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# Analysing and modelling pure and mixed forests. A German perspective

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

Presentation at Warszava University, April 13, 2011, Erasmus exchange program, 28692-IC-1-2007-1-DE-ERASMUS-EUCX-1
TUM Munich, Chair for Forest Growth and Yield Science and Warszava University of Life Sciences, Faculty of Forestry, SGGW

# Warsaw Declaration 2007
# „Forests for Quality of Life“

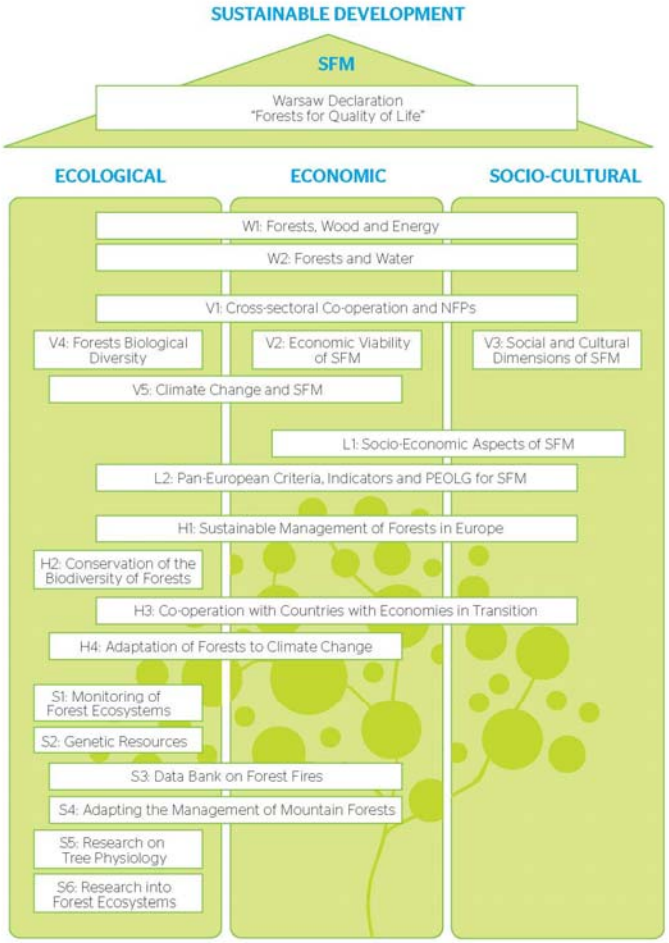


Figure 1. Resolutions adopted at five Ministerial Conferences, 1990–2007, and their relation to the three pillars of sustainable forest management (SFM).
Please note that the titles of the Resolutions are short titles.

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Model approaches for complex forests

SILVA 3.0 model

Mixed stand research

Summary and perspective

# Need for model approaches for complex forests

***Trends in forest management***

- Transition from pure to uneven-aged mixed stands
- Establishment of spatially explicit thinning rules (crop tree thinning)
- Change of site and growth conditions

***Trends in environmental policy and information demand***

- Rio 1992 (Agenda 21), Helsinki (H1), 1993, Lisbon (L2) 1998, Wien 2003, Warsaw 2007: Quantitative indicators for proof of sustainable forest management (6 MCPFE, 2000 criteria)

***Trends in information supply and information technology***

- Use of data from permanent inventories
- Availability of geodata (site conditions, digital terrain data etc.)
- New information flow in forest organizsations (e. g. decentral PC application with access to central data base server)

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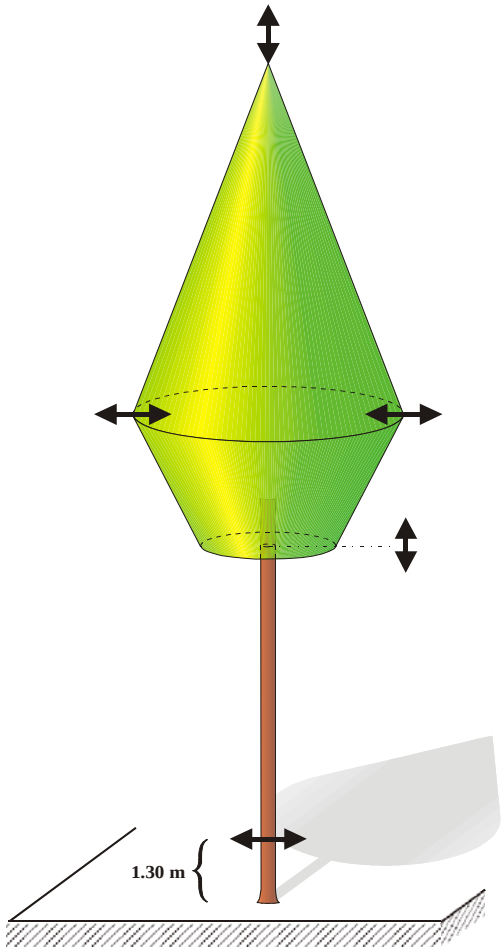
# SILVA 3.0: Spatial dependent individual tree growth model for pure and mixed stands

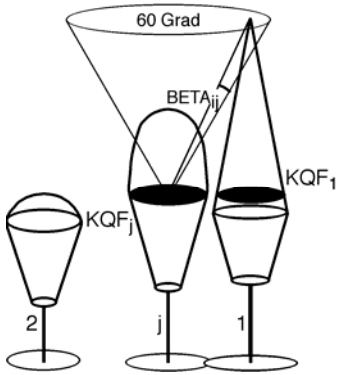



$$\frac{\Delta \text{height}}{\Delta t} = f_1(\text{height, crown, competition, site conditions})$$

$$\text{crown - diameter} = f_2(\text{height, diameter})$$

$$\text{crownbase} = f_3(\text{height, diameter})$$

Quantification of competition

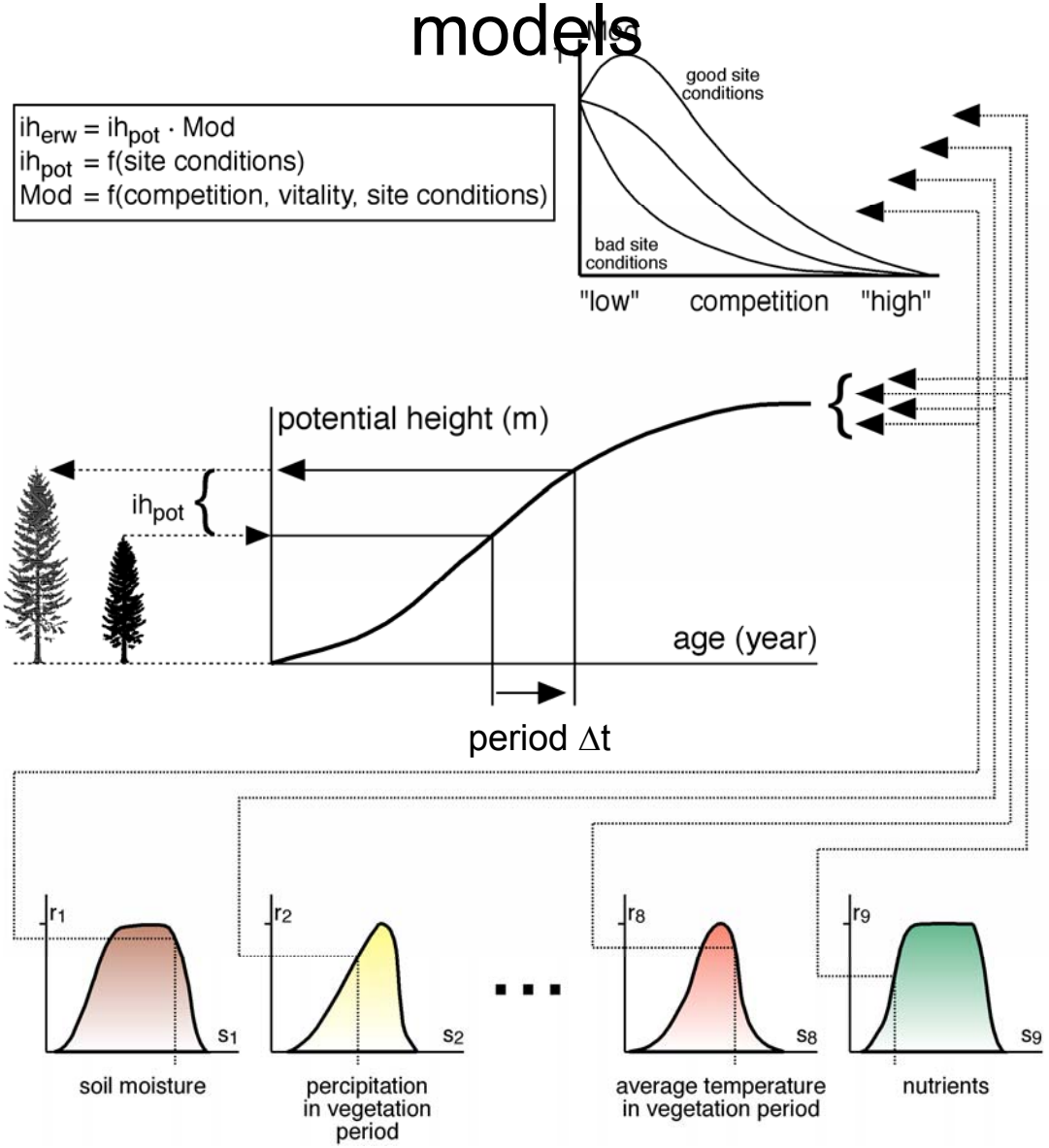



$$KKL_j = \sum_{\substack{i=1 \\ i \neq j}}^{n} BETA_{ij} \cdot \frac{KQF_i}{KQF_j} \cdot TM_i$$

$$\frac{\Delta \text{diameter}}{\Delta t} = f_4(\text{diameter, crown, competition, site conditions})$$

$$\text{mortality}_{\Delta t} = f_5\left(\text{height, diameter, } \frac{\Delta \text{diameter}}{\Delta t}, \text{ competition, site conditions}\right)$$

# SILVA 3.0: Potential-modifier-approach in tree models



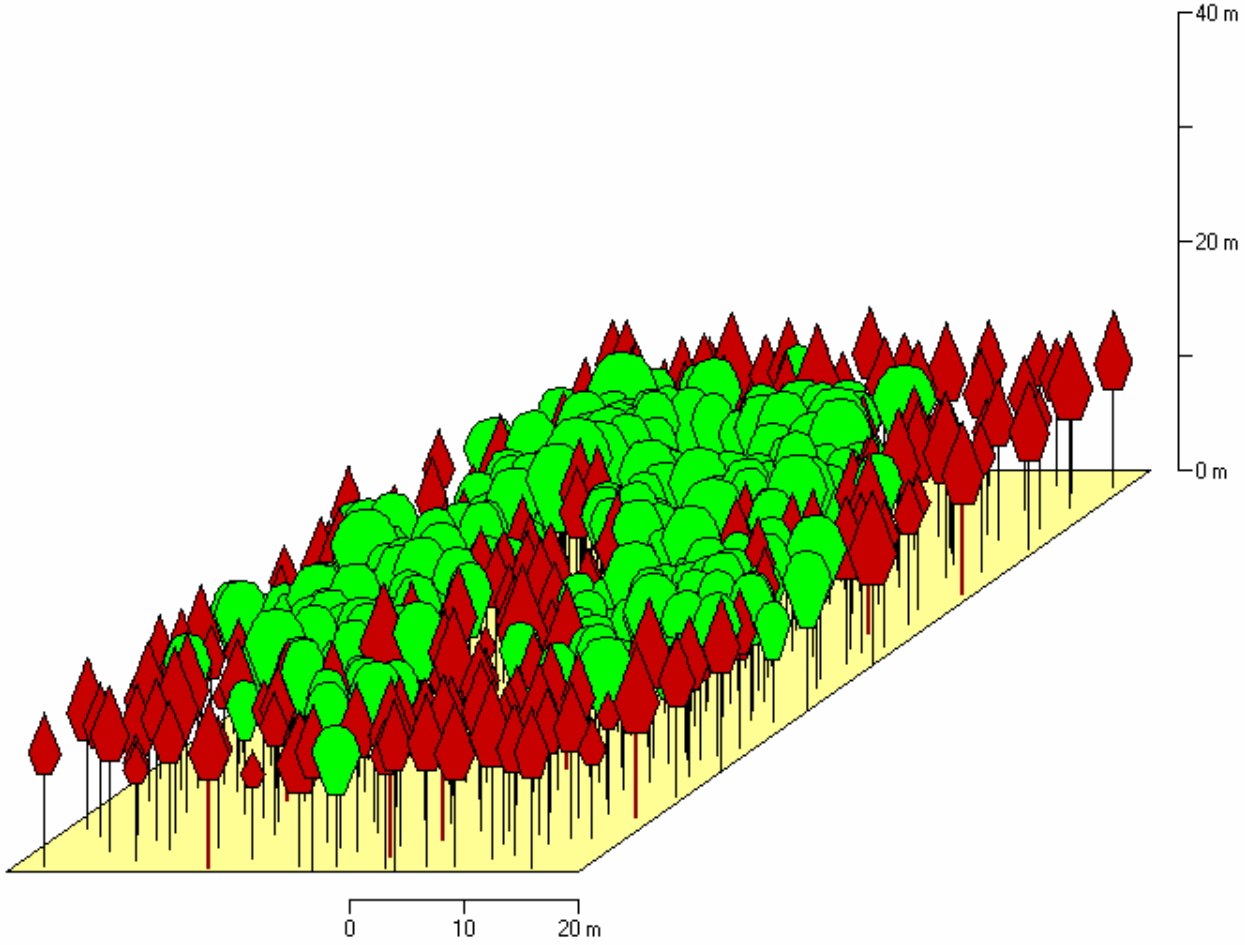
SILVA 2.2 - [Stand overview]

File Prognosis Results Configuration Extra Windows Help

## Stand overview

Legend | Period 1 | Save data | Copy image | Save image | Load image | Print image

FiBu____ Period 1



SILVA 2.2 - [Stand overview]

