Linking
Forest Stand and Enterprise Level Optimisation

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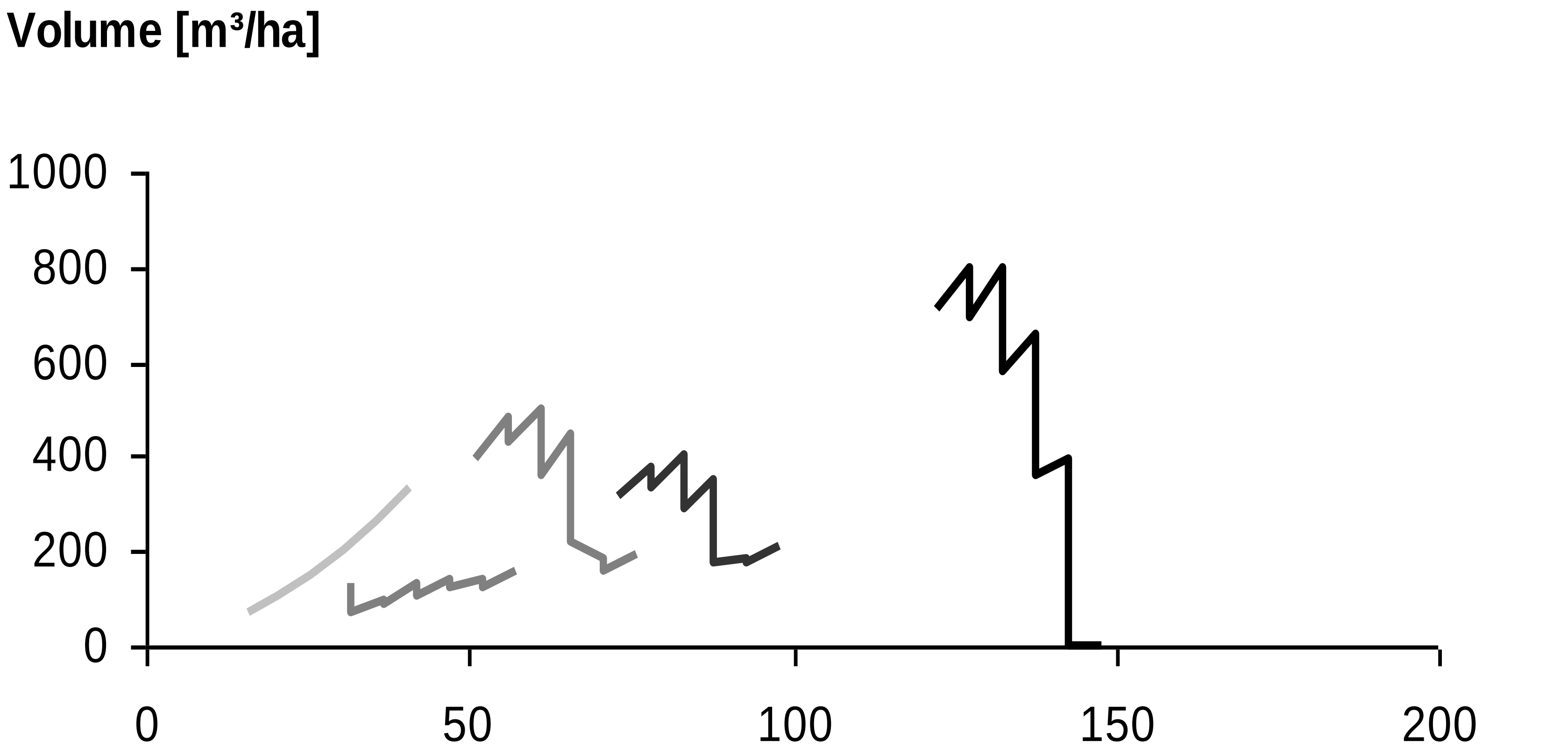
Hypothesis

By implementing stand treatment alternatives on an enterprise level there will be no gain in flexibility.

