Planting subsidies assist spruce forest owners to switch to uneven-aged mixed management and climate change mitigation

Joerg Roessiger[1)], Ladislav Kulla[1)], Vlastimil Murgaš[1)], Maroš Sedliak[1)], Miroslav Kovalčík[1)], Emil Cienciala[2,3)], Vladimír Šebeň[1)]

[1)] *National Forest Centre – Forest Research Institute Zvolen, T. G. Masaryka 22, 960 01 Zvolen, Slovak Republic*

[2)] *IFER – Institute of Forest Ecosystem Research, Cs. armady 655, 254 01 Jilove u Prahy, Czech Republic*

[3)] *Global Change Research Institute of the Czech Academy of Sciences, v. v. i., Bělidla 4a, 603 00 Brno, Czech Republic*

Management of old even-aged spruce stand requires a substantial change in species composition challenged by climate change and loss of biodiversity

- Forest owners urgently need to decide about the future to face spruce stand breakdown caused by storms and / or bark beetle related to ongoing climate change

- Relying on natural regeneration threatens to repeat spruce dominance in the following stand generation which relates again to spruce failure

- The shift towards a near-natural (uneven-aged, mixed, stable) forest management including fir and beech requires high financial investments

- Public expects forests to conserve biodiversity and to store carbon, justifying a funding for planting fir and beech by state finance

Necessity for a new planning tool that solves near-natural management and planting

The approach combines benefits of modelling for

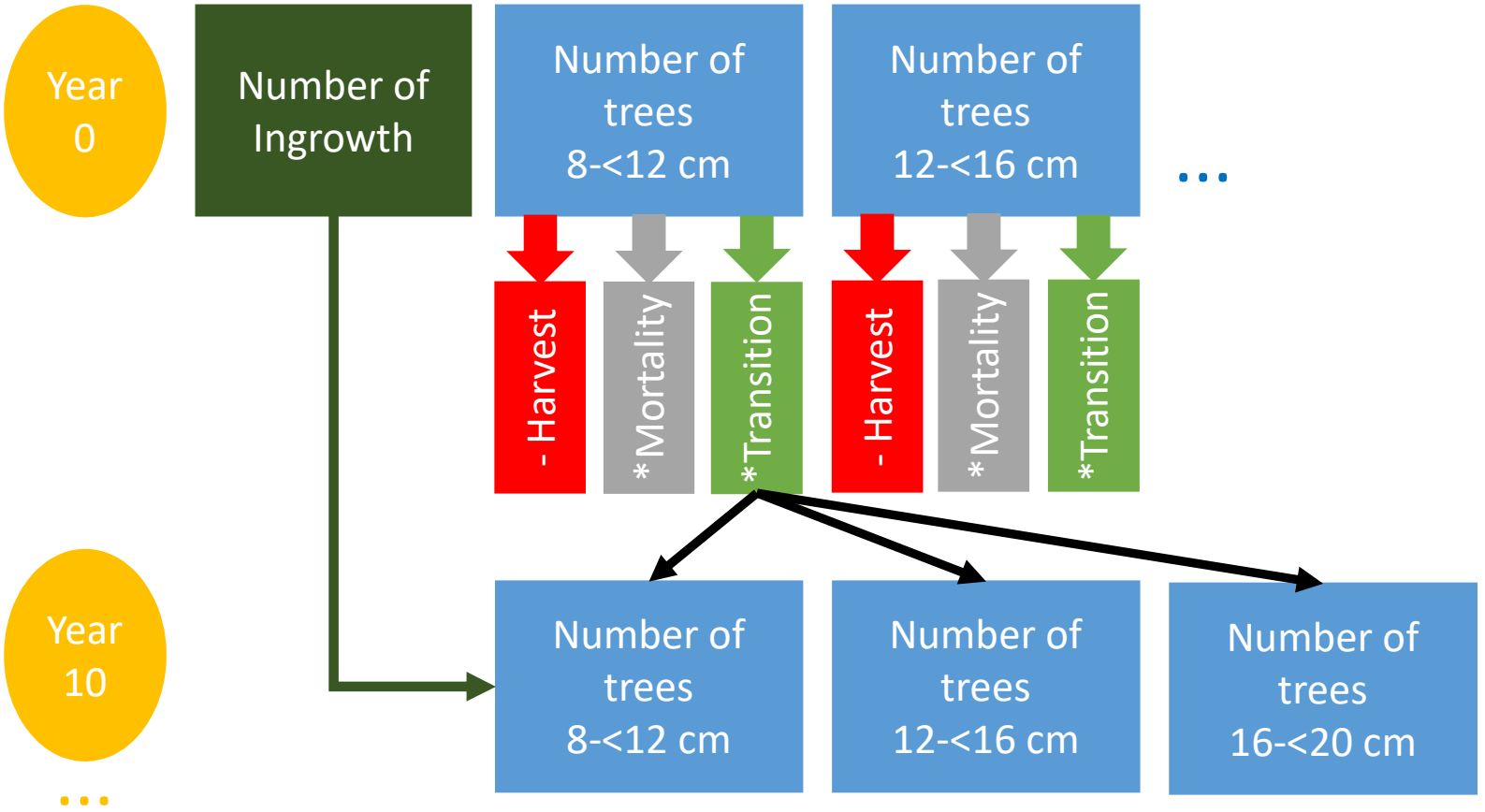
- even-aged (planting and tending; age < 30 years; dbh < 10 cm) and
- uneven-sized (density-dependent matrix transition model; dbh > 10 cm)