File Prognosis Results Configuration Extra Windows Help

## Stand overview

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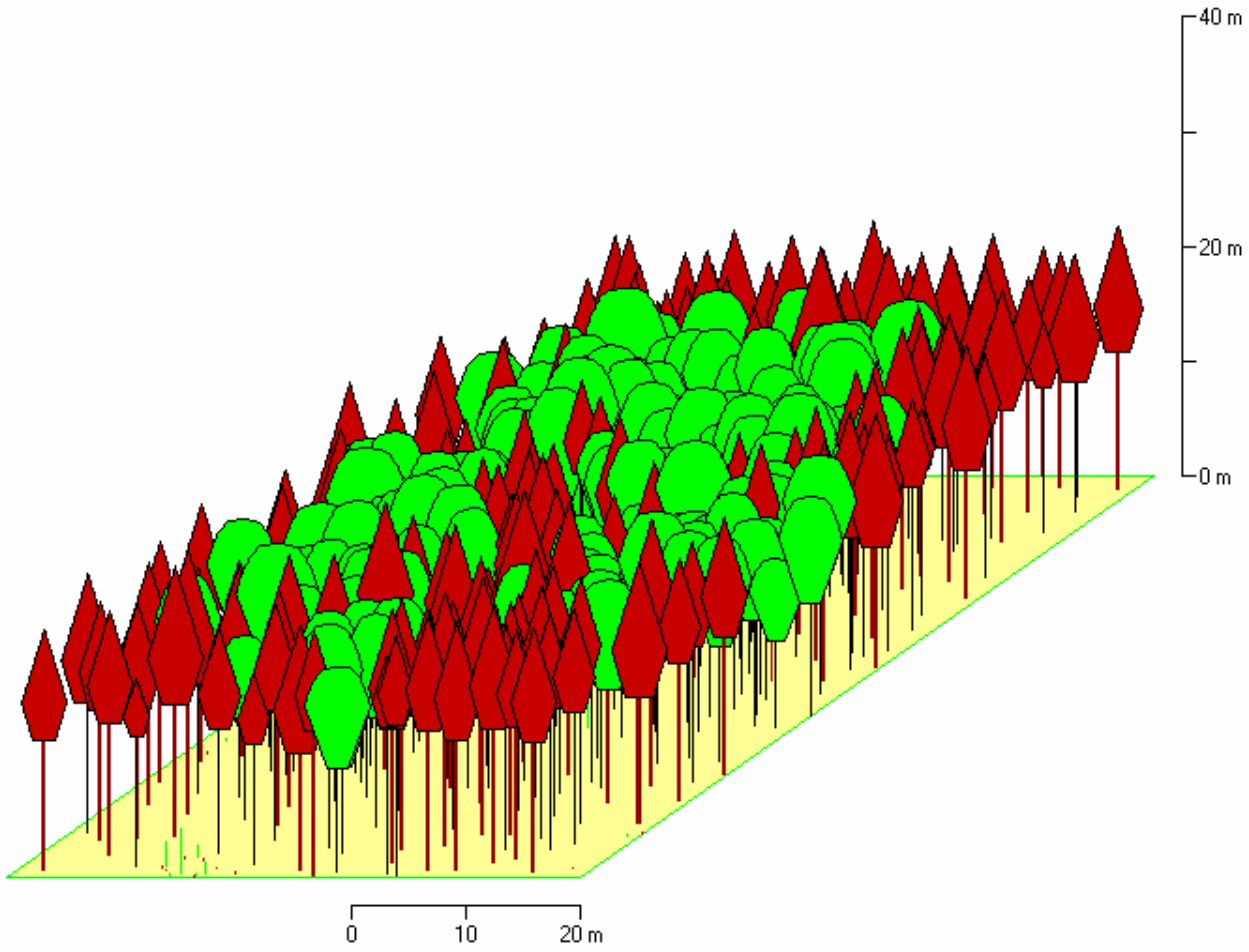
FiBu____ Period 5



SILVA 2.2 - [Stand overview]

File Prognosis Results Configuration Extra Windows Help

## Stand overview

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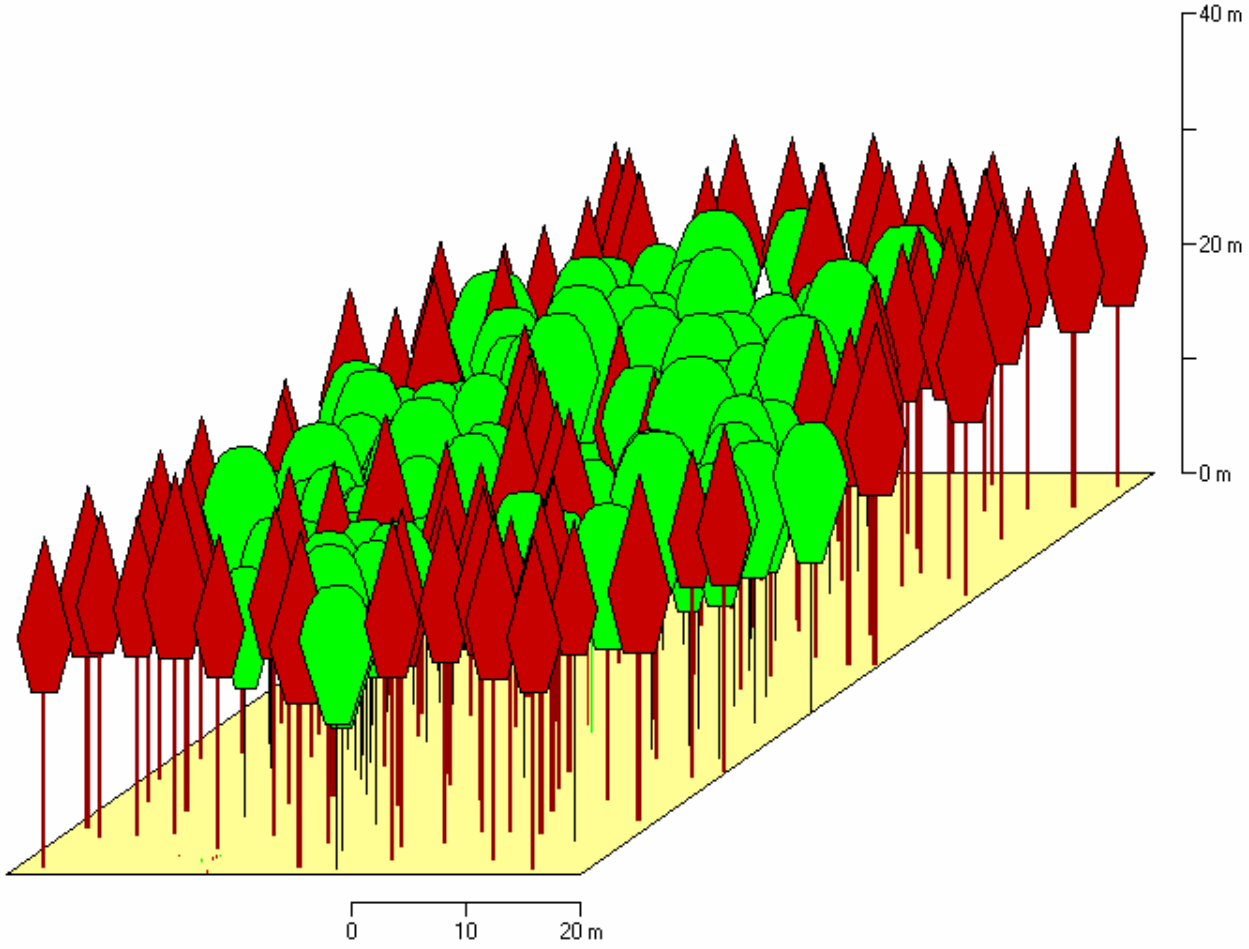
FiBu____ Period 10



SILVA 2.2 - [Stand overview]

File Prognosis Results Configuration Extra Windows Help

## Stand overview

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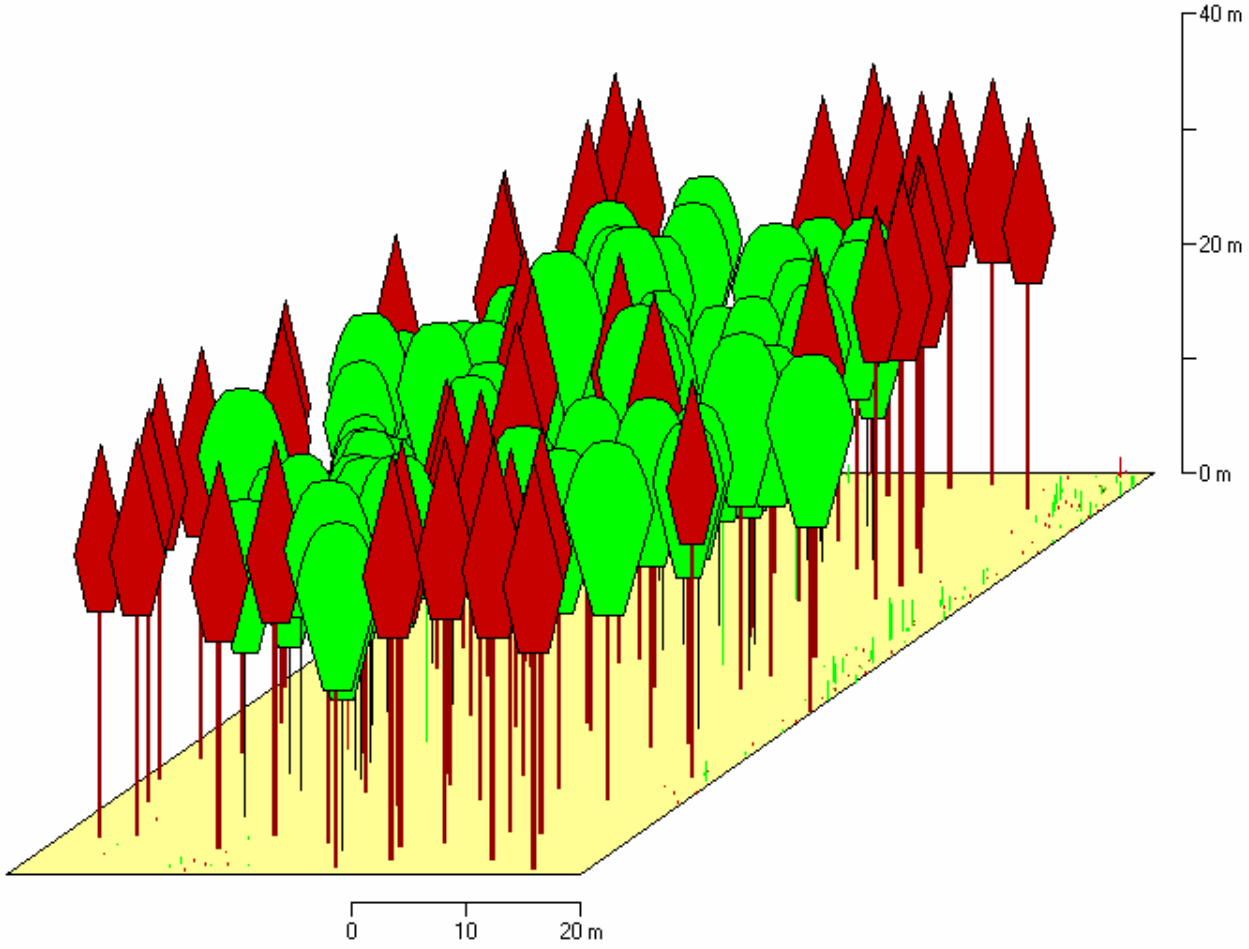
FiBu____ Period 15



SILVA 2.2 - [Stand overview]

File Prognosis Results Configuration Extra Windows Help

## Stand overview

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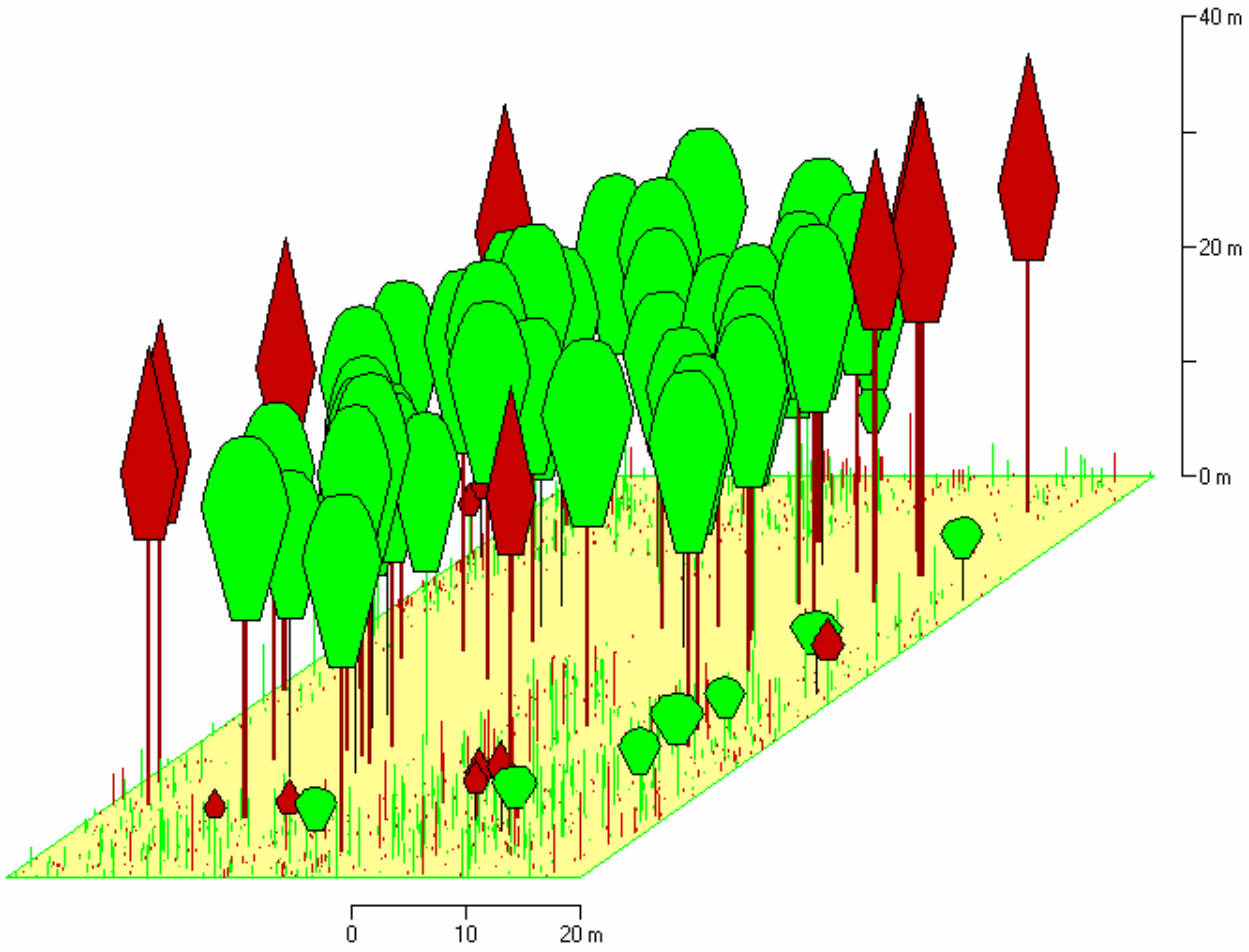
FiBu____ Period 20



