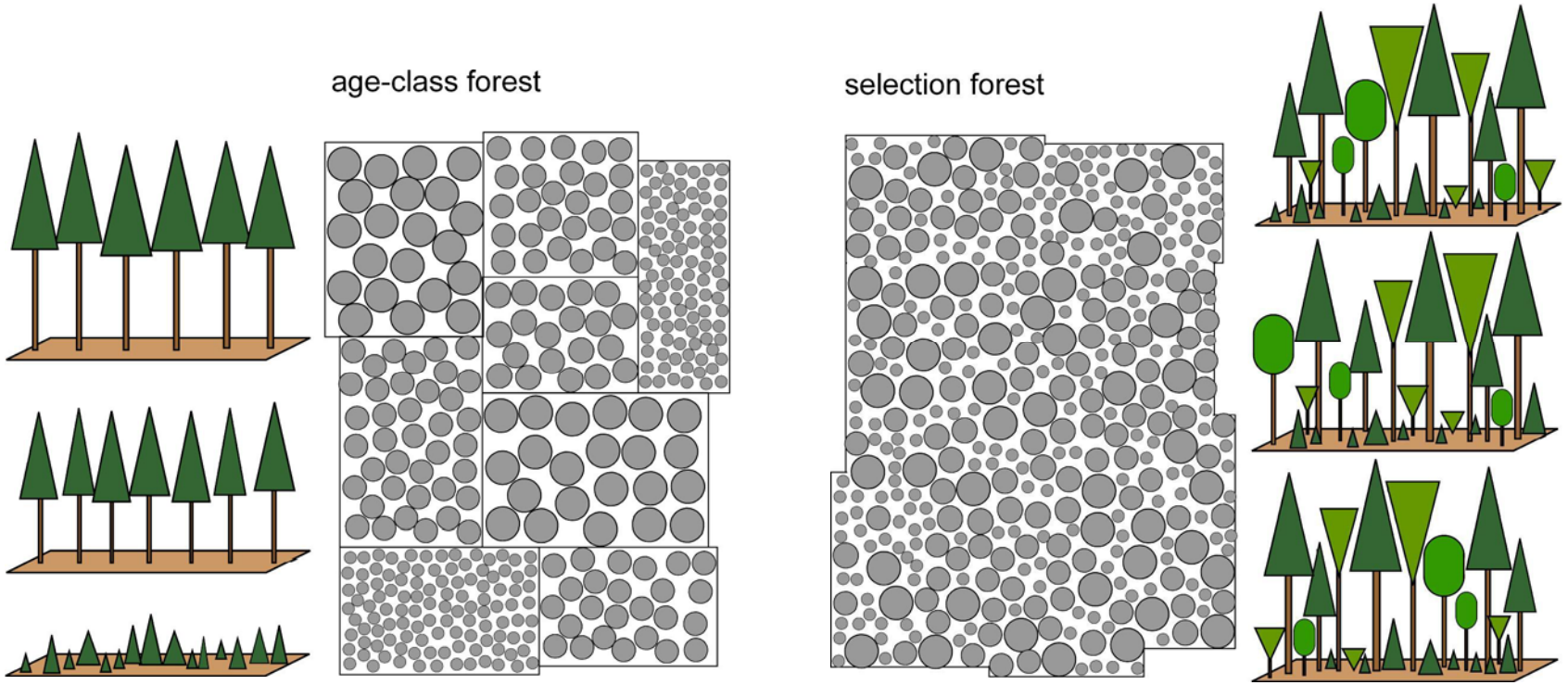
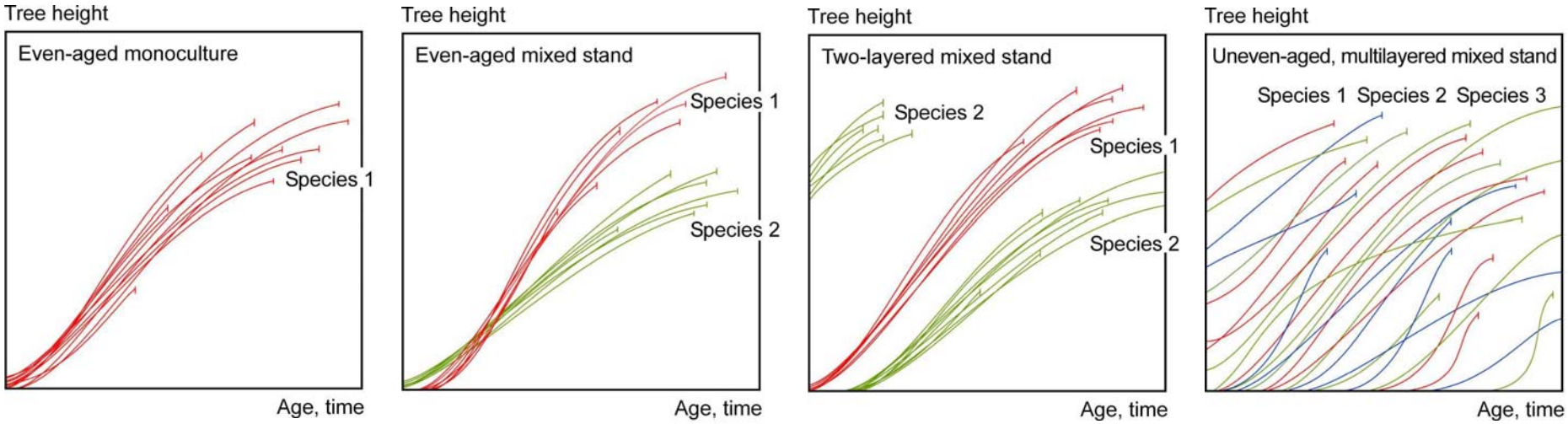
Systemanalyse