A financially driven optimisation detects optimal stand management pathways by determining

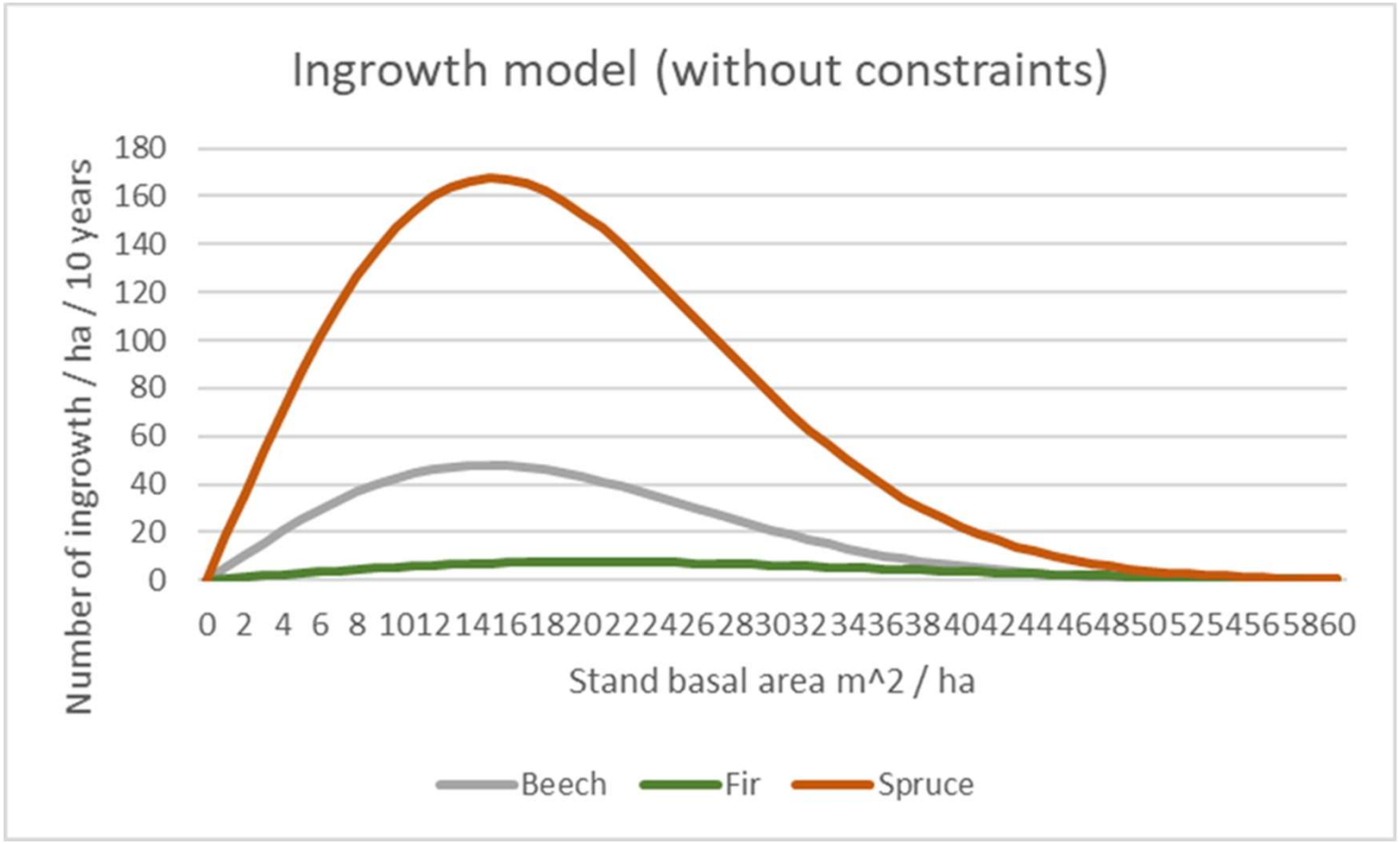
- numbers of harvested trees
- numbers of planted trees
- of spruce, fir, and beech