SILVA 2.2 - [Stand overview]

File Prognosis Results Configuration Extra Windows Help

## Stand overview

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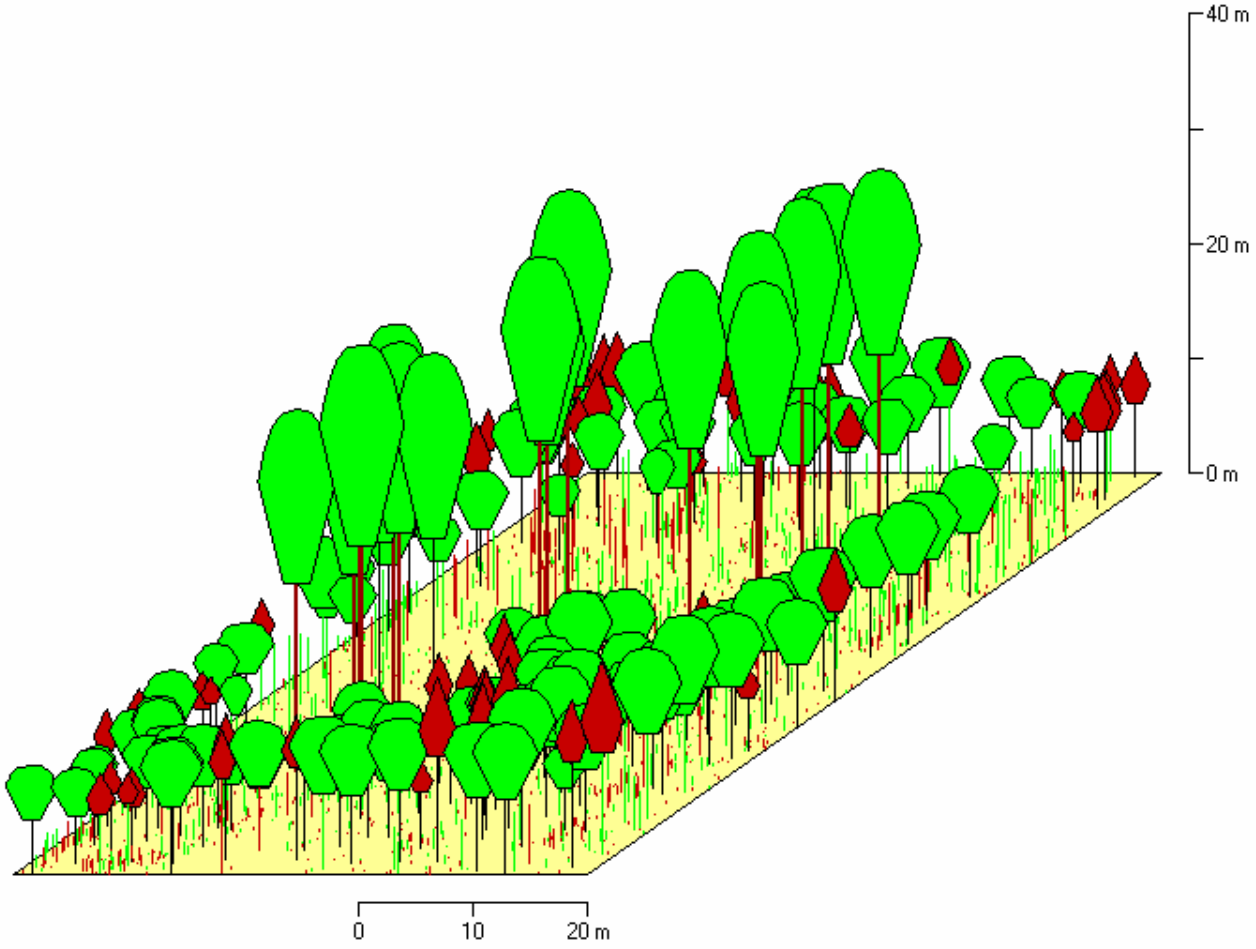
FiBu____ Period 25



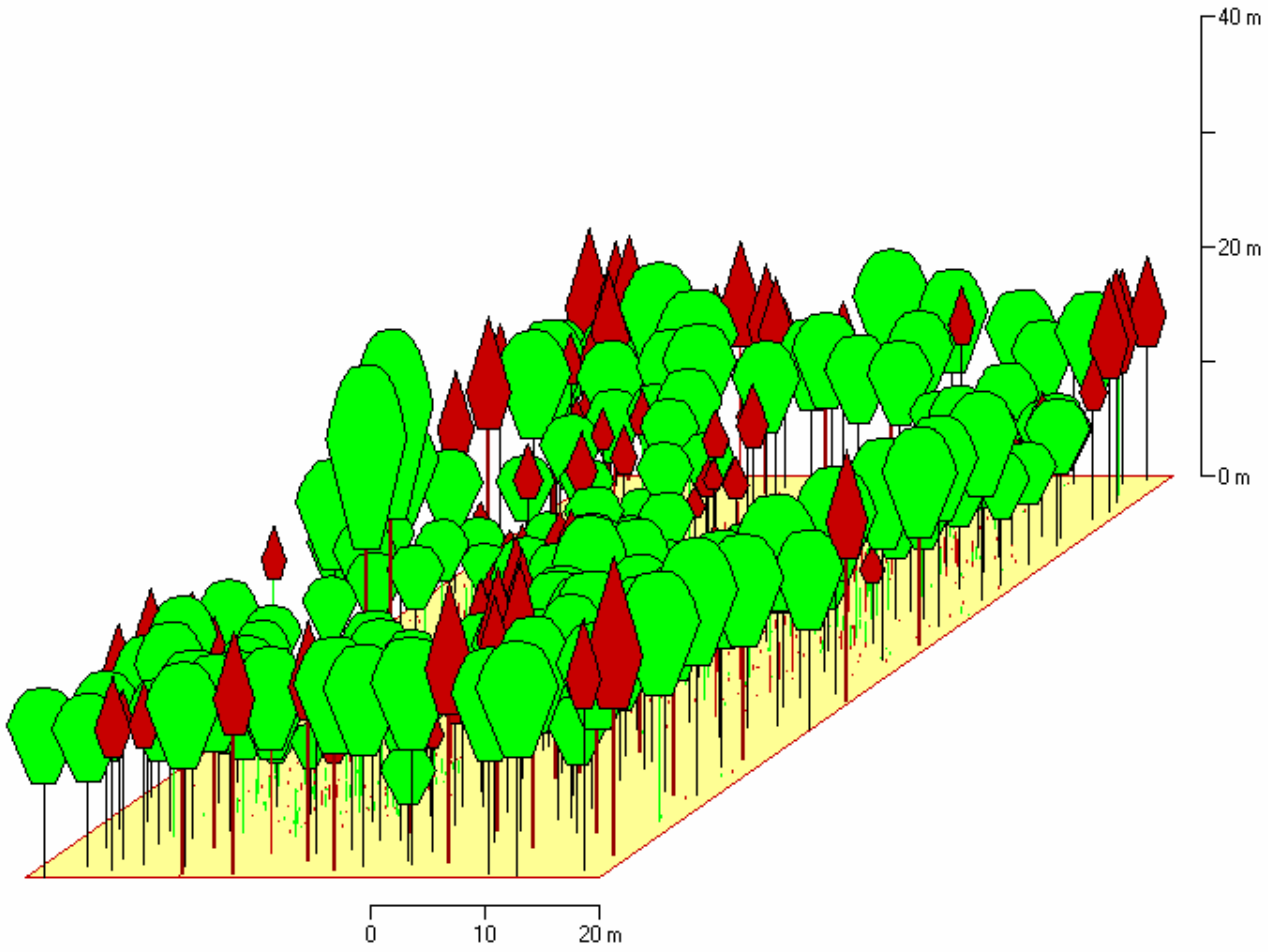
SILVA 2.2 - [Stand overview]

File Prognosis Results Configuration Extra Windows Help

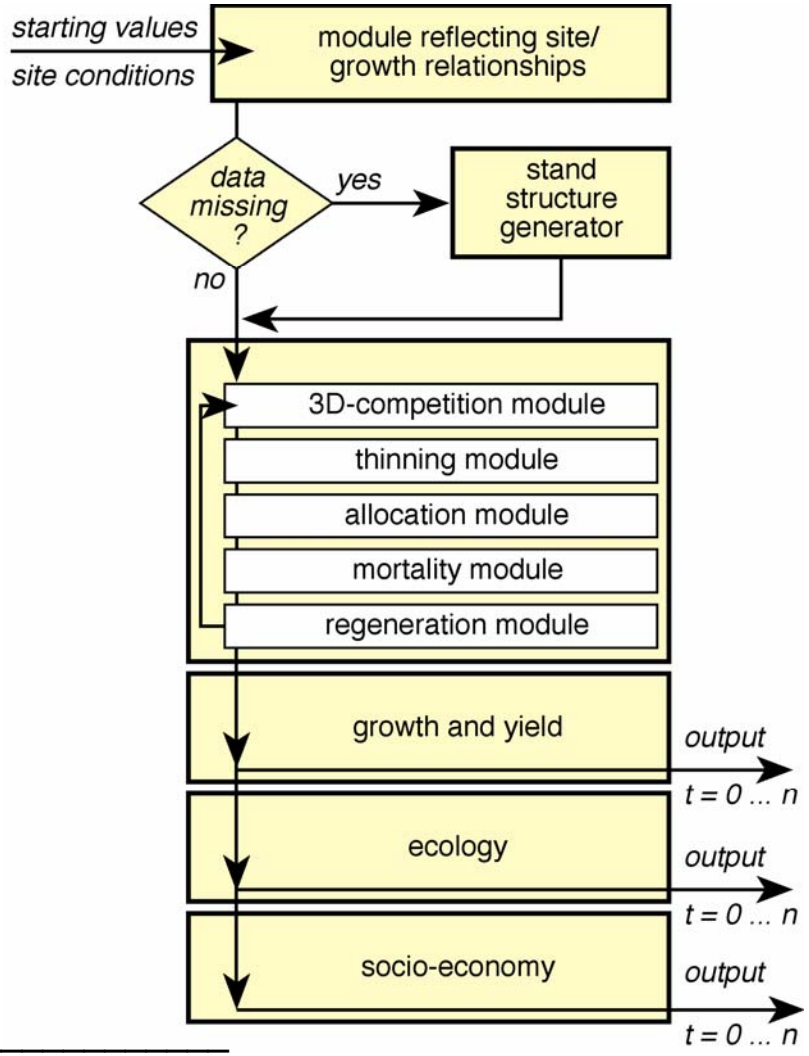
## Stand overview

Legend | Period 30 | Save data | Copy image | Save image | Load image | Print image

FiBu____ Period 30



# Essential elements of SILVA 3.0




PRETZSCH, H., BIBER, P. und DURSKY, J., 2002: The single tree based stand simulator SILVA. Construction, application and evaluation, Forest Ecology and Management, 162: 3-21