Conversion of artifical pure spruce stands to selection forest



Waldwachstumskunde
Systemanalyse

The continuum from even-aged monocultures to uneven-aged mixed-species stands. Representation by the height growth trajectories



Waldwachstumskunde
Systemanalyse

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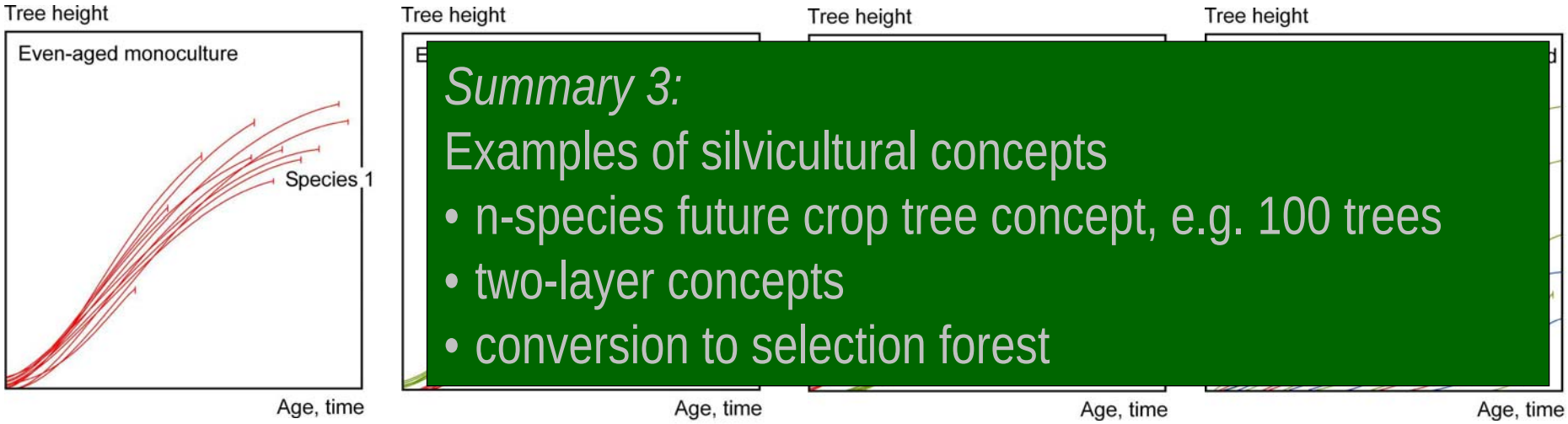