Case study Polom, Beskydy mountains, West Carpathians

Principal of the matrix transition model, based on diameter rather than age classes:
Within 10 years ingrowth enters in the lowest diameter class; number of trees existing in a diameter class reduce by harvest and by mortality; surviving trees either remain in their class or move to higher classes

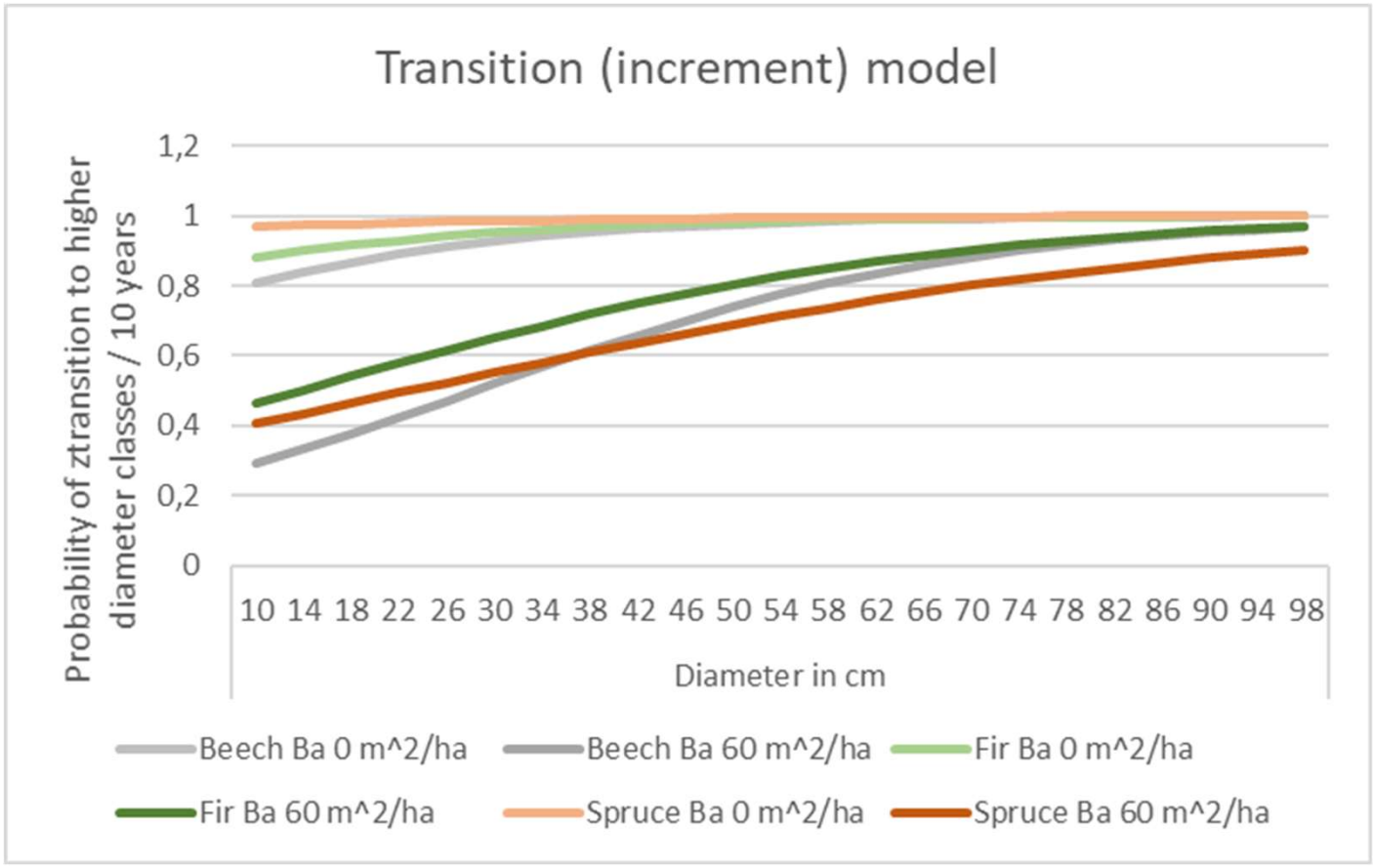


Ingrowth for a low stand basal area is limited by missing seed trees and for a high stand basal area is limited by high stand density and competition