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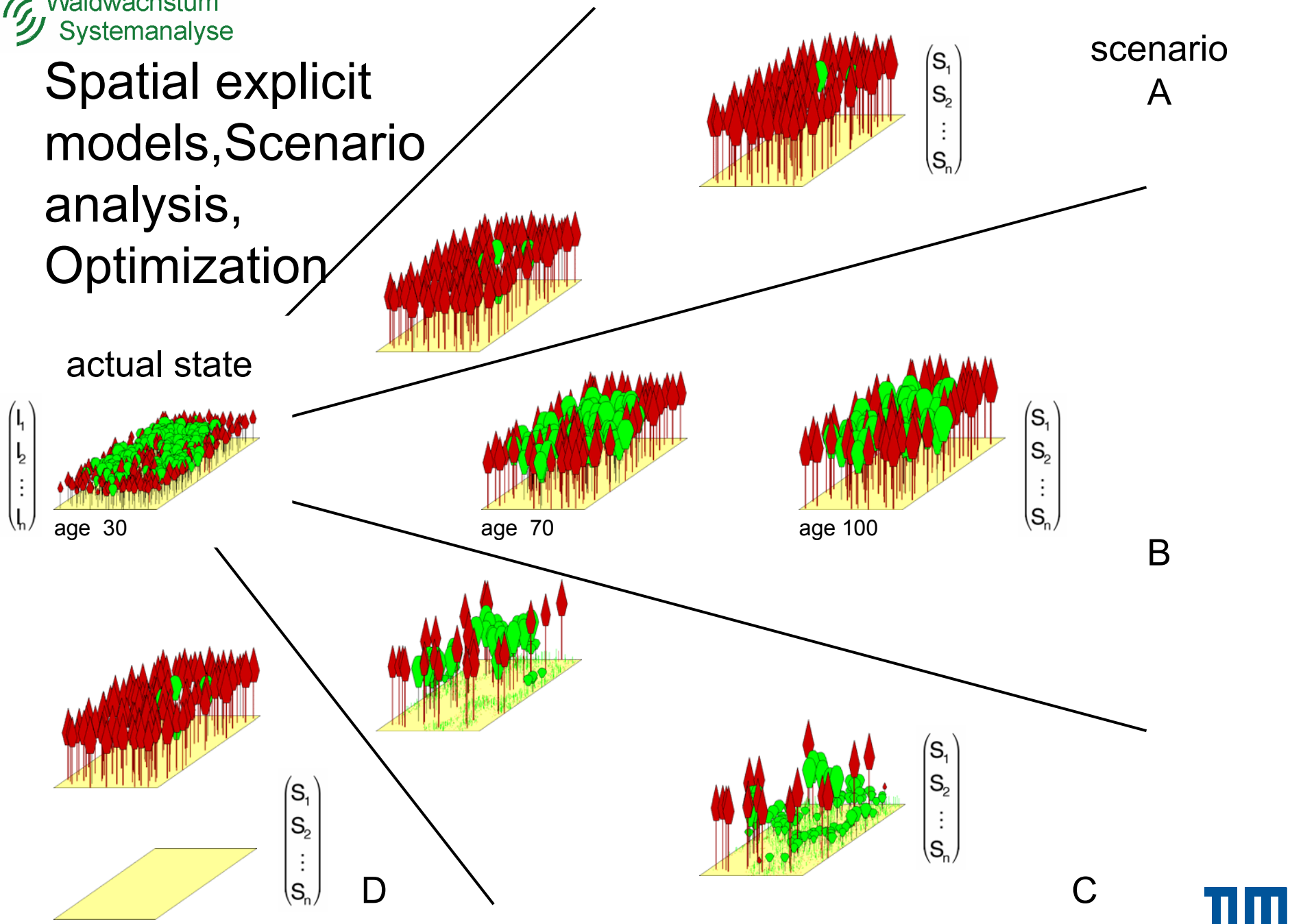
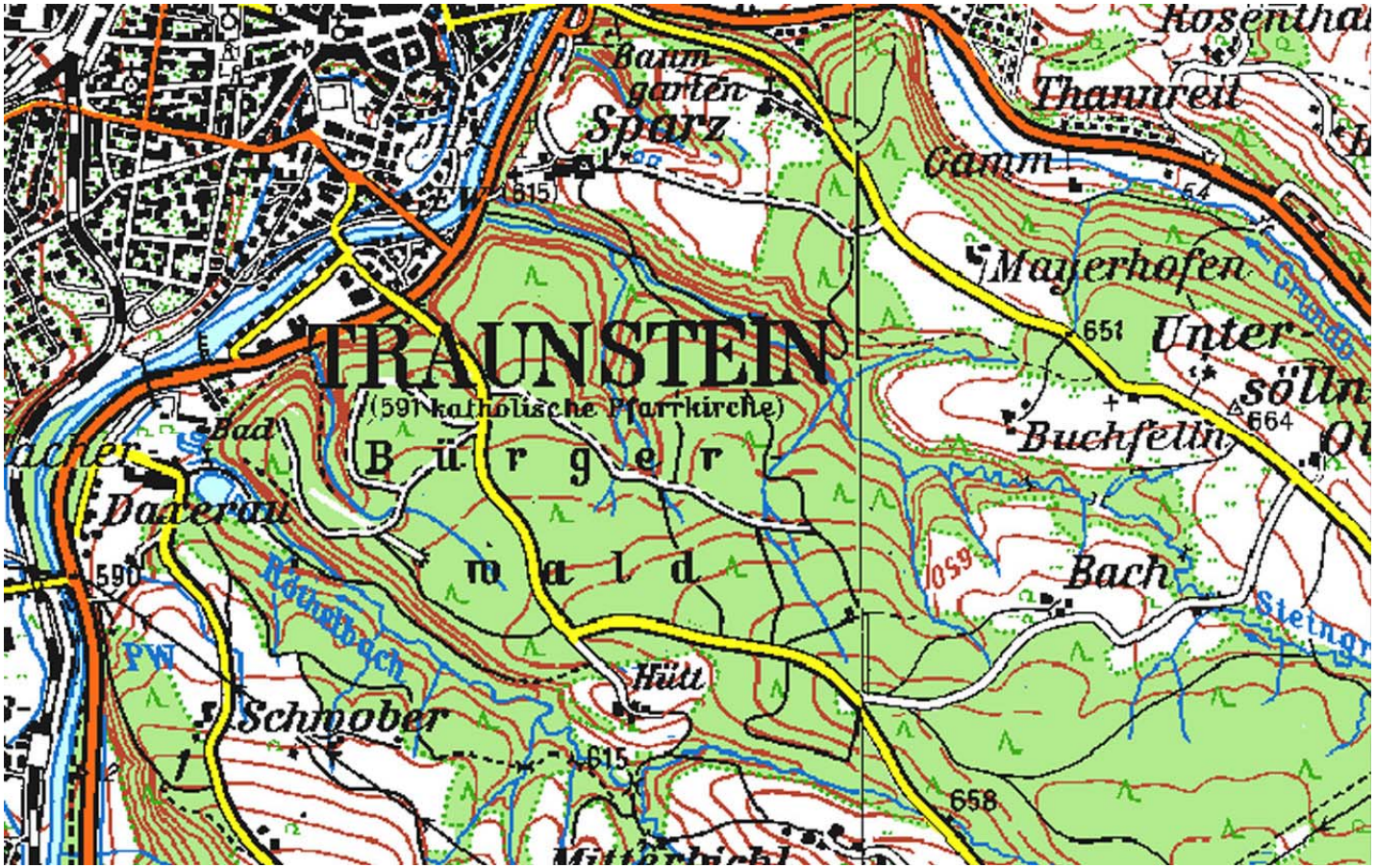
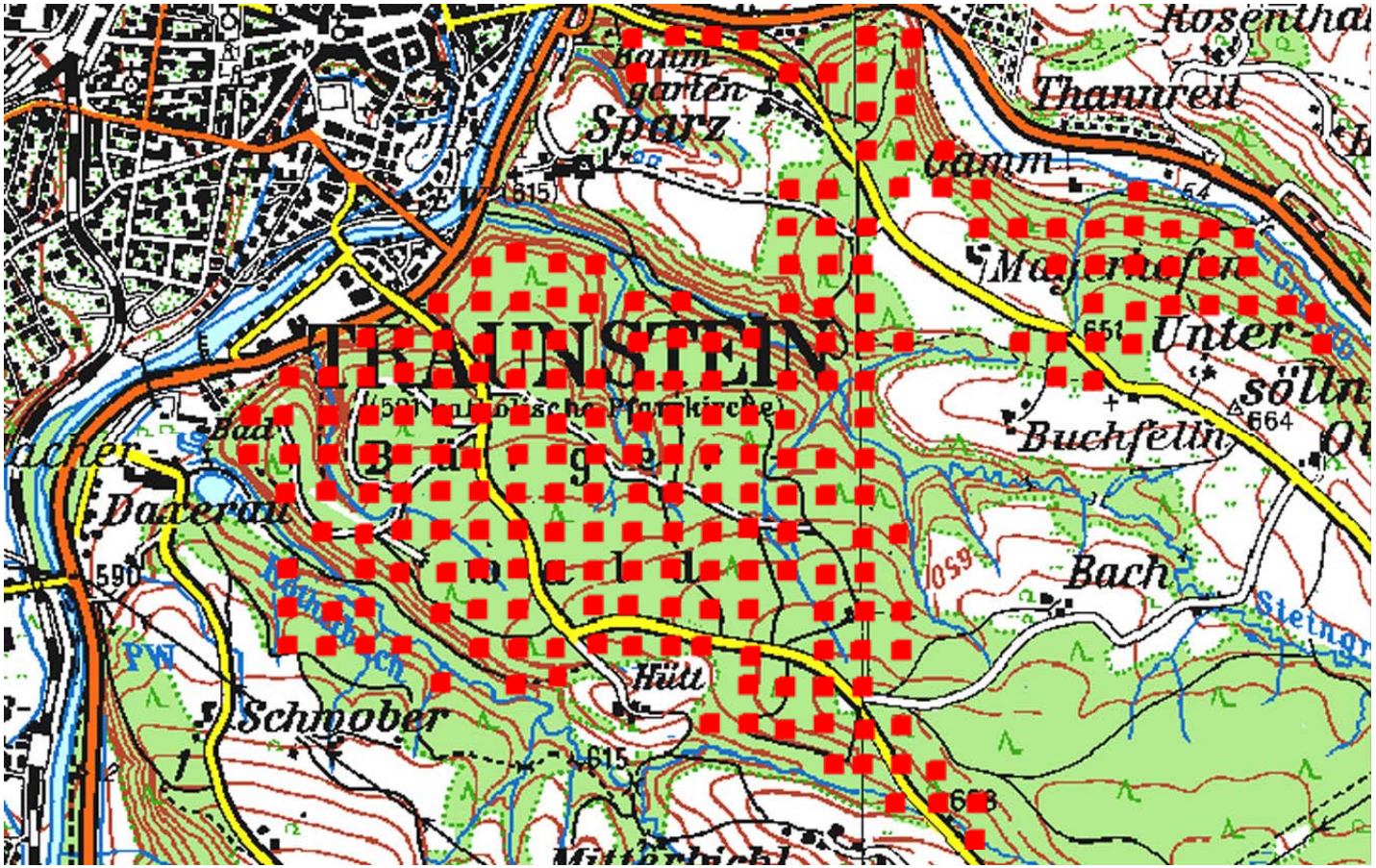
# Spatial explicit models,Scenario analysis, Optimization



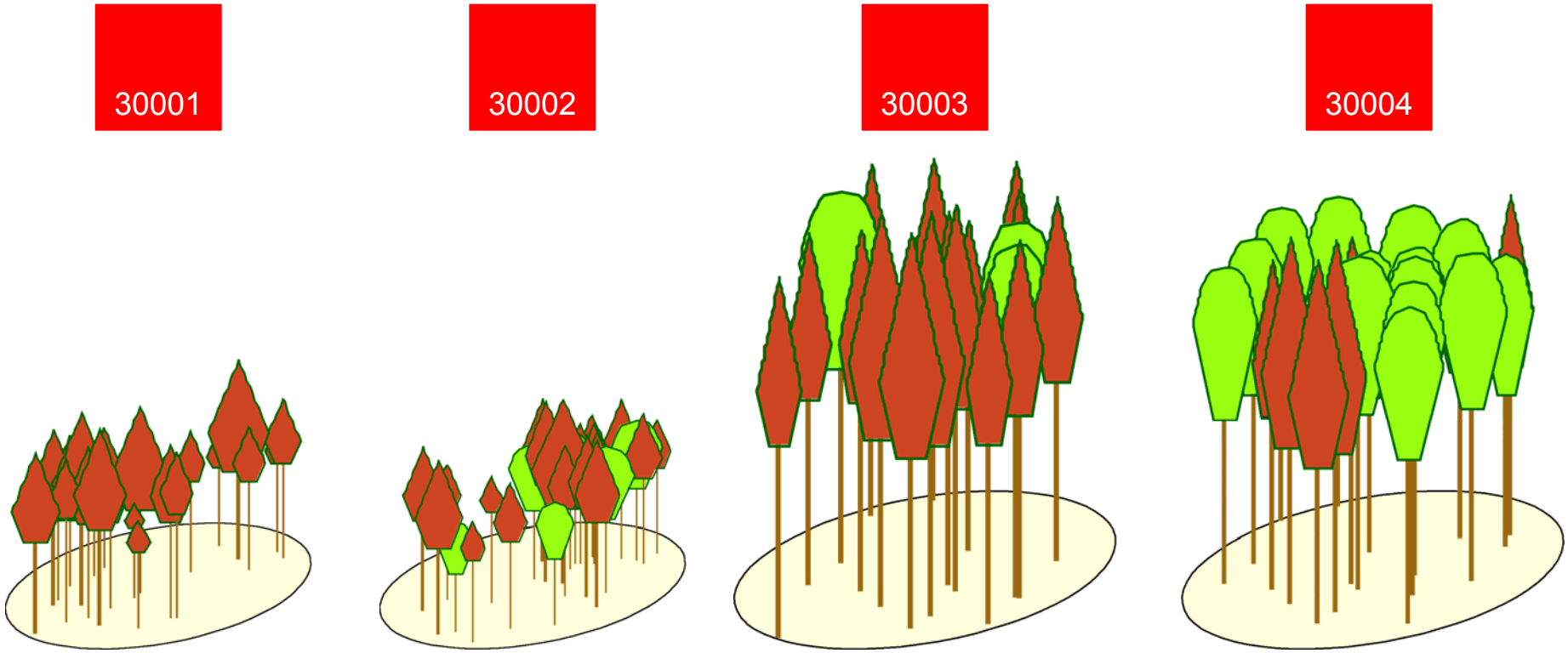
# Scaling from stand to regional level: Municipal forest Traunstein



# Grid of permanent inventory plots in municipal forest Traunstein

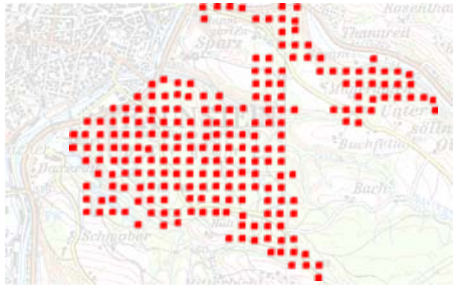


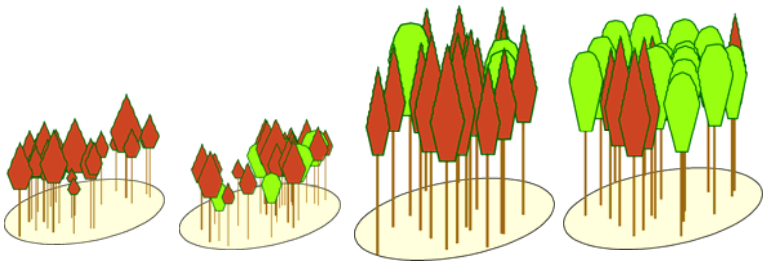
# SILVA 3.0: Inventory plots as base for stratification and model initialization



# SILVA 3.0: Management plans on estate level

(1) Access to inventory Data

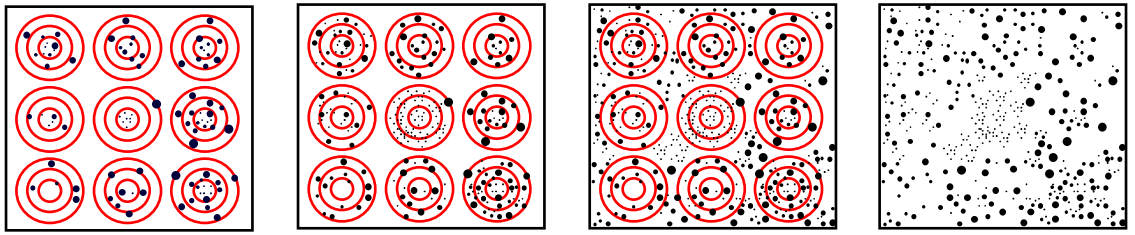




(2) Stratifi-cation

Species - site conditions – growth stage

(3) Generation of simulation units



(4) Assign-ment of silv. treatment

For predefined Dbh- or top height stages:
kind, severity, intensity of th.; final cut
e.g.: n of future trees, degree of release,
threshold diameter, min-max removal $m^3$

# SILVA 3.0: Management plans on estate level

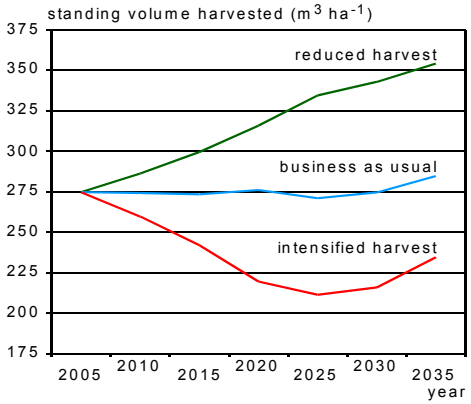
(5) Test of harvesting rules

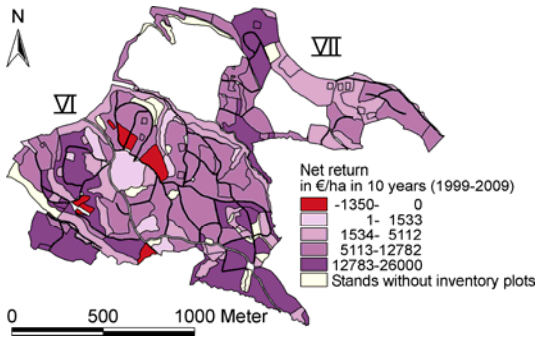
selection of representative strata or estates
comparison projected vs. observed harvest
adjustment of the harvesting rules

(6) Simulation

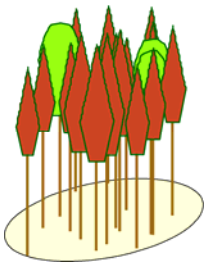
simultaneous on a series of PCs or on a mainframe computer

(7) Visual-ization of results



# SILVA 3.0: Iterative planning and optimization



Inventory- and
Site data

Initialization

Stratification

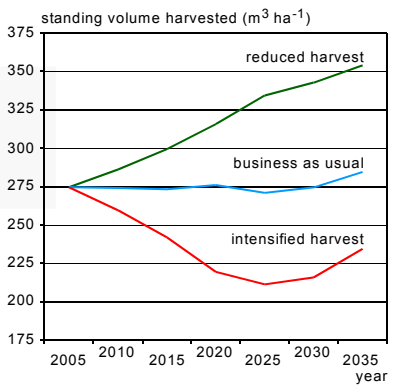
Silv. treatment

Scenario calc.