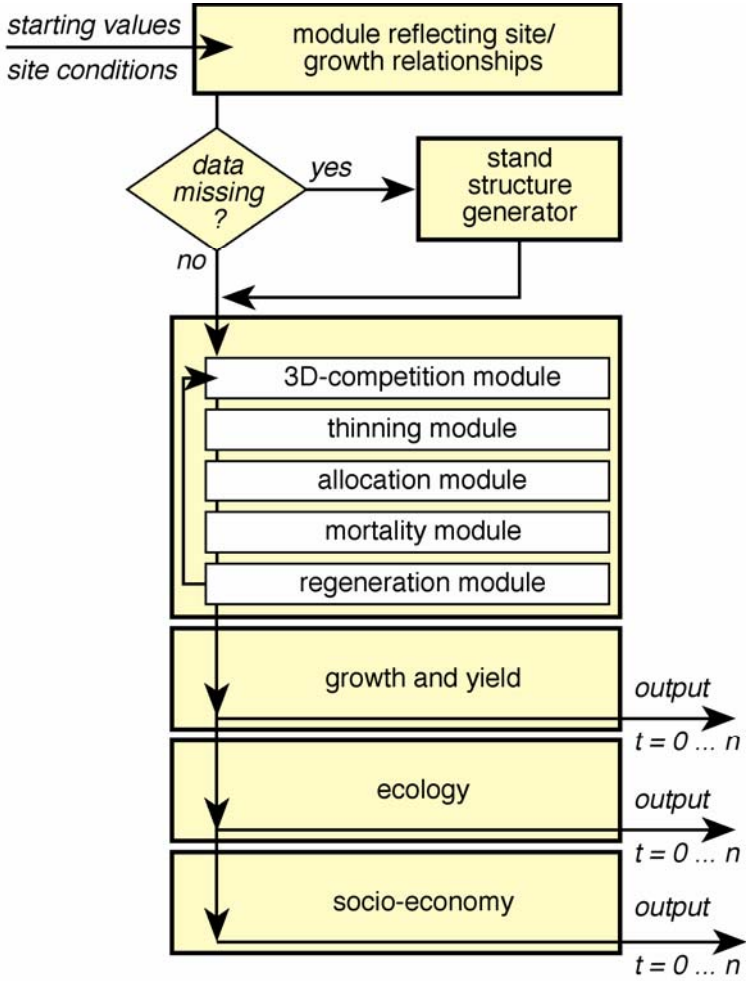
Summary 3:

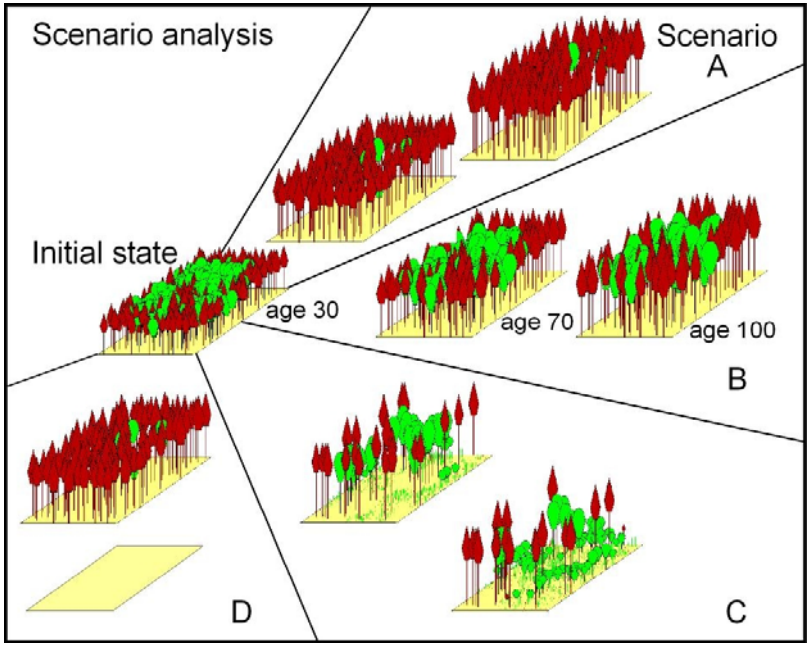
Examples of silvicultural concepts

- n-species future crop tree concept, e.g. 100 trees
- two-layer concepts
- conversion to selection forest

Waldwachstumskunde
Systemanalyse

Models for the design of mixed stands: SILVA as example of a spatially explicit individual tree model





Pretzsch, Biber, Dursky (2002)

Waldwachstumskunde
Systemanalyse

Criteria for sustainable forest ecosystem management.