Optimal Thinning Strategies



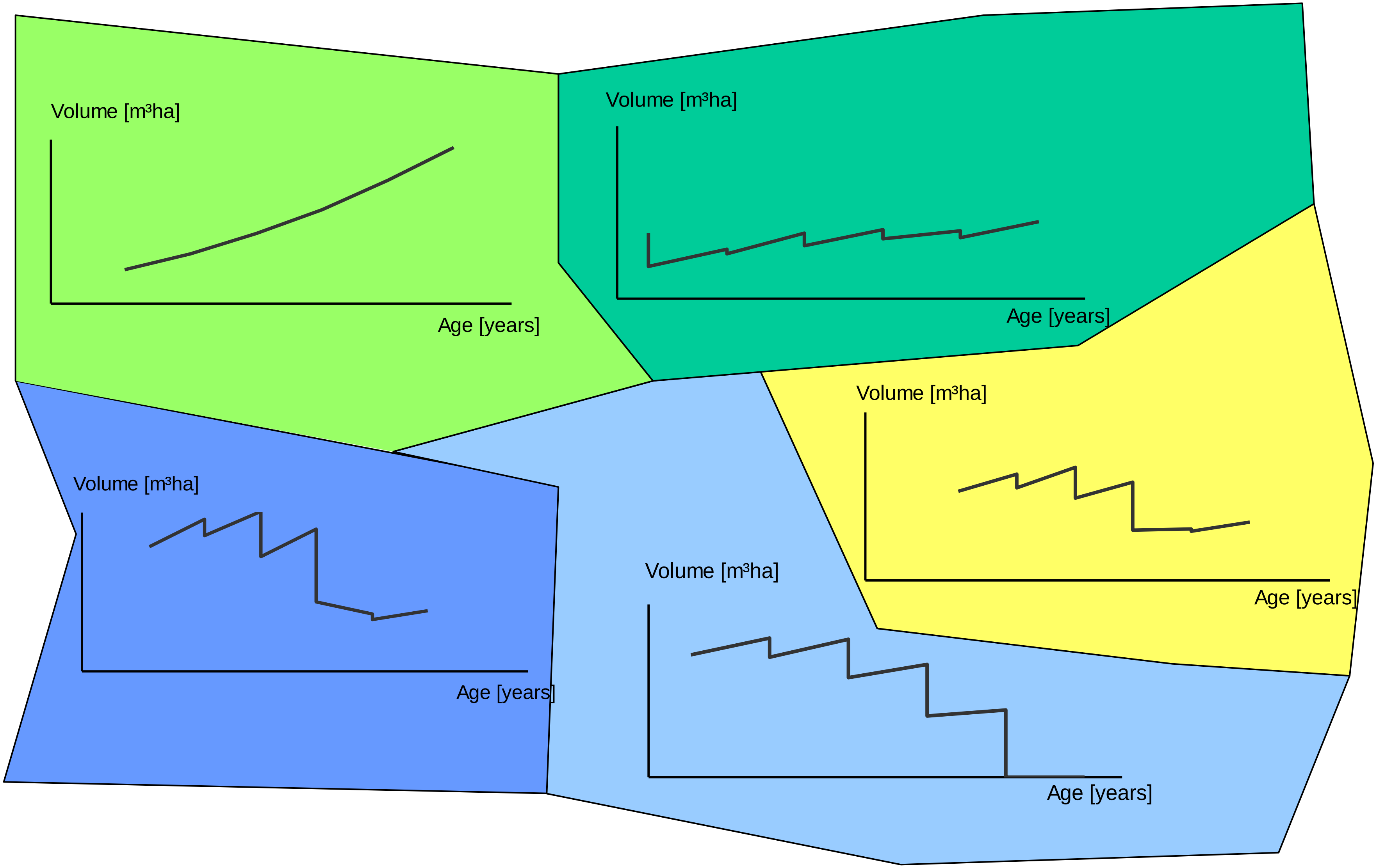
Mixed beech stand, 2% interest rate

Enterprise Level Optimisation

simultaneous multiperiod allocation problem

- Linear Programming
- Constraints
- Implementation

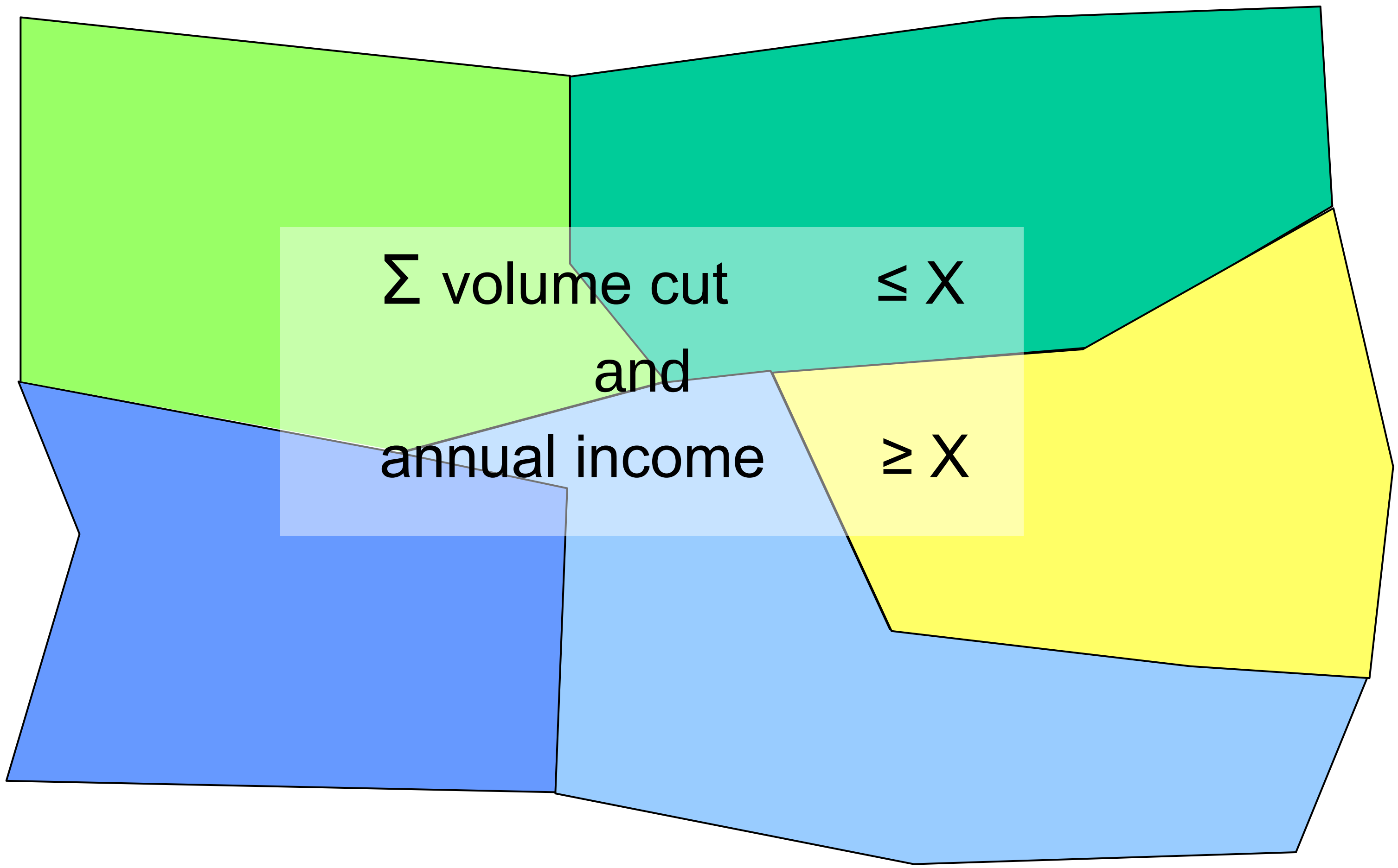
Summed stand treatments



Types of Constraints

Biophysical	Financial
Maximum volume cut	Minimum yearly earnings
Minimum standing volume/inventory	Minimum value at end of time horizon