Synthesis

Enterprise and landscape information

Iterative planning



# SILVA 3.0: Scenario analysis α-, β-, γ- diversity

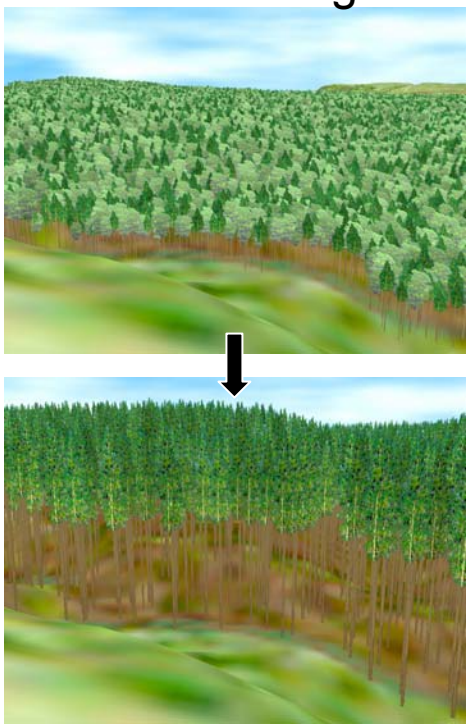
no active mgt.

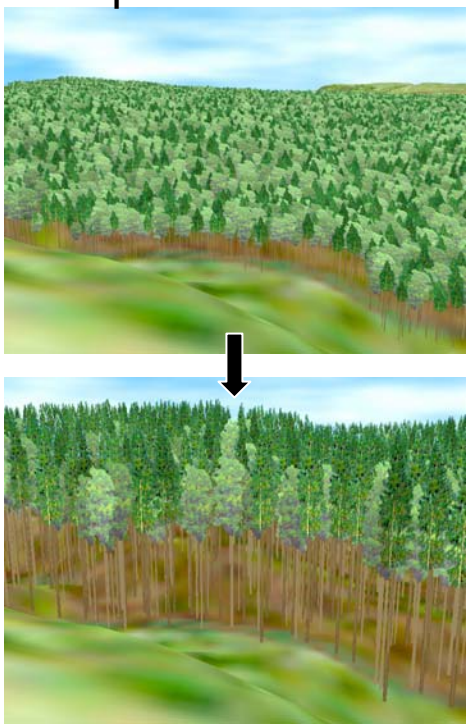
mod. promotion beech

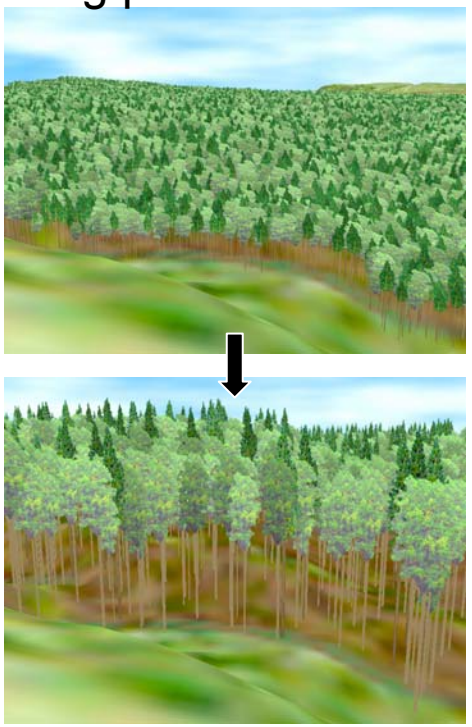
strong promotion beech

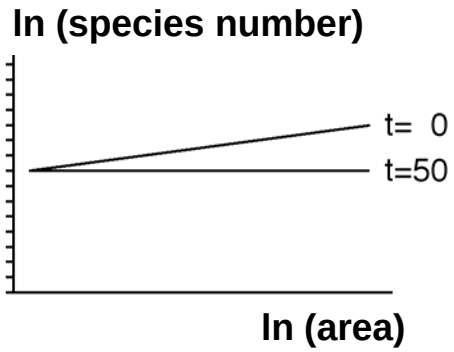
t= 0

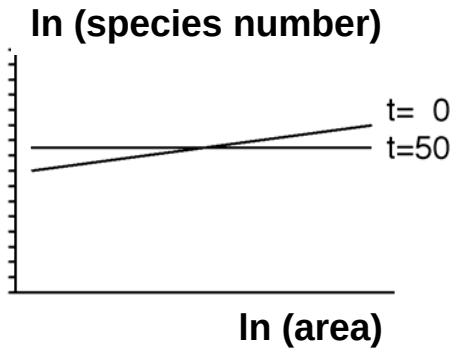
t=50

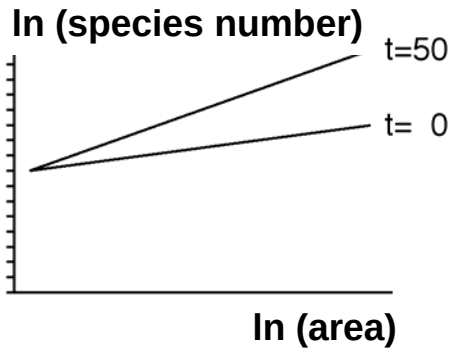








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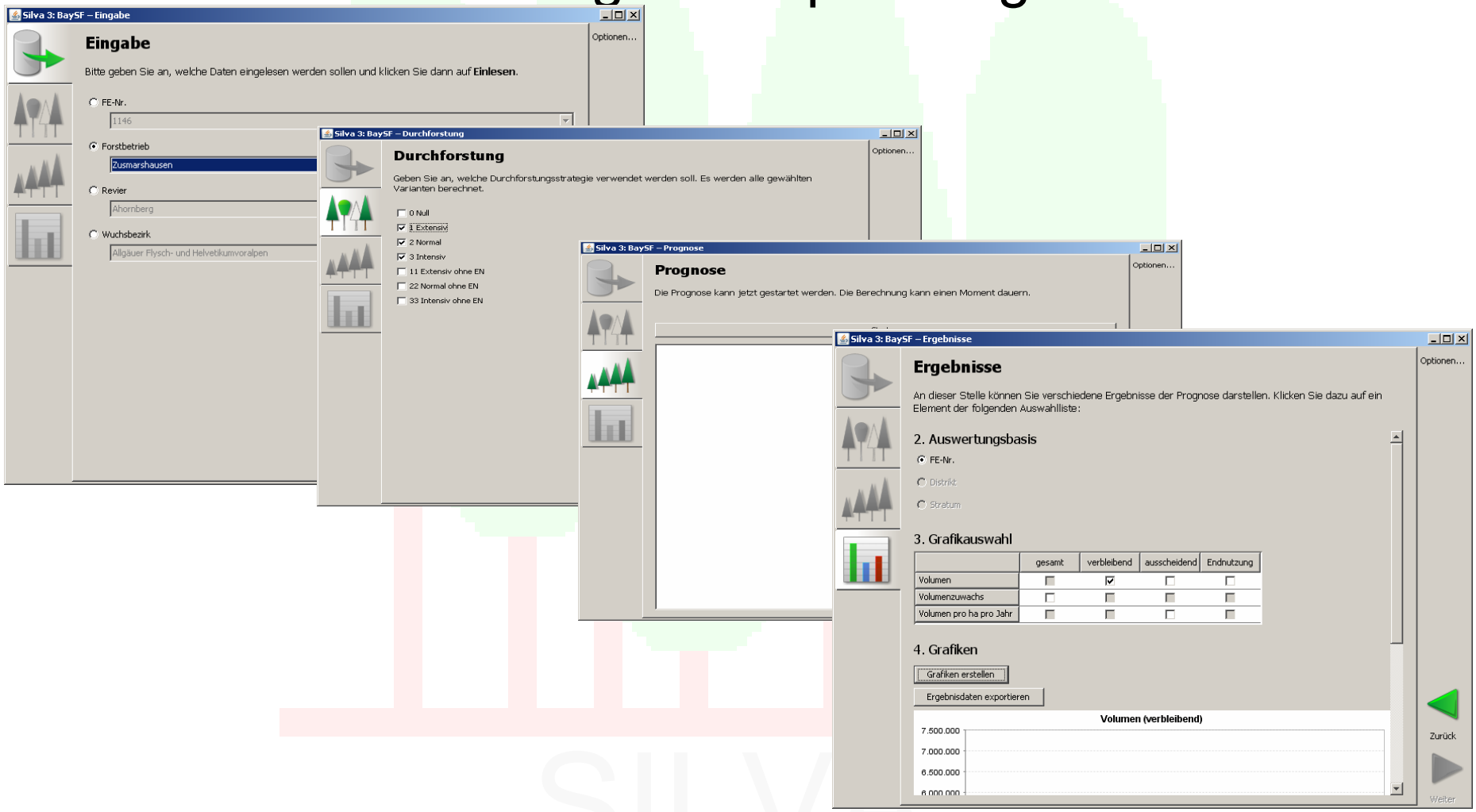
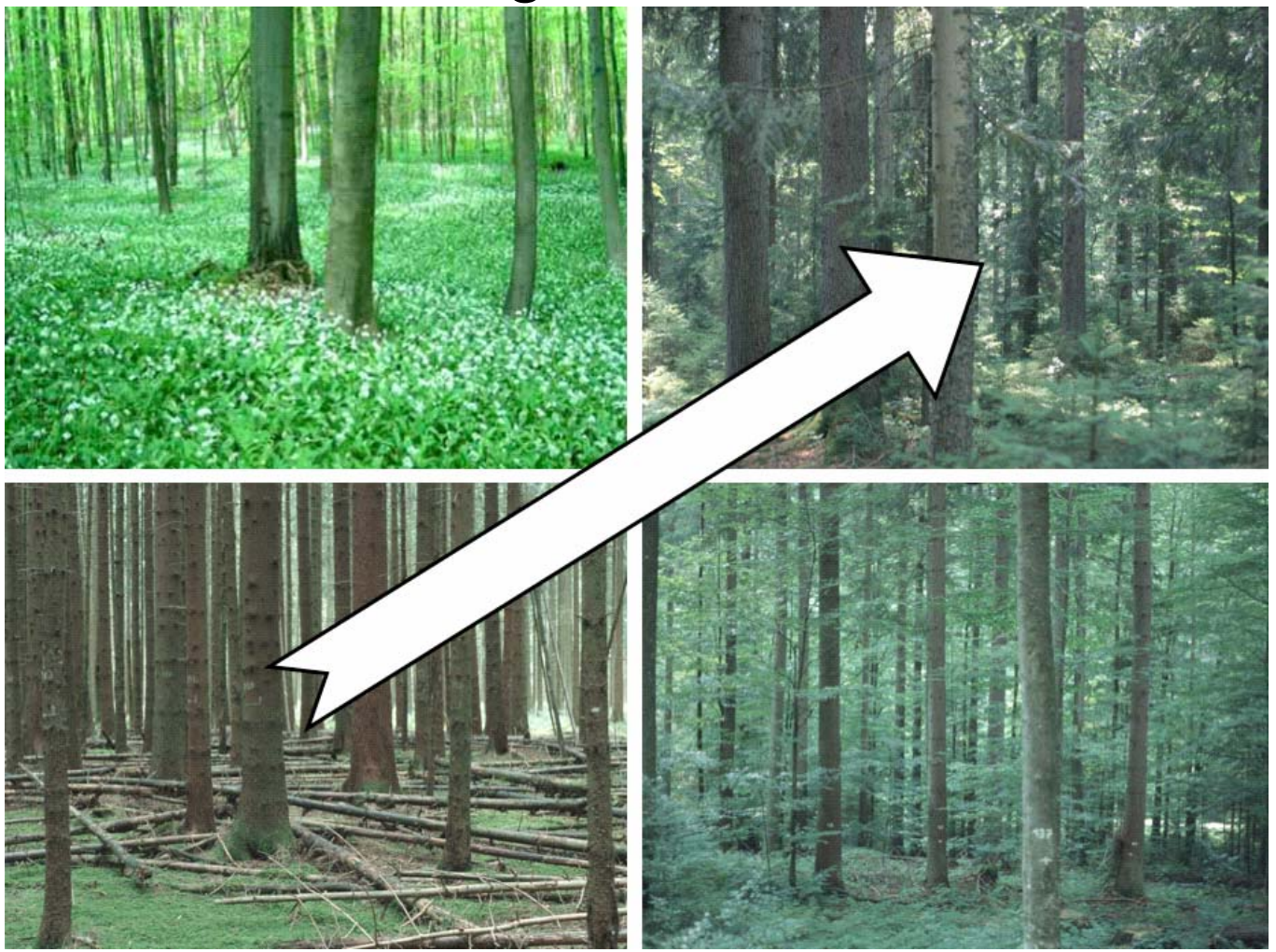
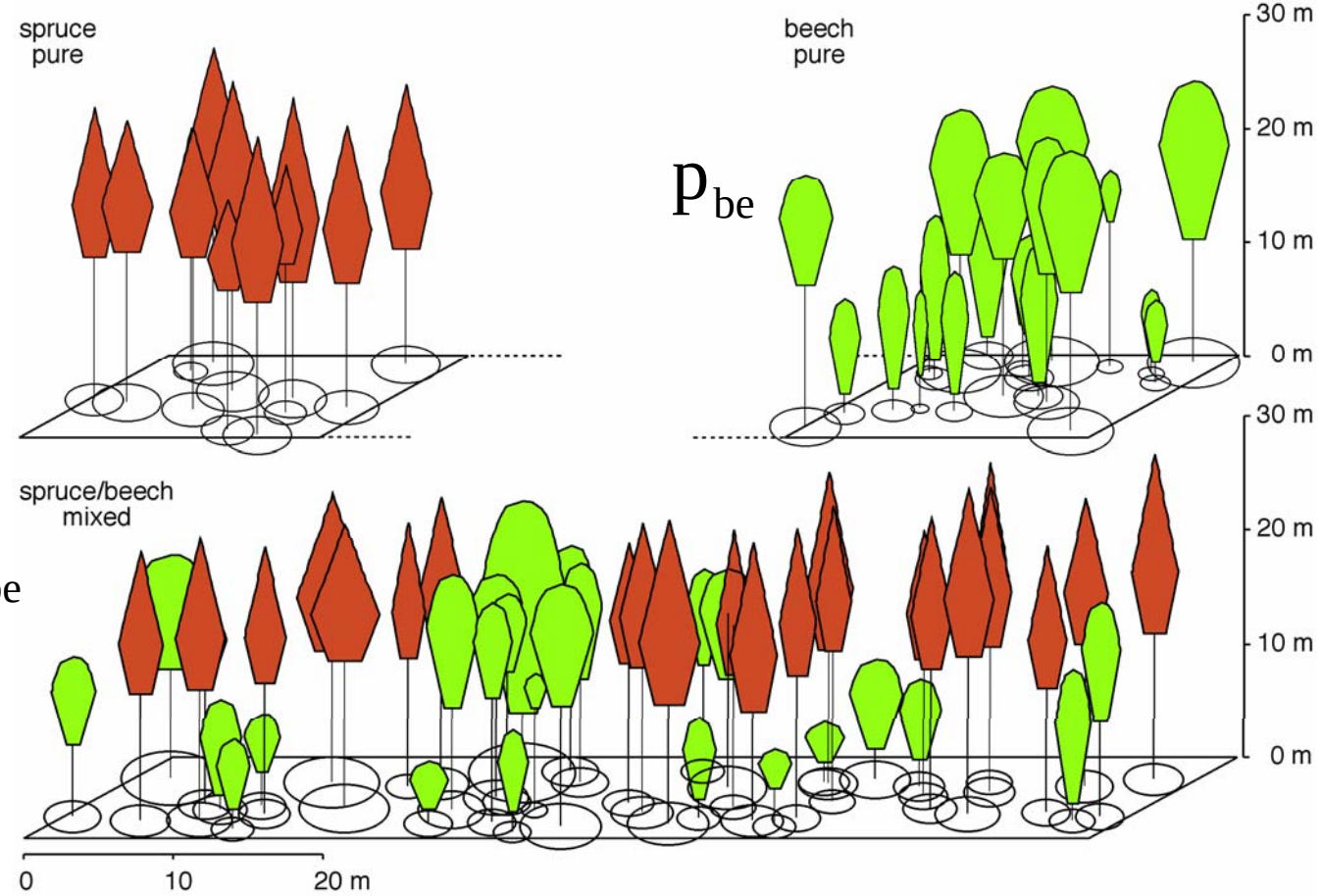
# SILVA 3.0-BaySF for routine application for management planning