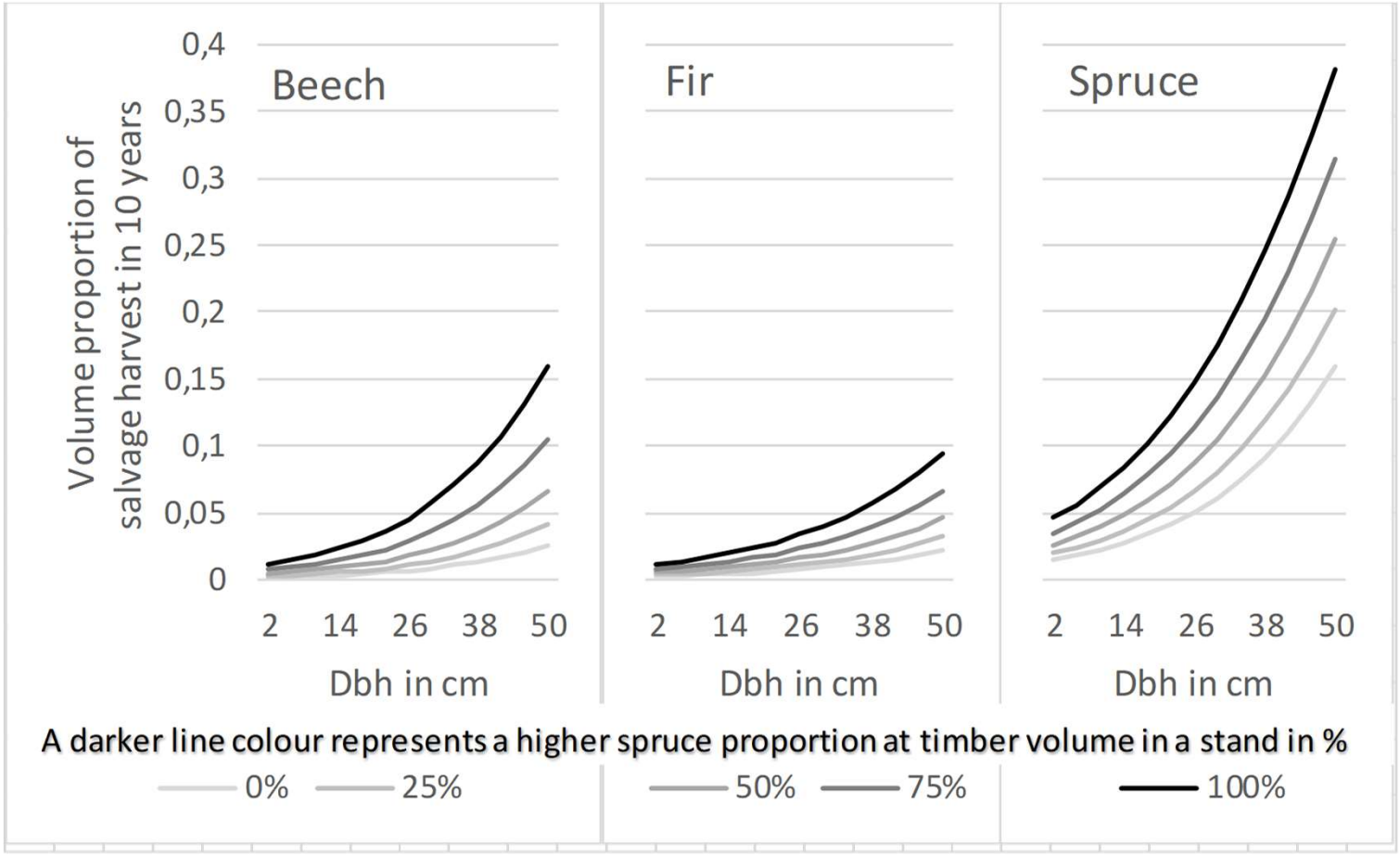


Transition to next higher diameter classes increases with dbh, decreases with stand ba (darker colours)

Spruce has the highest increment in bare land conditions, under dense conditions fir grows better than spruce, thin beech has the lowest increment