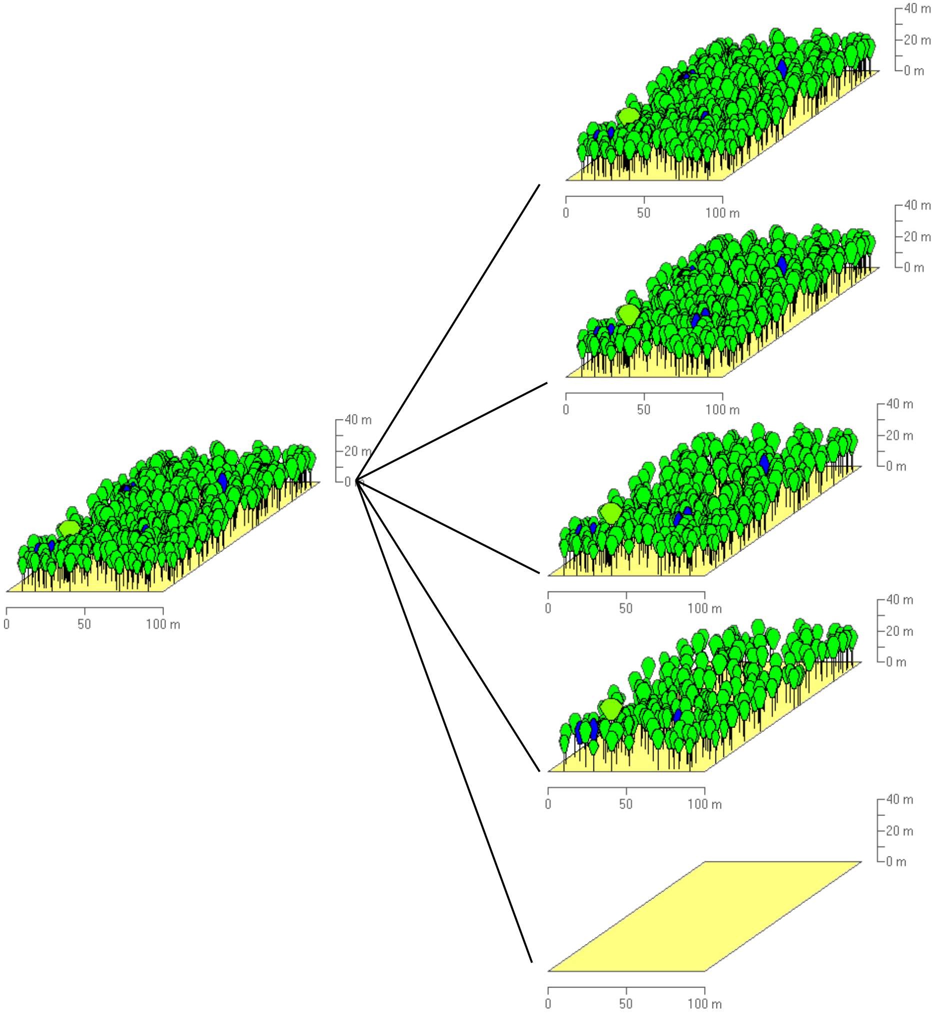
Adding Constraints



Linking Forest Stand and Enterprise

- Choosing treatment alternatives
- Allowing choice within a forest enterprise framework