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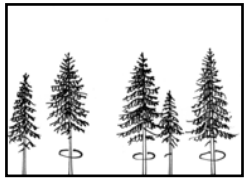
Protective functions	soil, water, climate, noise, protection
Socio-economic functions	employment, recreation, esthetics, proximity to nature

according to MCPFE, 2000

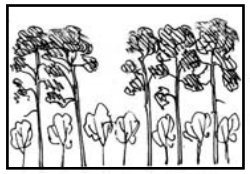

Thanks for funding by
DFG
EU: CLIMO, REFORM, CARE4C
MStELF, MStU, BaySF
Thanks for provinding data to
partner institutions in Sweden, Denmark,
England, Poland, France, Germany, Austria,
Switzerland, Italy, Bulgaria, Spain, and others
http://waldwachstum.wzw.tum.de/index.php?id=presentations

Waldwachstumskunde
Systemanalyse

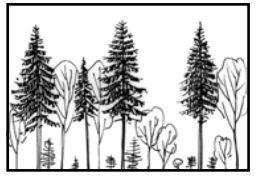
Examples of silvicultural prescriptions for mixed-species stands



- Future crop tree thinning in monocultures and mixed-species stands



- Two-cohort systems with generation overlap



- Conversion of artifical pure spruce or pine stands to close to nature forests

- Selection forest

- Shelterwood-femel-coupe

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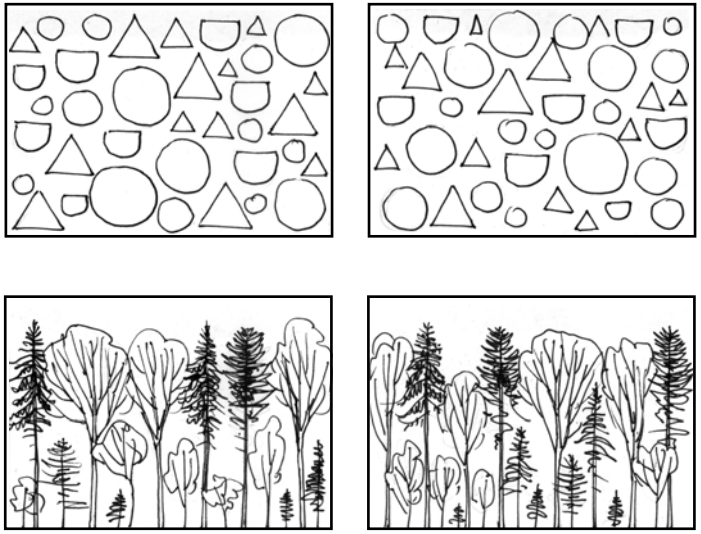
Systemanalyse