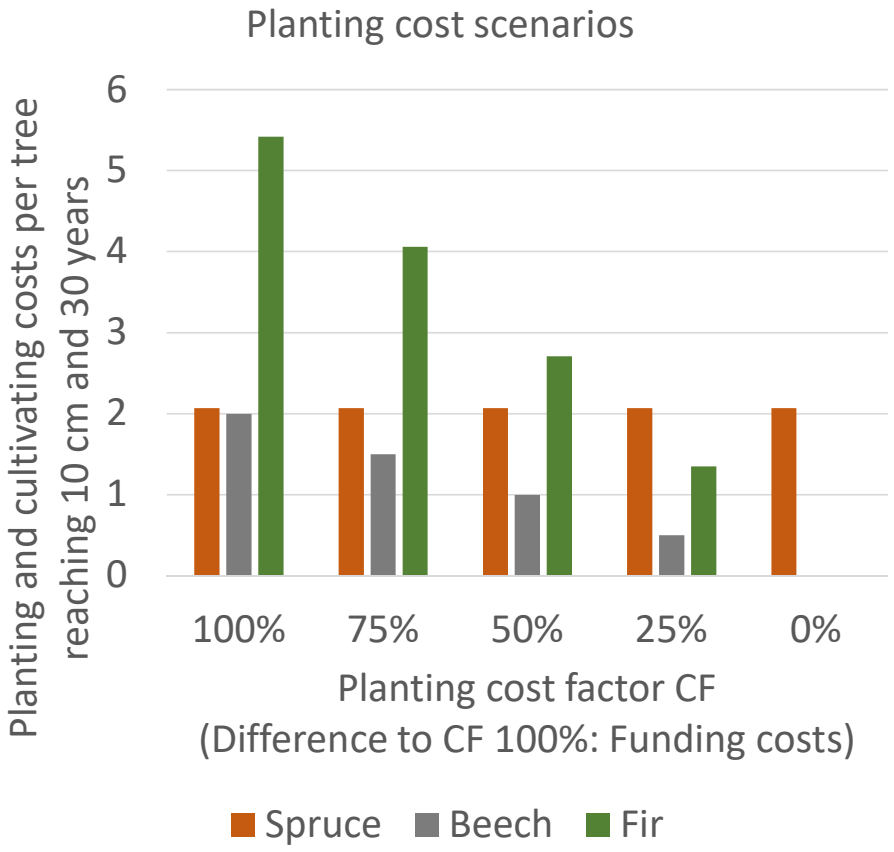


Mortality rates (based on salvage harvest records) increase with dbh and with spruce volume proportion (darker colour), a tree species admixture to pure spruce stabilises stands