Thinning alternatives



0: No Thinning

1: Cutting 10%

2: Cutting 25%

3: Cutting 50%

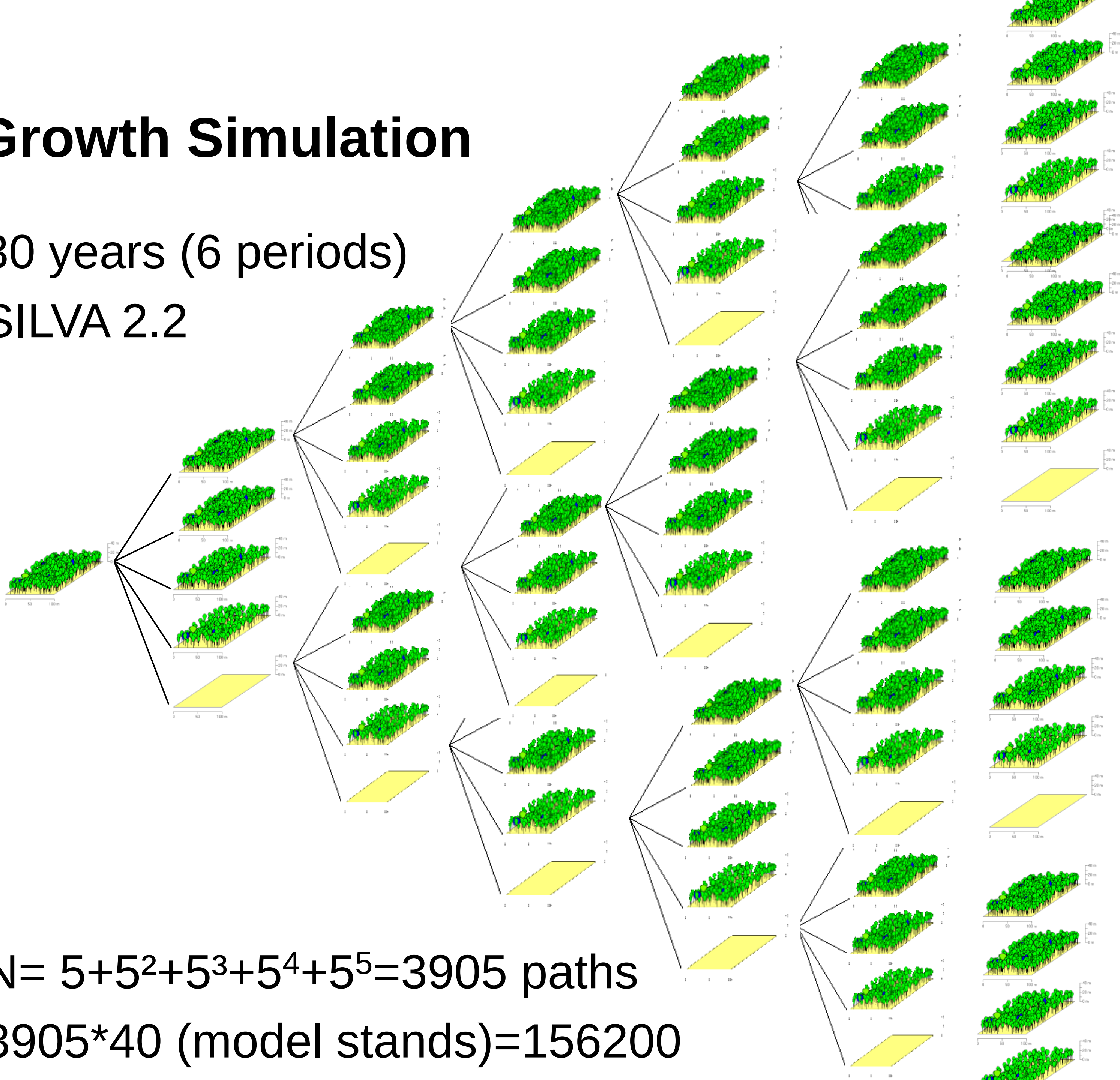
4: Total Harvest

Linked to basal area/ha

Growth Simulation

30 years (6 periods)

SILVA 2.2



N= $5+5^2+5^3+5^4+5^5=3905$ paths

3905*40 (model stands)=156200

Fitting to a Linear Programming Solution

- limiting number of treatment alternatives to
  - no thinning
  - regular light thinning
  - regular medium thinning
  - regular heavy thinning
  - alternating light and medium thinning
  - alternating medium and heavy thinning
  - decreasing thinning intensity with pauses

  & optimal treatment if not part of upper alternatives

- chosen treatments alternatives have to be followed
- adding constraints on enterprise level

Solution with LINDO's What's*best!* Software

Formula

$$FM_{opt} = \max \sum_{s=1}^{40} \sum_{\substack{i=1 \\ v \in \{0,4\}}}^{5} \sum_{tr=1}^{8} TH_{i,s,v,tr} \cdot q^{-5i} \cdot a_{i,s,tr} \cdot \lambda_i$$

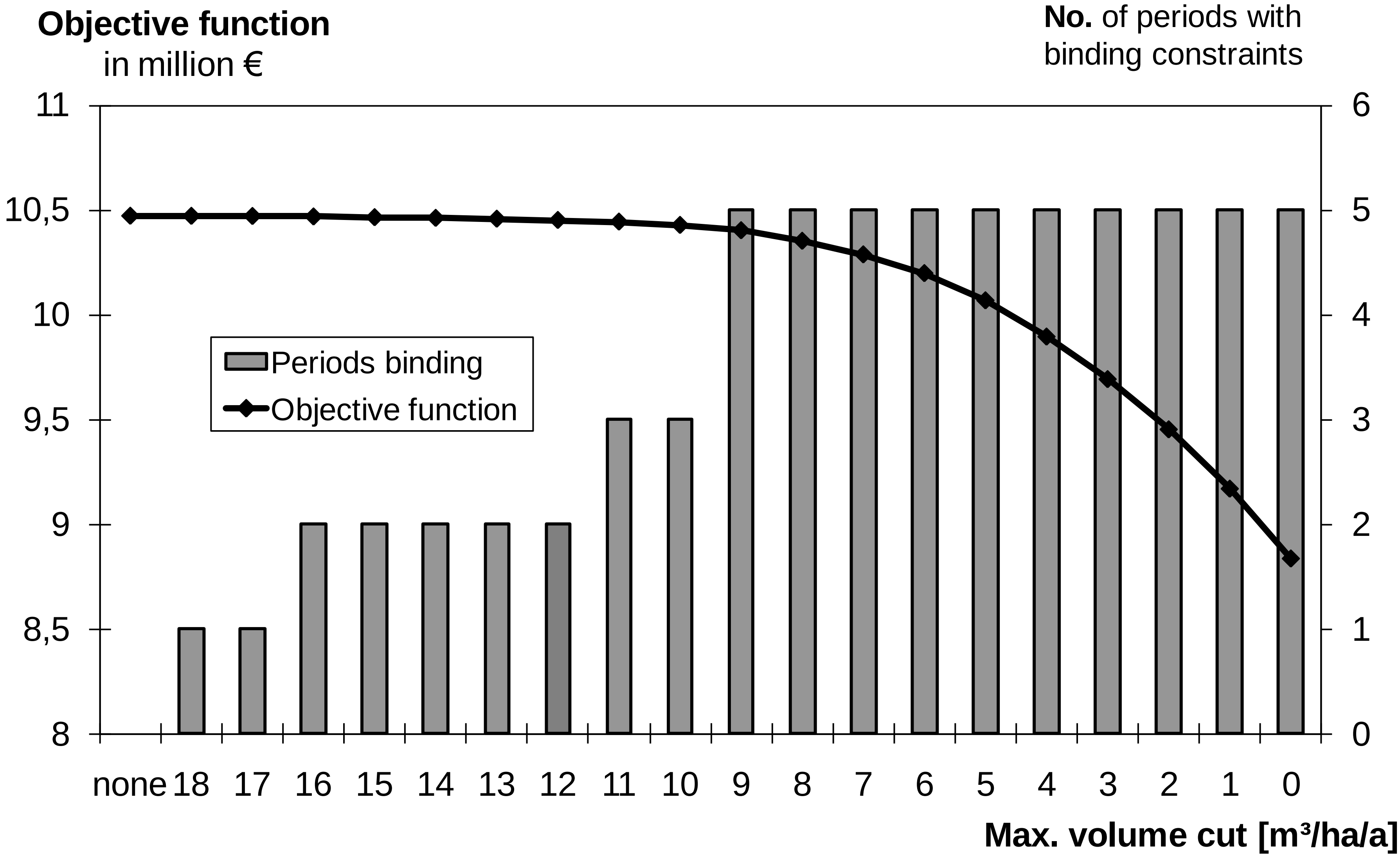
$$+ V_{30,s,tr} \cdot q^{-30} \cdot a_{30,s,tr} \cdot \lambda_{30} + LEV_s \cdot q^{-(5i\delta + 30\lambda_i)} \cdot a_{i,s}$$