Selection forest
Schematic representation

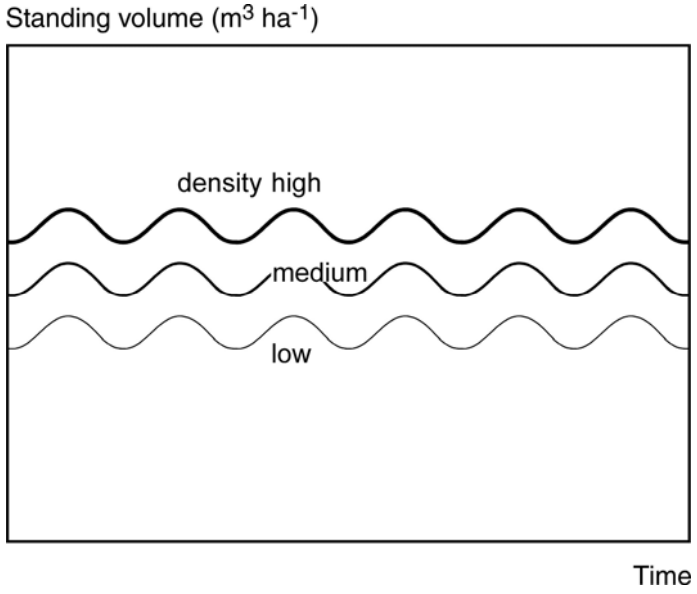


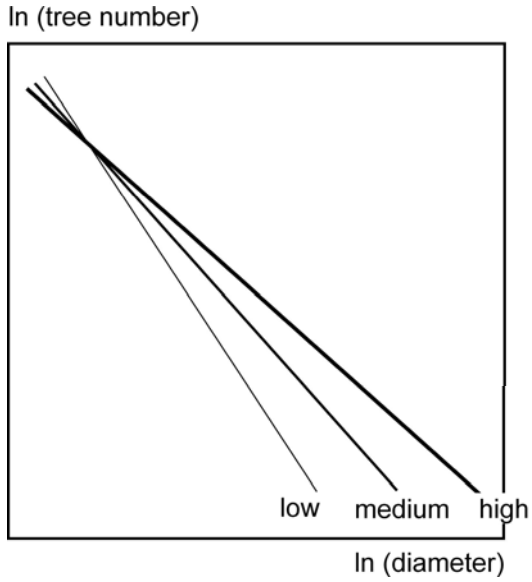
1950 2010

Selection forest - Norway spruce, Silver fir, European beech

Waldwachstumskunde
Systemanalyse

Selection forest
Steady state equilibrium on density levels depending on site conditions and target diameter





Pretzsch (2009) Forest Dynamics, Growth and Yield, Springer, 653 p.

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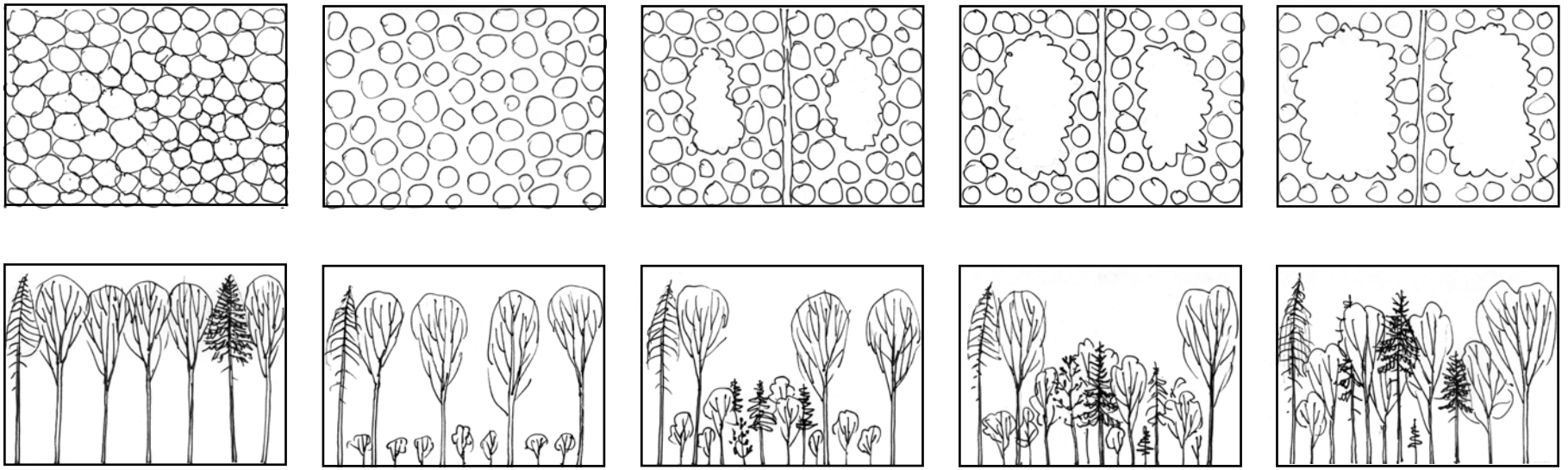
Shelterwood-femel-coupe
Schematic representation