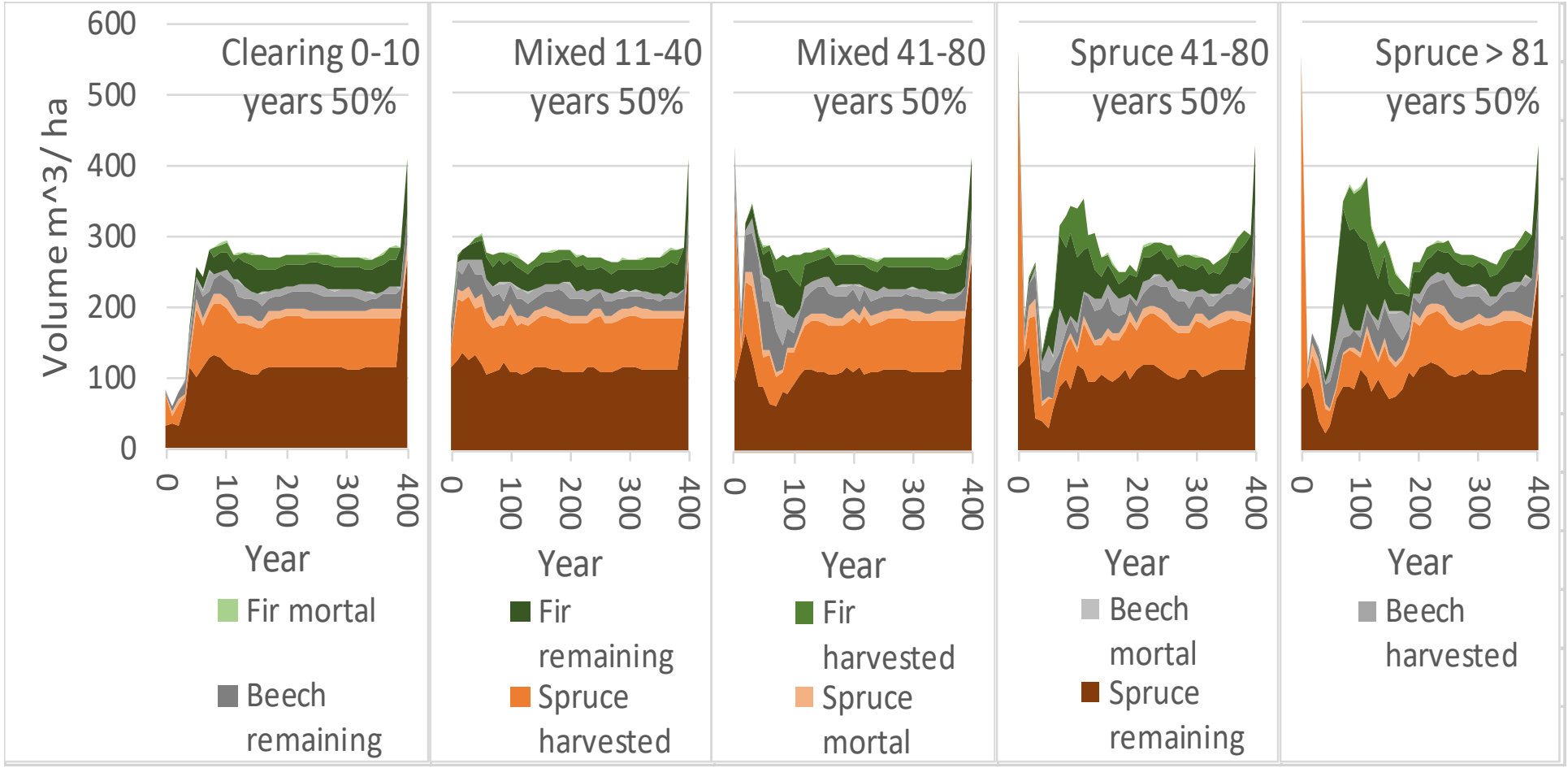
Financial optimisation by maximising net present value with an interest rate of 2%

- Net present value considers:
  - harvest tree net values
  - mortal timber: net values reduced by 42%
  - costs for planting and cultivating (**5 funding scenarios**)
  - value of intial stand at the beginning (**5 different initial stand strata scenarios**)
  - value of remaining stand at the end of the optimisation (to avoid a clearcut)
- Constraint species mixture of plantings: max. 30% spruce, min. 10% fir, min. 20% beech
- Full ingrowth potential requires 20 seed trees / ha with a minimal dbh of 40 cm
- A stand basal area higher than 27.5 m^2/ha disallows for planting