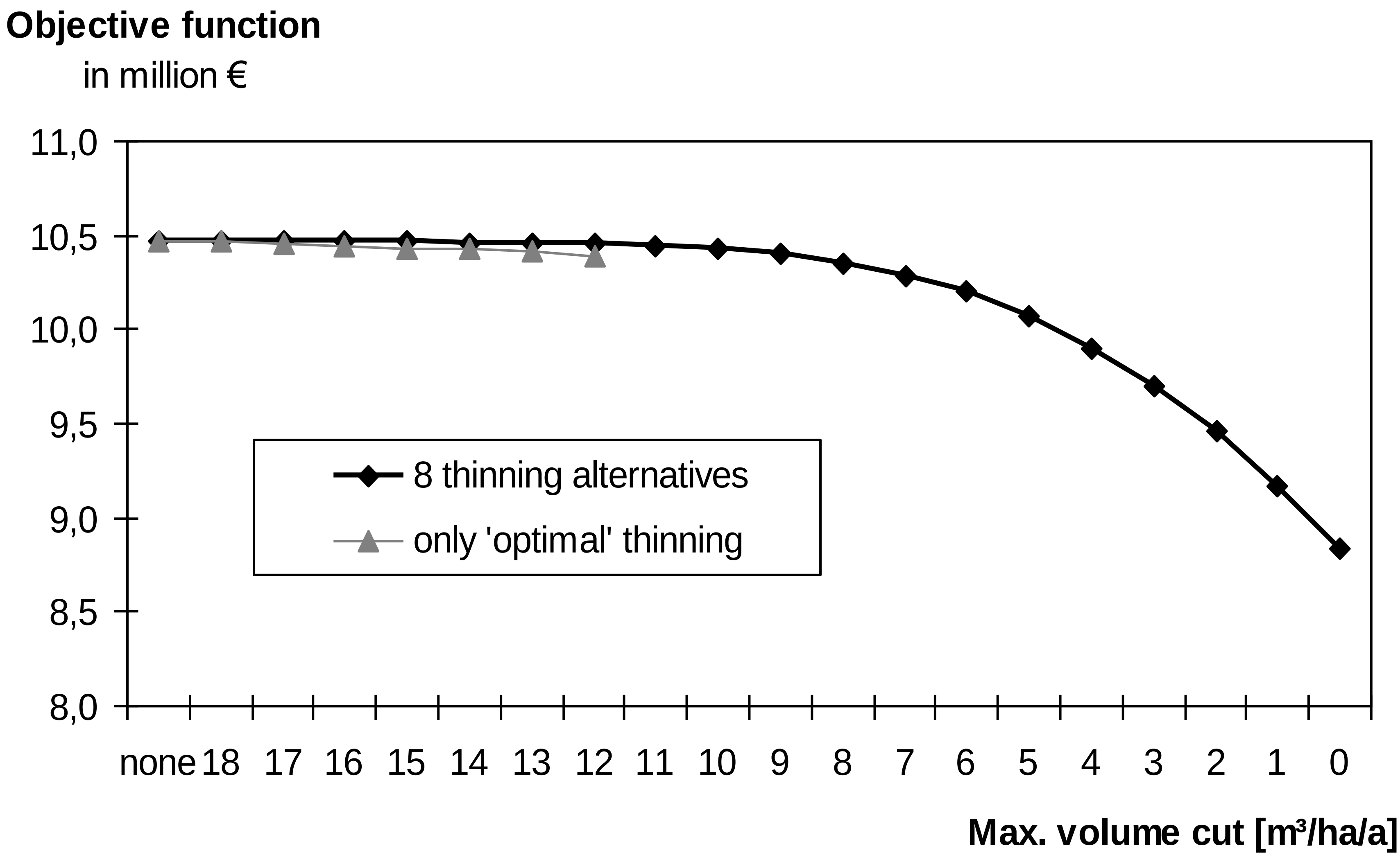
i = time period (multiplied by 5 = time in years) $i \in \{1,...,5\}$
s = stand types $s \in \{1,...,40\}$ *defined by species, age class and growth potential*
TH = thinning revenue