# Mixed stand research: Transition to heterogeneous stands



# Quantification of mixing effects on stand level
# Zwiesel 111/3,4,5 Bavarian Forest




$p_{sp}$

$p_{be}$

$p_{sp,be}$

$m_{sp}$

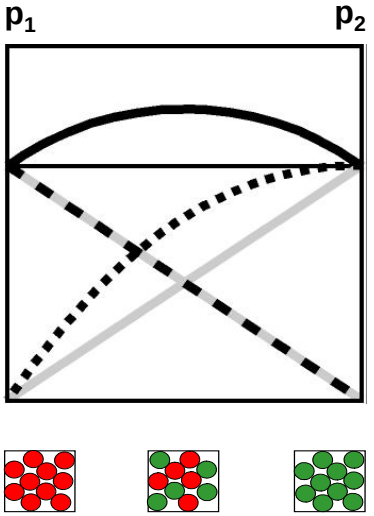
$m_{be}$

$$\hat{p}_{sp,be} = p_{sp}\, m_{sp} + p_{be}\, m_{be}$$

Pretzsch (2008) Forest Dynamics, Growth and Yield, Springer, 653 p.

# Mixed stand reserach: over-/underyielding of volume growth in mixed versus pure stands

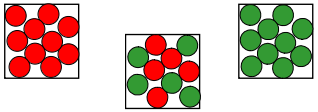
spruce/beech [1, 2, 3)]: –20 to +40%
pine/beech [4, 5, 6)]: –30 to +40%
larch/spruce [7)]: +2 to + 28 %
spruce/fir [8)]: –10 to + 10 %
pine/spruce/birch [9, 10, 11)]: - 10 to + 15 %
Eucalypt/Acacia[12)]: +30 to + 50 %

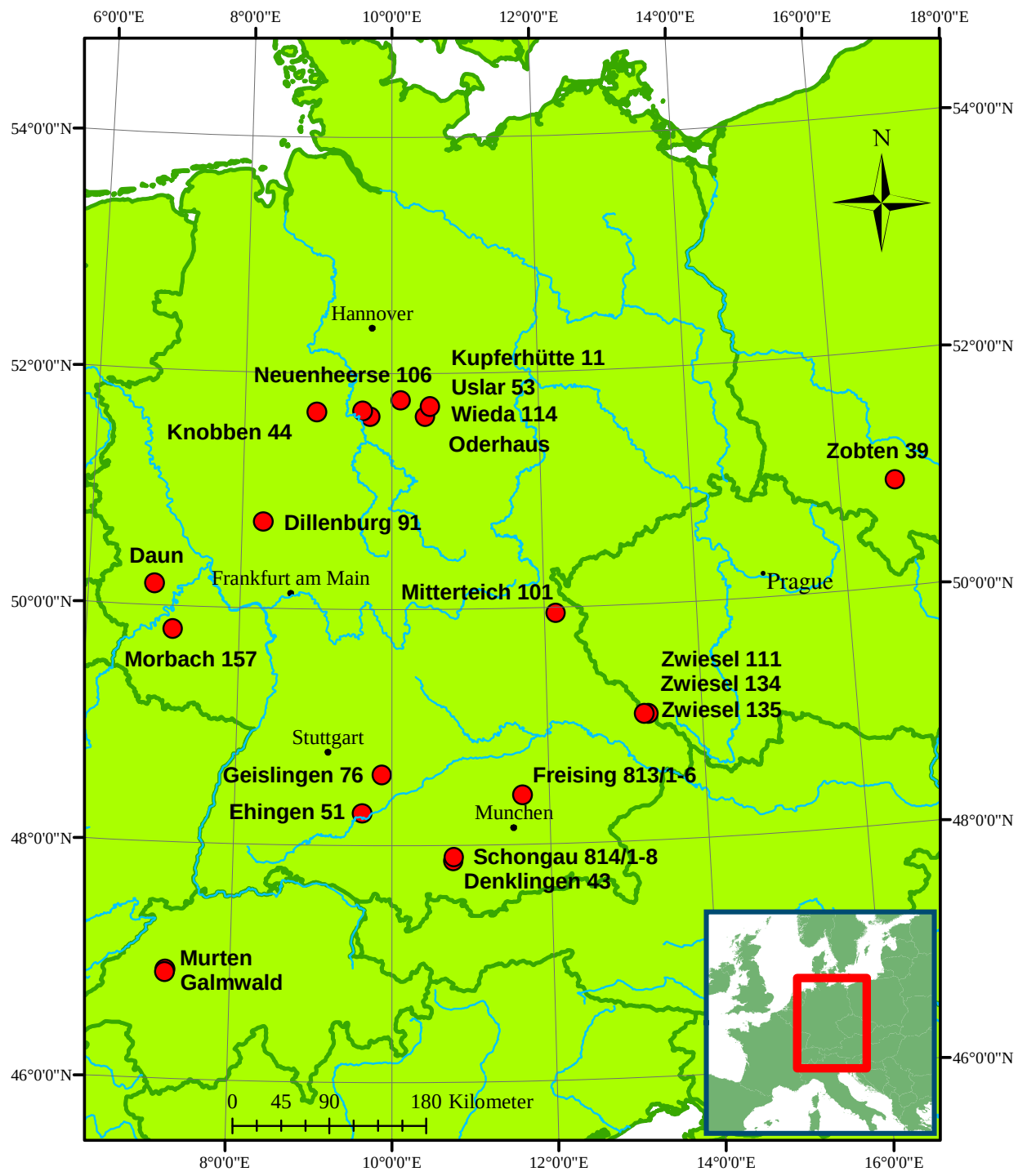



European forest (low niche different.): - 30 to + 40 %
grasland: + 30 to + 50 %

[1)] Kennel (1965), [2)] Pretzsch (1992, 2008, 2010), [3)] Wiedemann (1942, 1943), [4)] Bonnemann (1939), [5)] Dittmar et al. (1986), [6)] Knapp (1991), [7)] Zöhrer (1969), [8)] Jensen (1983), [9)] Mielikainen (1980, 1985), [10)] Frivold and Kolström (1999), [11)] Frivold and Frank (2002), [12)] DeBell et al. (1989)

# Transect study of Norway spruce/ European beech






24 experiments
52 triples
207 surveys

from:1895
to: 2009

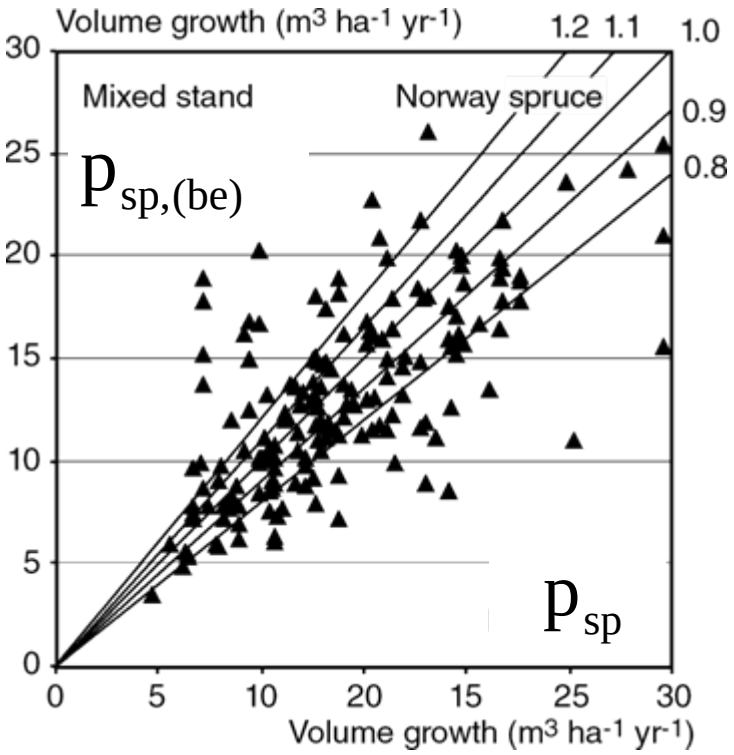
from: moist, acid sites
to: dry, alkaline sites

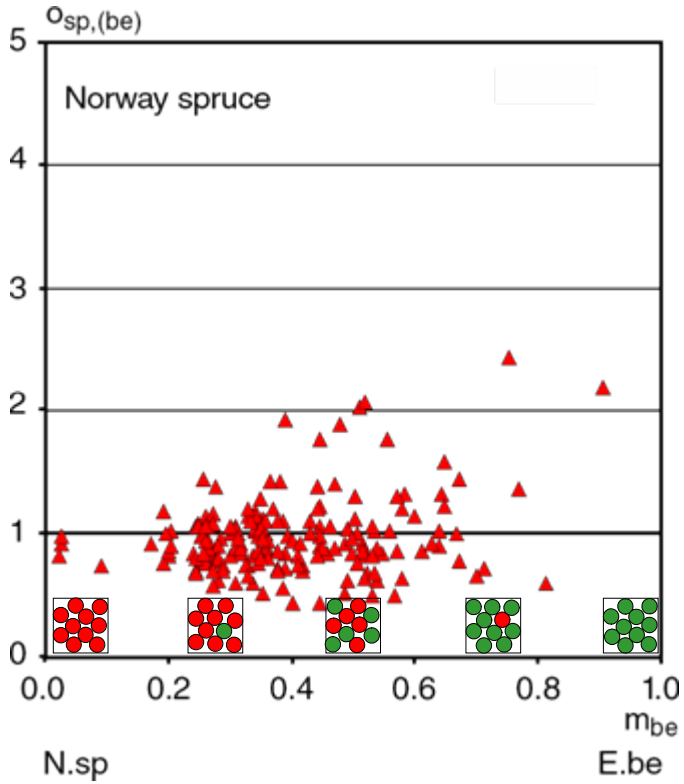
from $m_{sp}$:$m_{be}$: 0.05:0.95

to $m_{sp}$:$m_{be}$: 0.95:0.05

unthinned-moderately th.