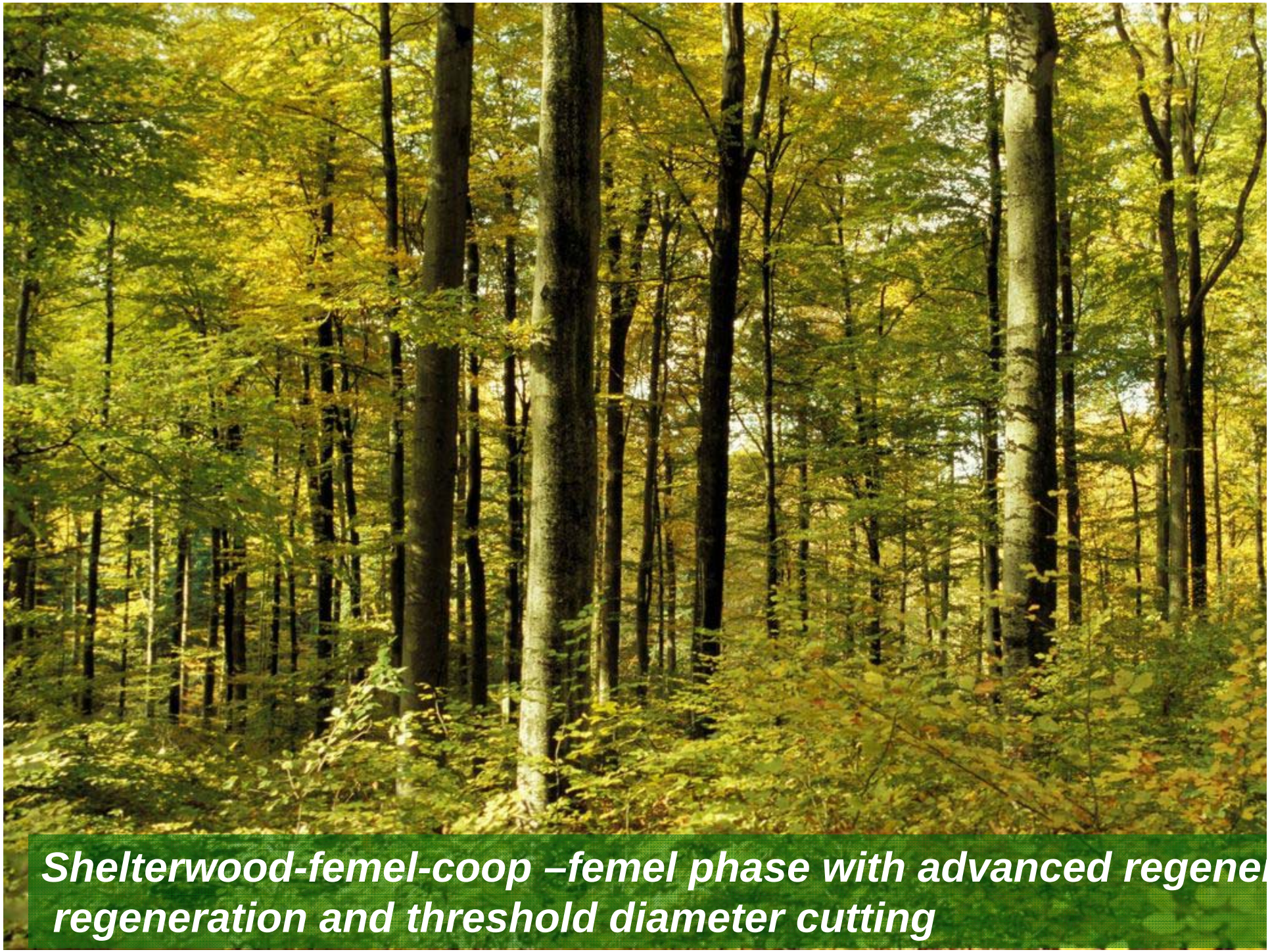


age 100 age 110 age 120 age 130 age 140


Shelterwood-femel-coop – initial shelterwood phase

Shelterwood-femel-coop – advanced shelterwood phase

Shelterwood-femel-coop – advanced femel phase with watch shaped regeneration clusters



Shelterwood-femel-coop –femel phase with advanced regenel regeneration and threshold diameter cutting

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The continuum from even-aged monocultures to uneven-aged mixed-species stands (from left to right).Representation by the current annual volume increment