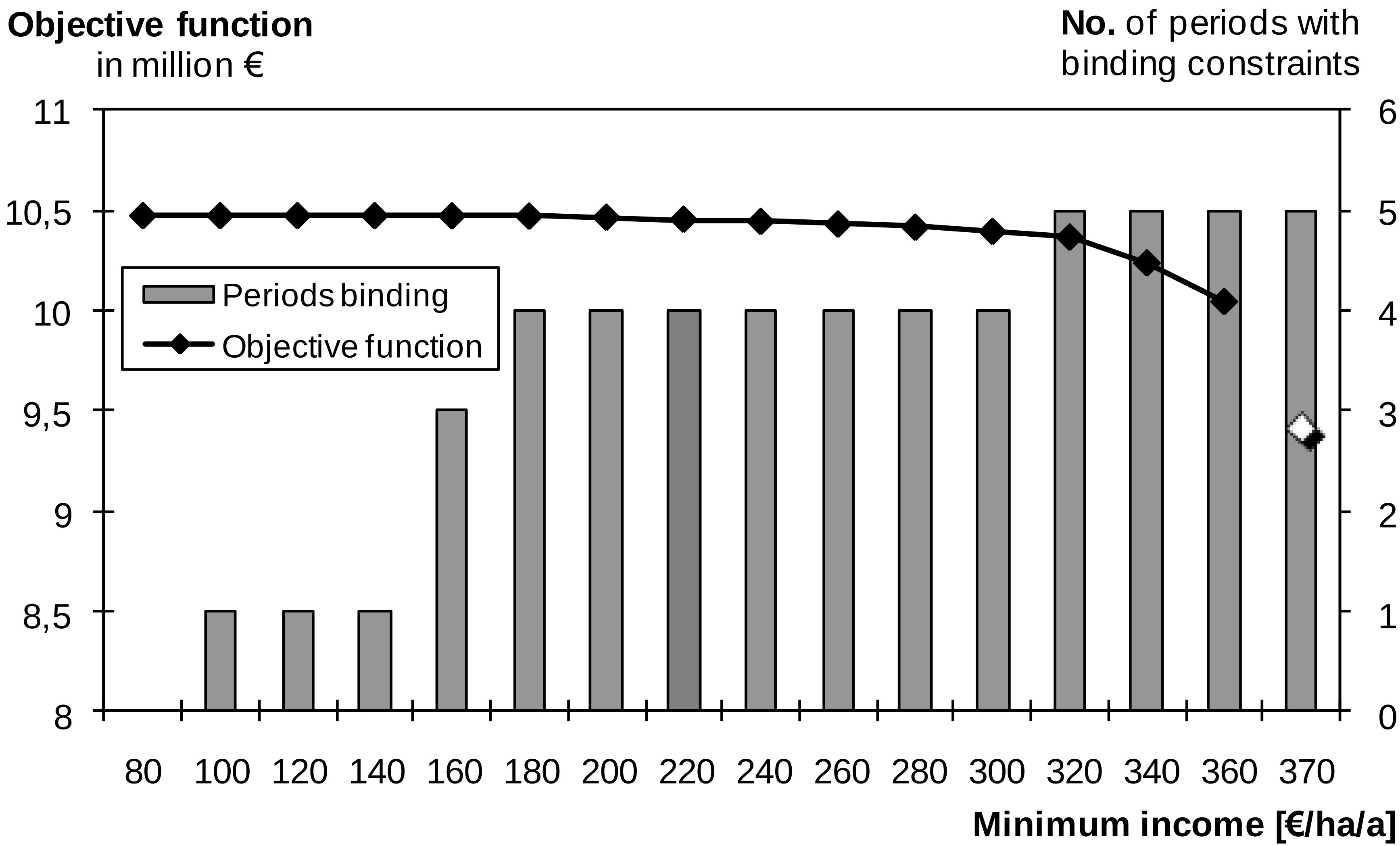
V = value of the remaining stand after 30 years
a = area
q = discount factor (1+interest rate)
v = treatment alternative $v \in \{0,4\}$ *0 = thin stand 4 = harvest stand*
tr = thinning regime $d \in \{1,...,8\}$
LEV = land expectation value
λ, δ *= correction factor*