# Gain and loss of Norway spruce in mixture with European beech

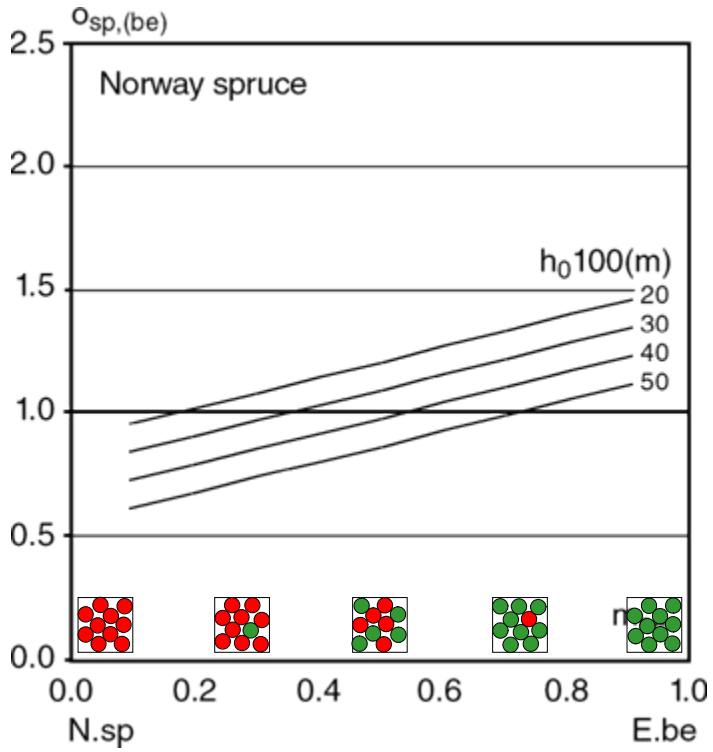


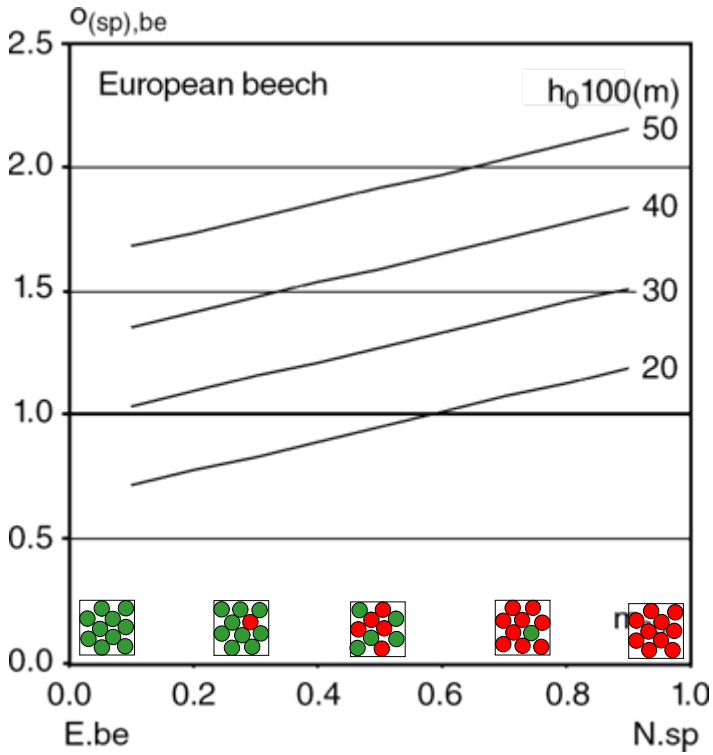




**volume growth in $m^3\ ha^{-1}\ yr^{-1}$**
**mean: - 0.94 $m^3\ ha^{-1}\ yr^{-1}$**
**min: - 16.81 $m^3\ ha^{-1}\ yr^{-1}$**
**max: + 13.11 $m^3\ ha^{-1}\ yr^{-1}$**

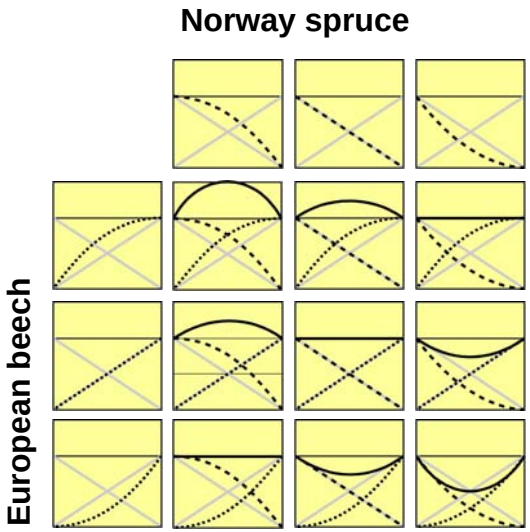
**over- / underyielding**
**mean: 1.01**
**min: 0.43**
**max: 2.41**

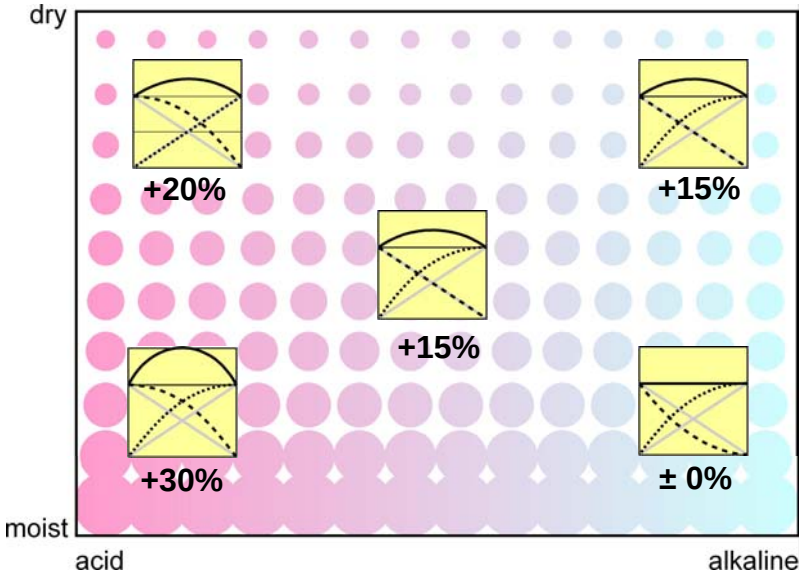
# Over-/underyielding of Norway spruce and European beech depending on site conditions



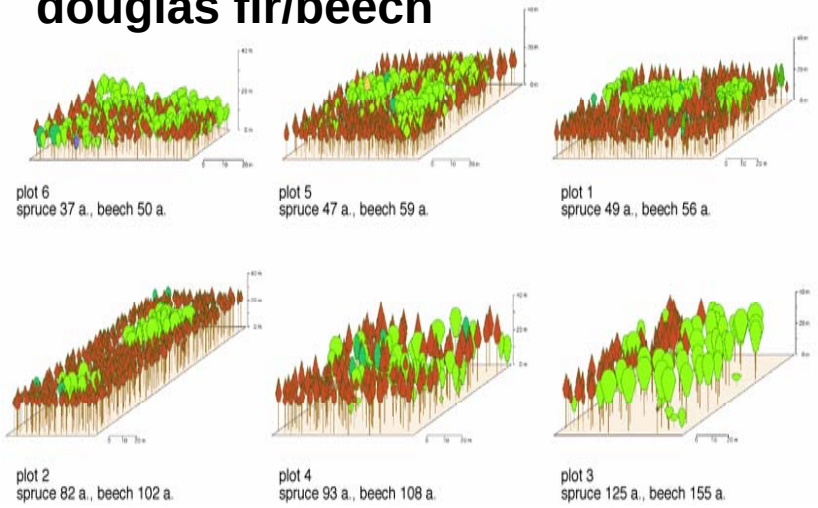
# Conclusions: Understanding site-specific mixing reactions of N. spruce and E. beech

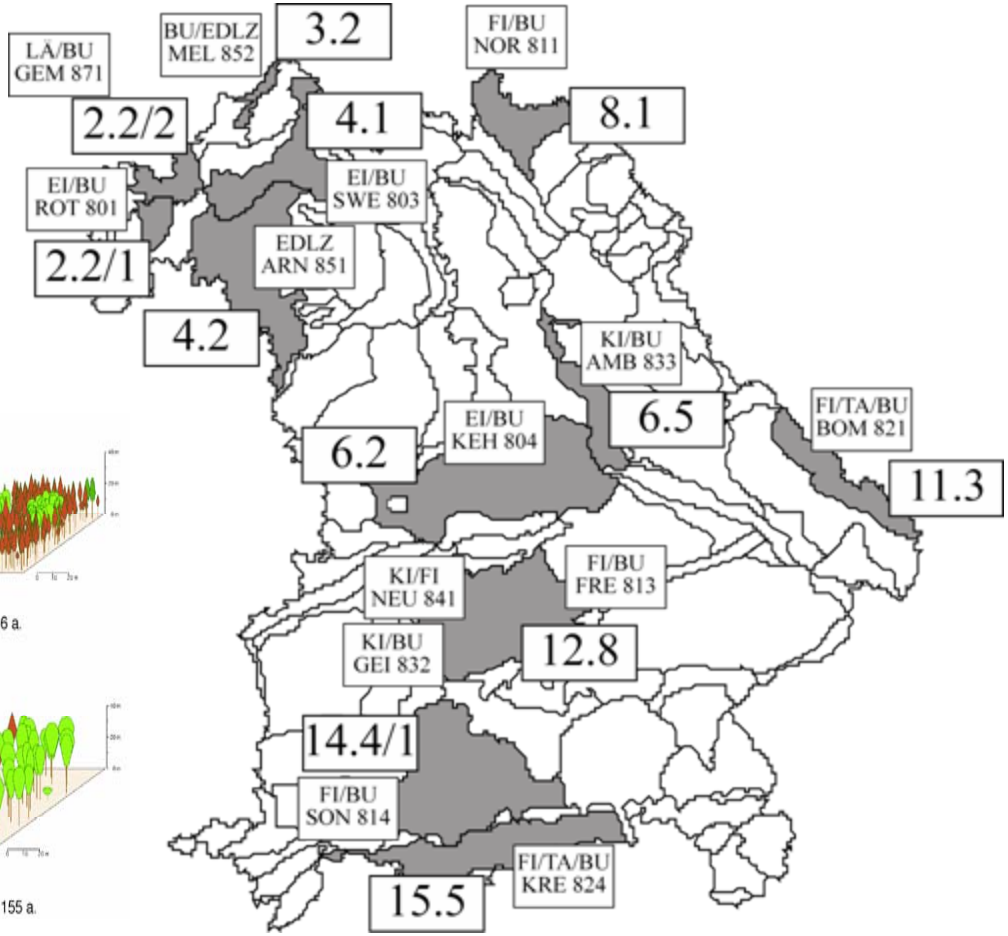


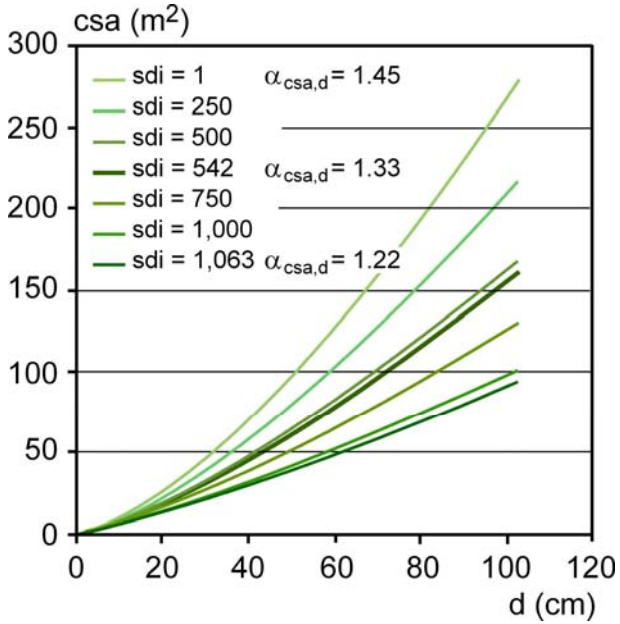
# New data source for mixed stand research: 14 artificial time series with 80 plots

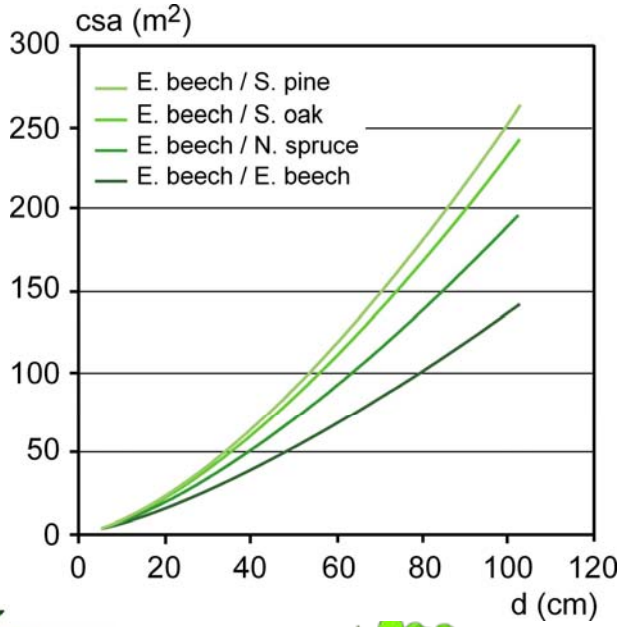
**spruce/beech**
**spruce/pine**
**beech/oak**
**spruce/fir/beech**
**ash/maple**
**larch/beech**
**douglas fir/beech**

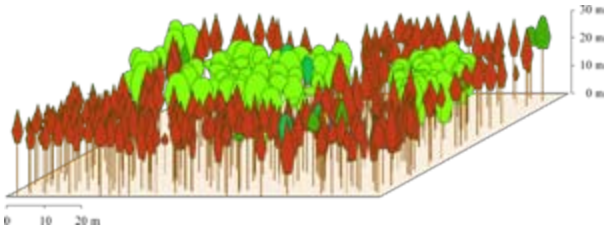


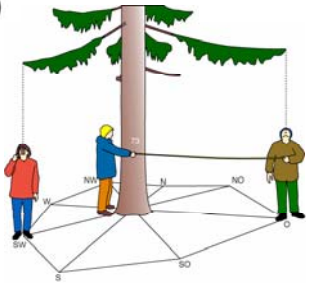



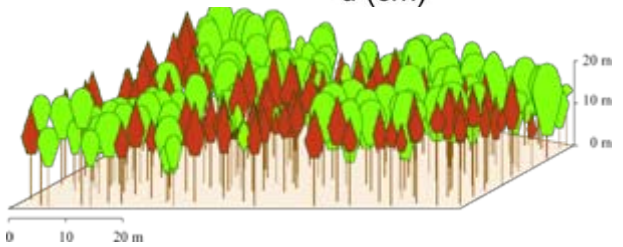
# Crown plasticity of European beech in pure and mixed species stands