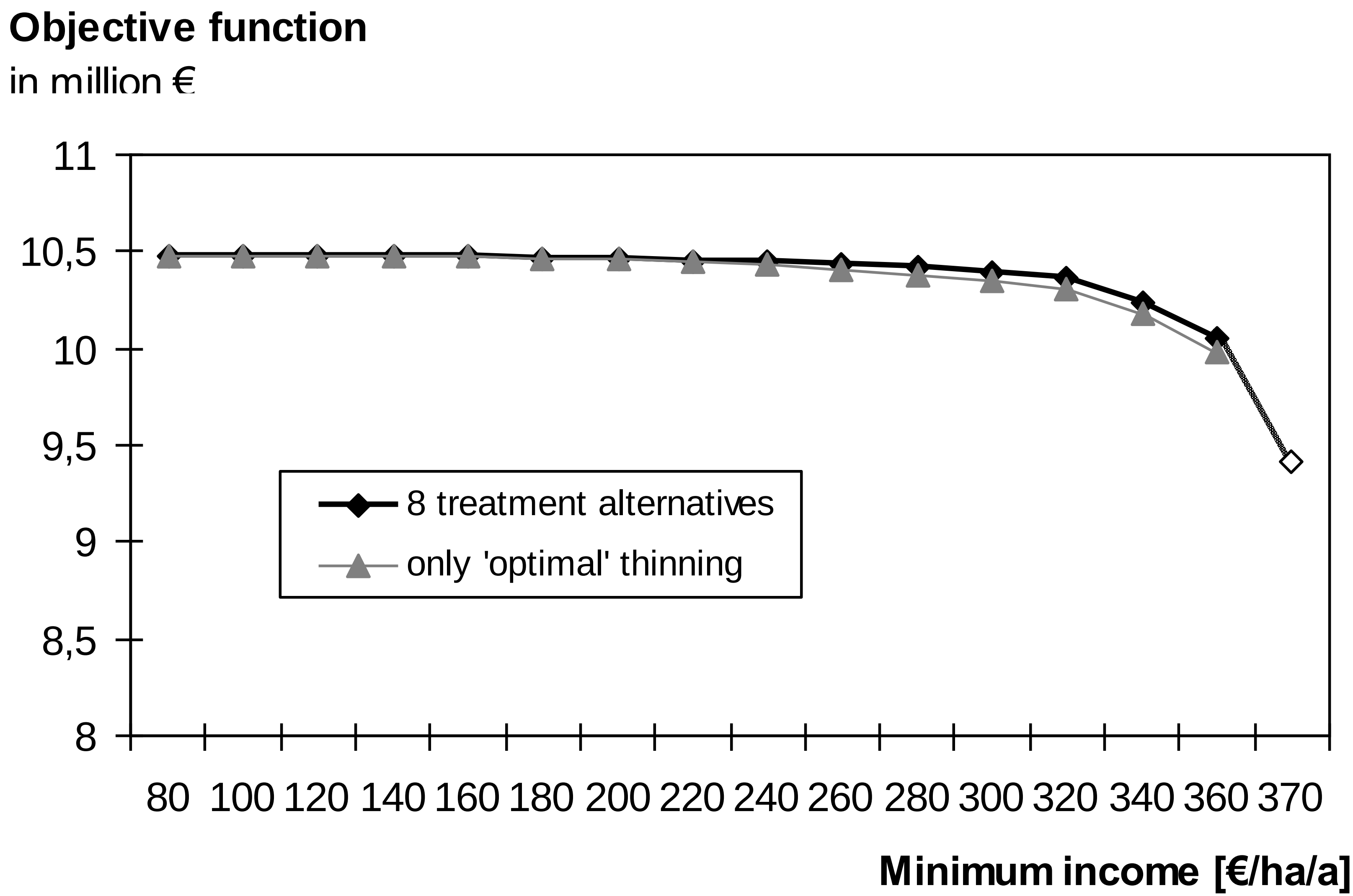
$\lambda_i, \ldots, \lambda_{30} = 0$ *and* $\delta=1$ *if* $v_{i-1} = 4$
else $\lambda_i = 1$ *and* $\delta=0$

Results


Objective function
in million €
No. of periods with
binding constraints
11
10,5
10
9,5
9
8,5
8
6
5
4
3
2
1
0
Periods binding
Objective function
none 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Max. volume cut [m³/ha/a]


Objective function
in million €
11,0
10,5
10,0
9,5
9,0
8,5
8,0
8 thinning alternatives
only 'optimal' thinning
none
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Max. volume cut [m³/ha/a]

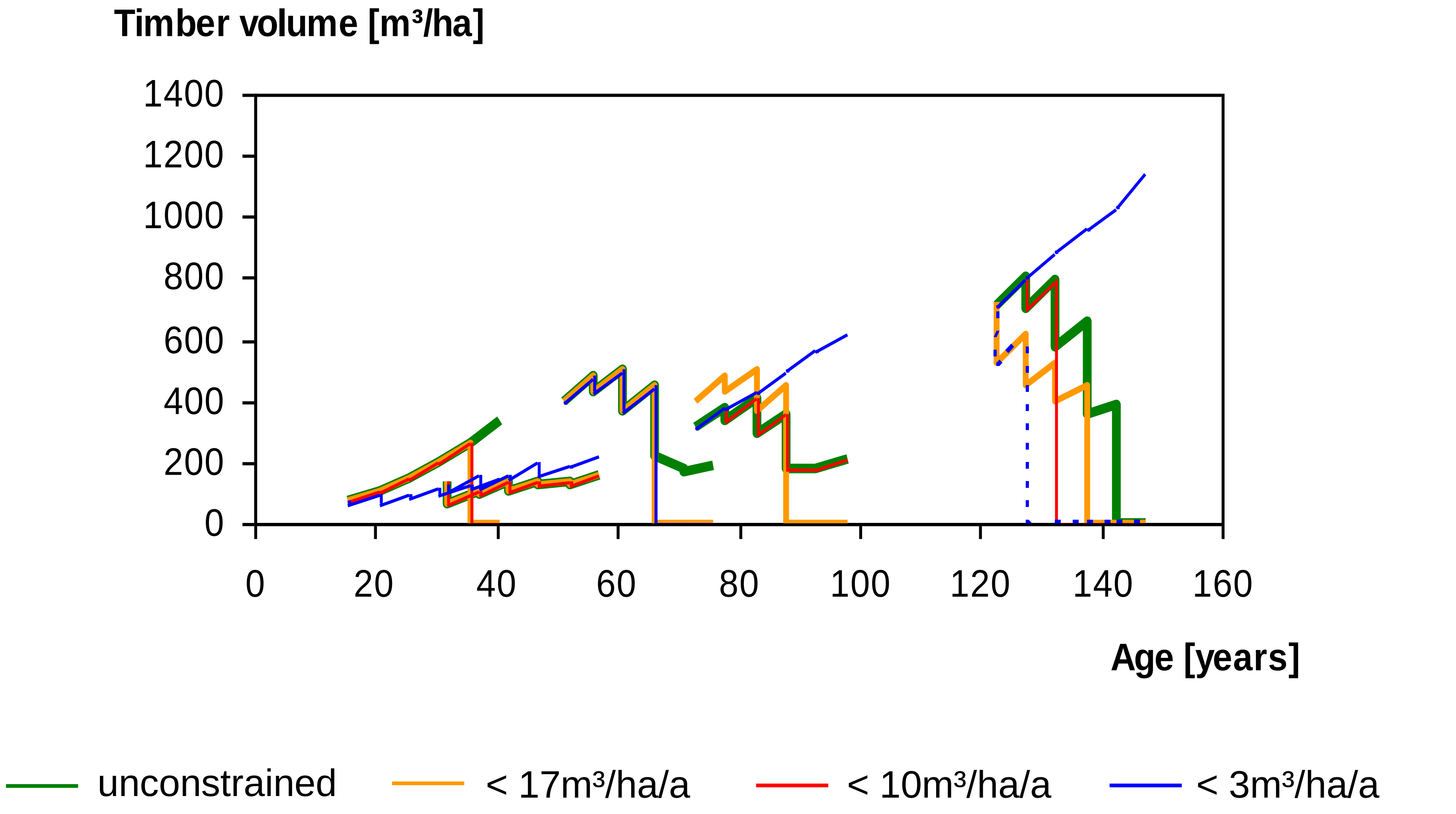

Objective function
in million €
No. of periods with
binding constraints
11
10,5
10
9,5
9
8,5
8
6
5
4
3
2
1
0
Periods binding
Objective function
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
370
Minimum income [€/ha/a]


Objective function
in million €
11
10,5
10
9,5
9
8,5
8
8 treatment alternatives
only 'optimal' thinning
80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 370
Minimum income [€/ha/a]

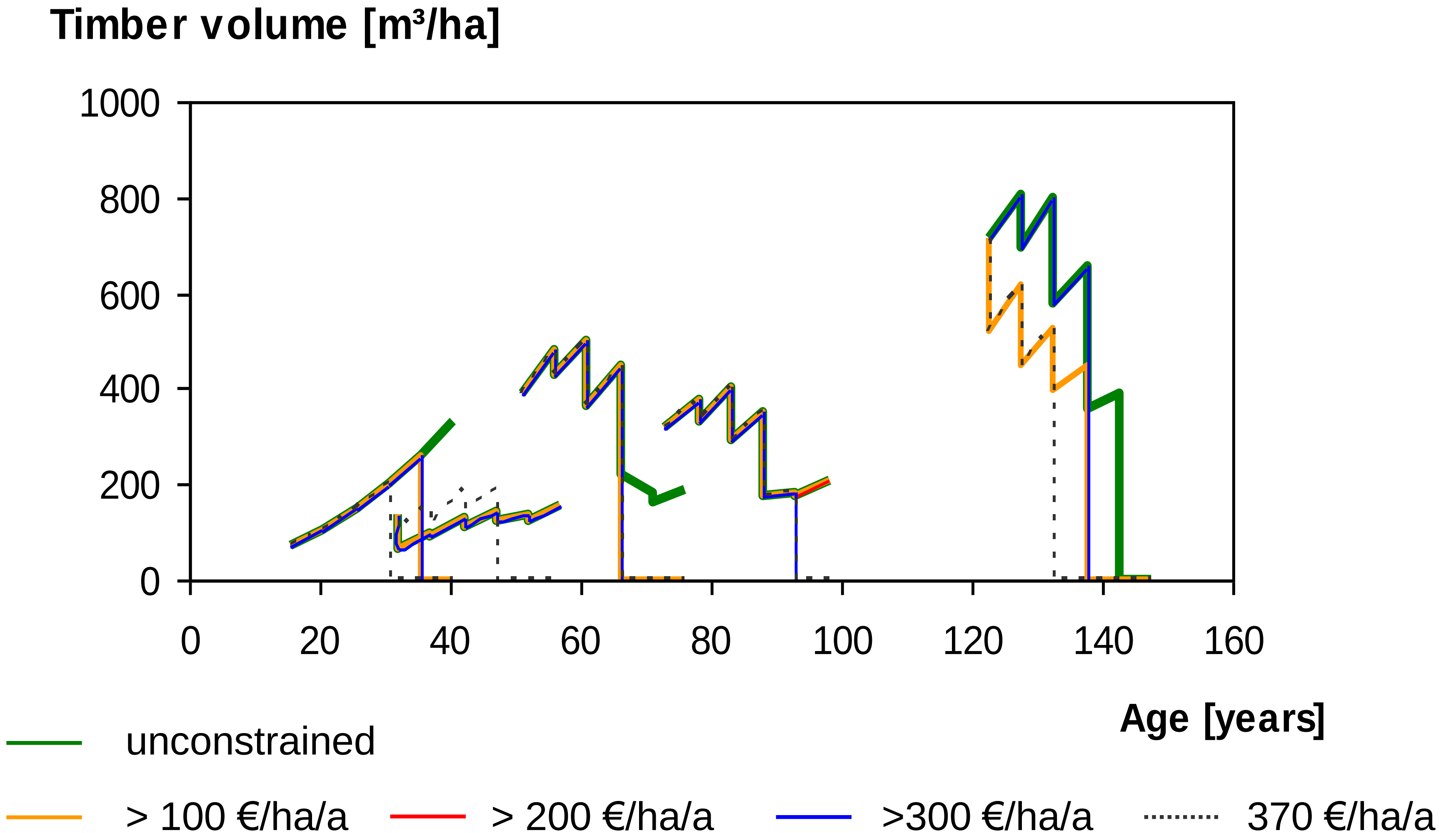
Volume vs Income

- reduction of premature thinning
- timing of harvest
- change in harvest strategy

Volume Constraint



Income Constraint



Summary

- Change in objective function value not spectacular
- Exponential relationship between how binding the constraint is and objective function value
- Type of constraint has important effect on structure of the forest
- Integrating treatment alternatives in a linear programme on an enterprise level makes real options and outcome clearer
- **Gain in flexibility**