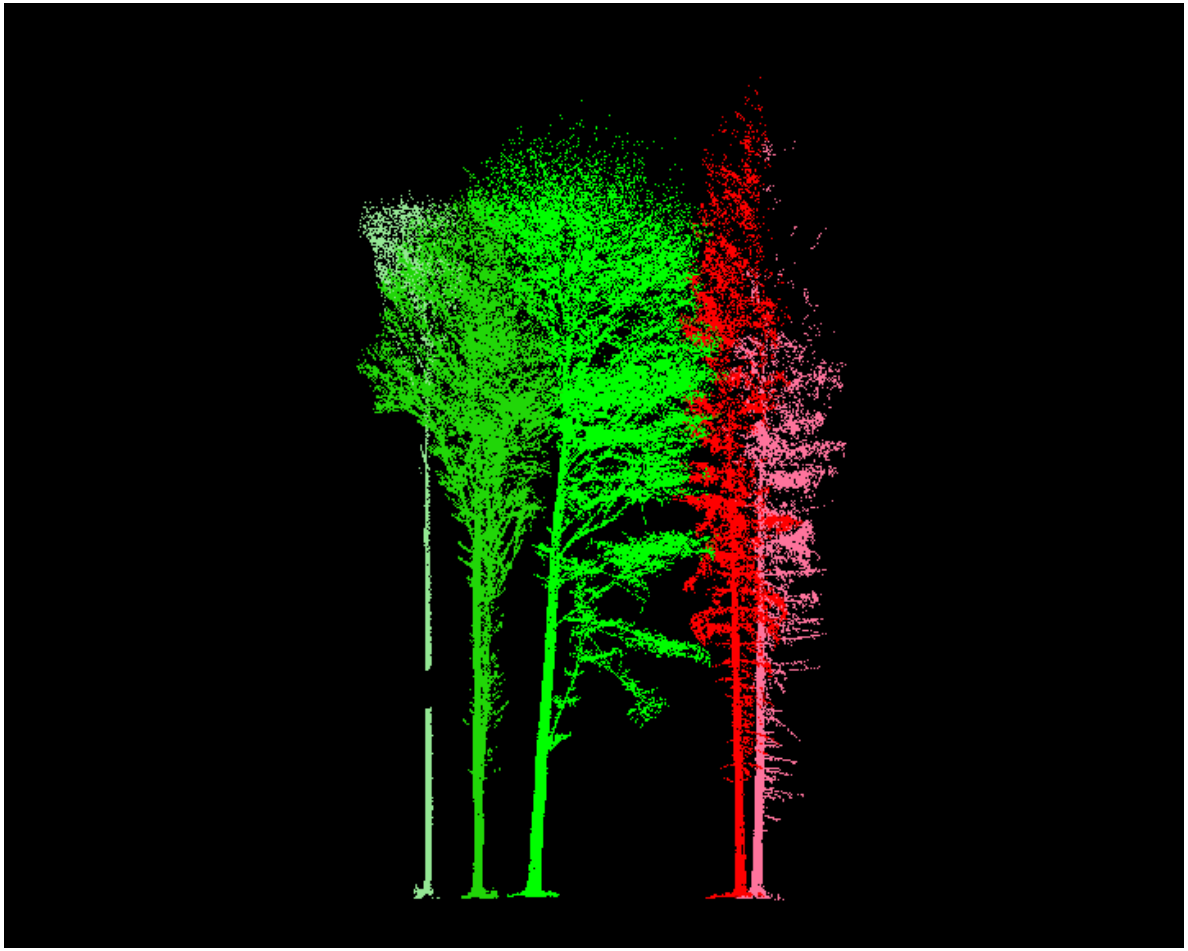





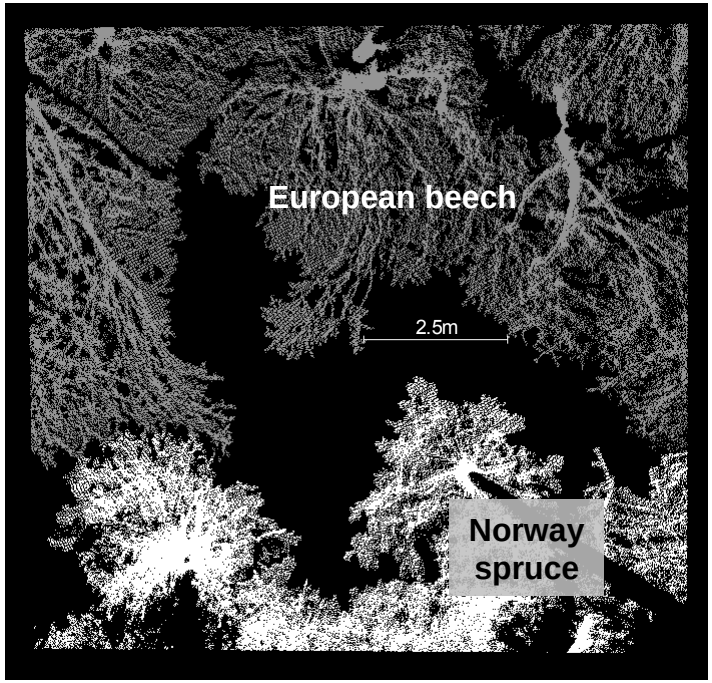


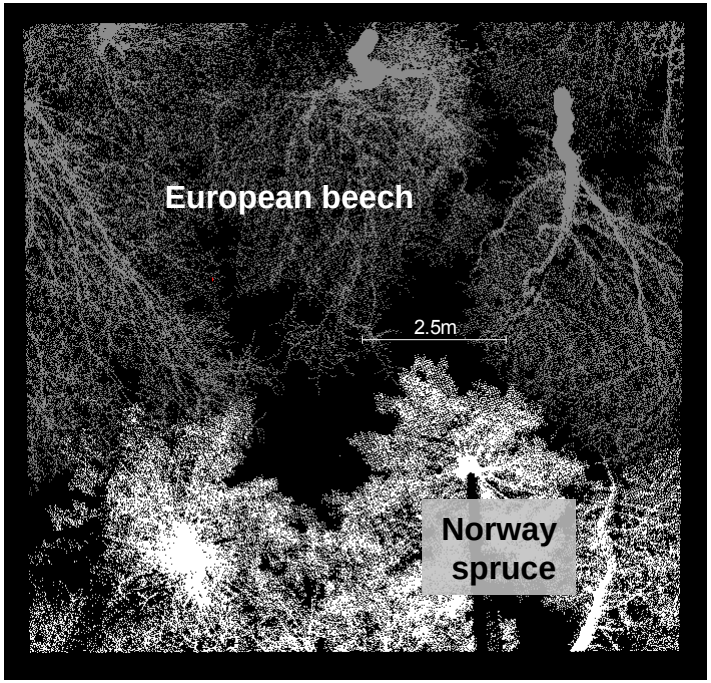
Data base: 88 experiments, 147 plots, 182 surveys, 4035 beeches, 1977 be-be, 66 be solitary, 1020 be-oak, 833 be-sp, 139 be-pi

# TLidar for measuring crown morphology and space occupation in complex stands

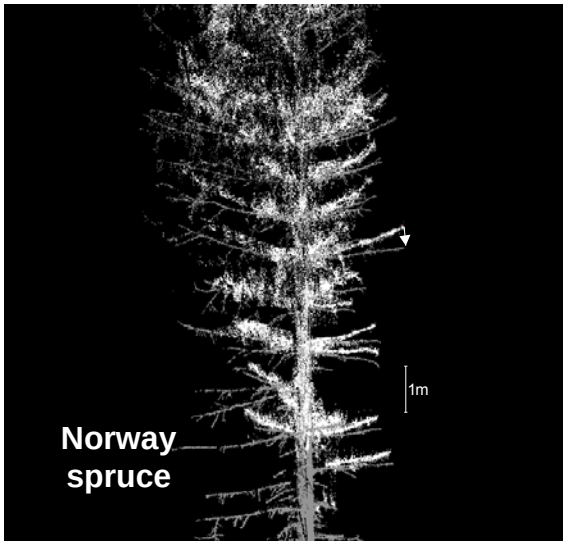


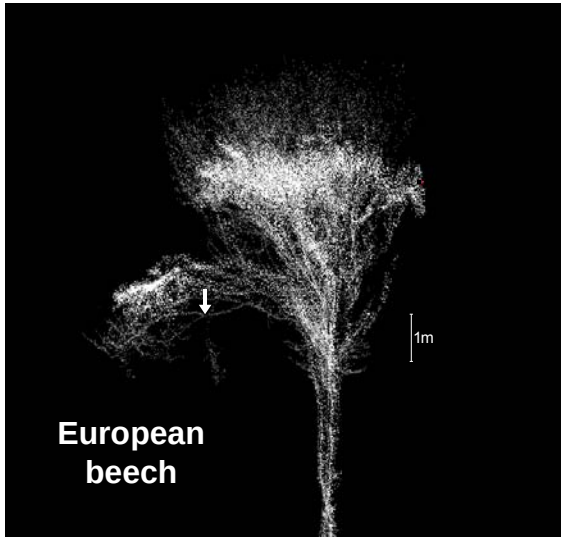
# Mixed stand research: Gap filling by Norway spruce and European beech from 2006-2010

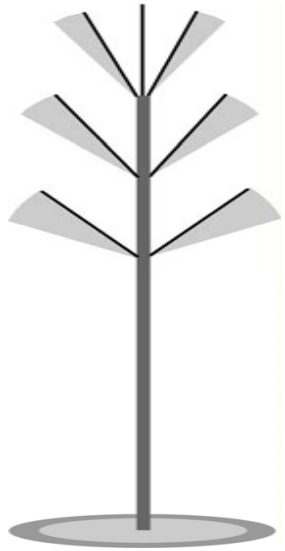


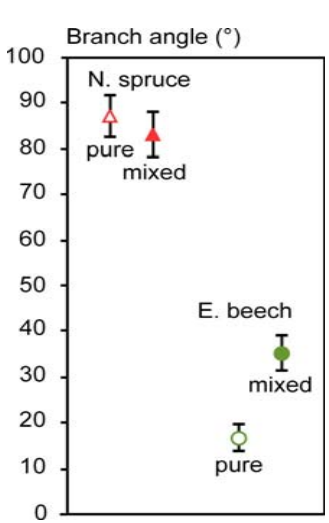



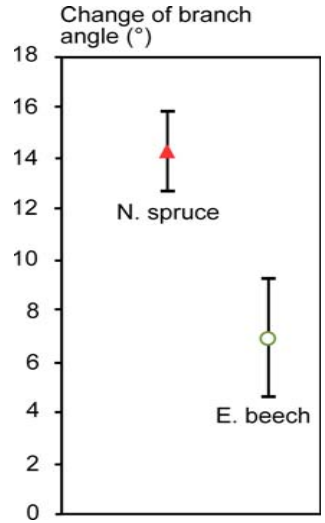
# Mixed stand research: Branches 2006-2010

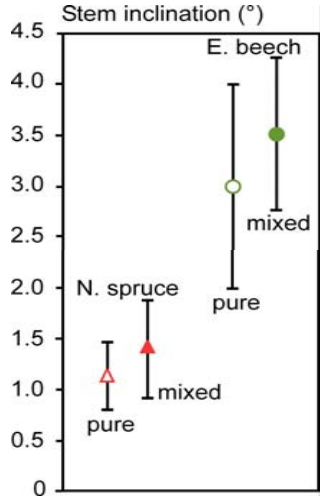


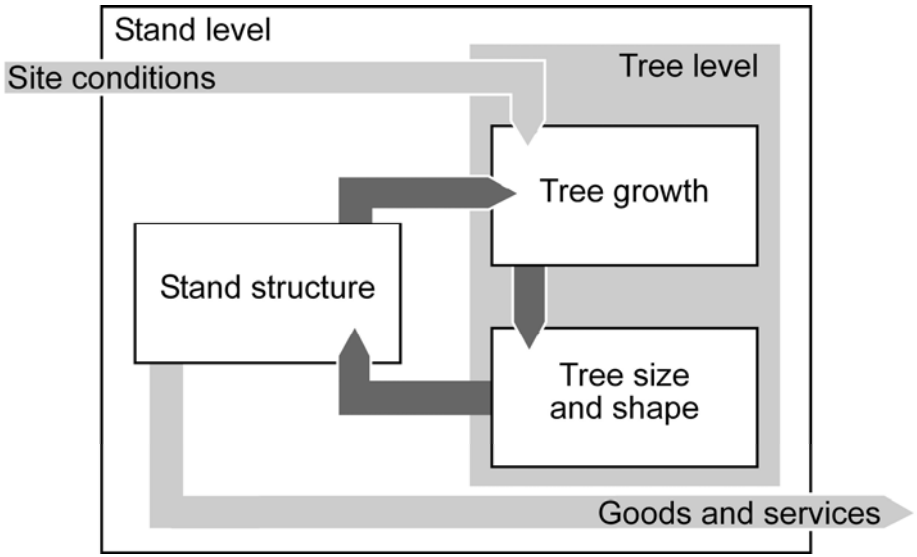



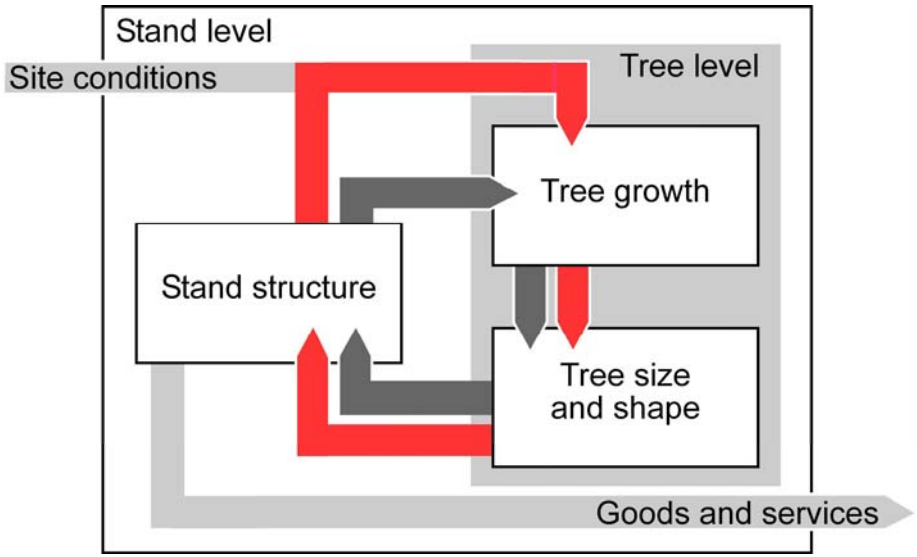


# Conclusions: Mixed stand research for model improvement

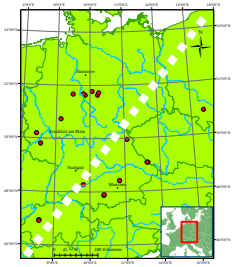


# Perspectives and lines of cooperation

Site conditions as modifier of growth, thinning effects, mixing effects, stability

→ transect studies along ecological gradients



4D character of forest stands and the effect on, e. g., diversity, mixing effects, wood quality

→ Lidar, CT scanning, spatially explicit models

Theory, models, new experimental set-ups, combination of experimental and inventory data

→ theories: holobiont, stress gradient, optimal partitioning, allometry