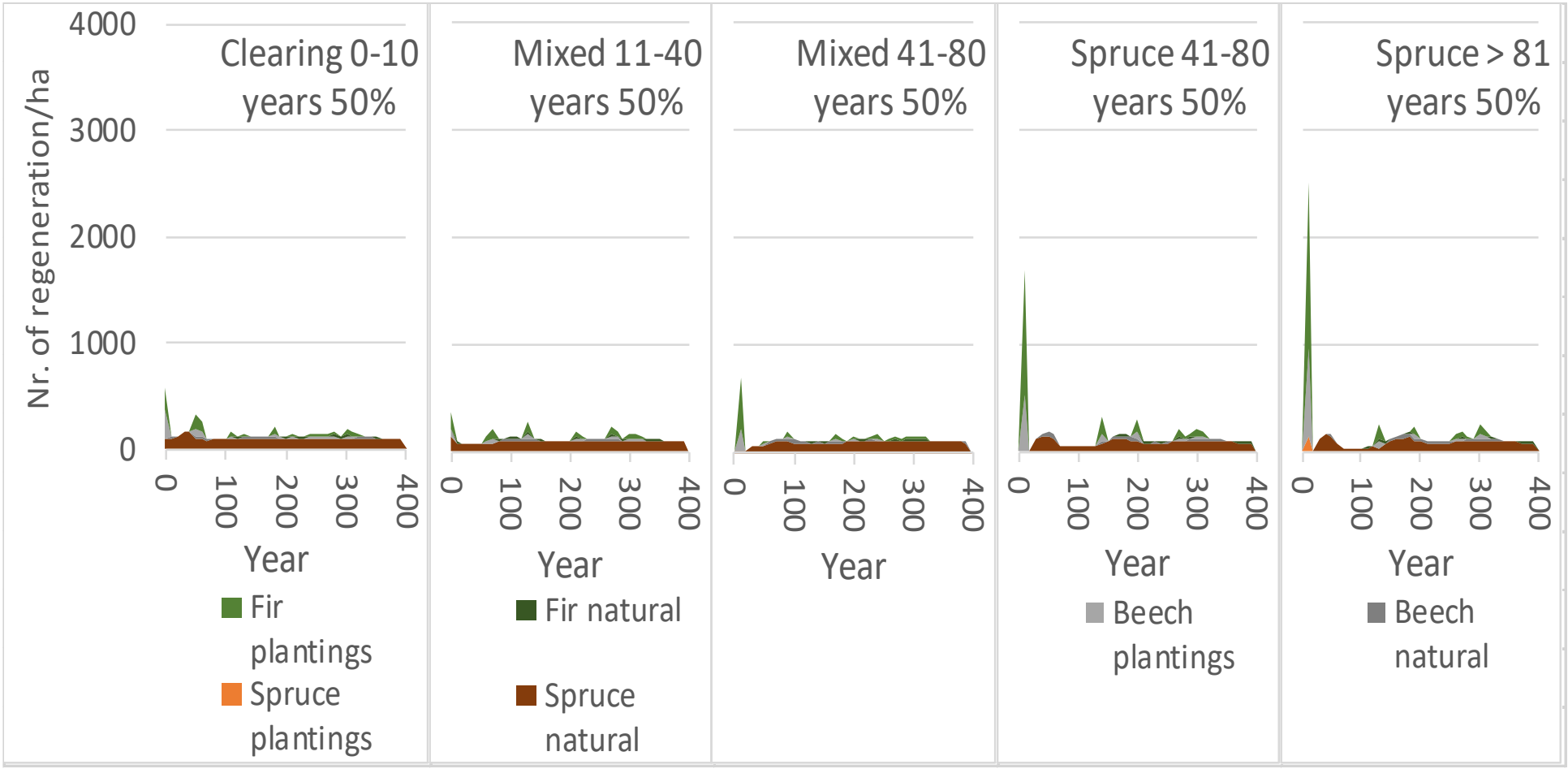


Age in years	0-10	11-40	41-80	> 81
Clearing	■			
Mixed (spruce ≤ 90%)		■	■	
Spruce (spruce > 90%)			■	■

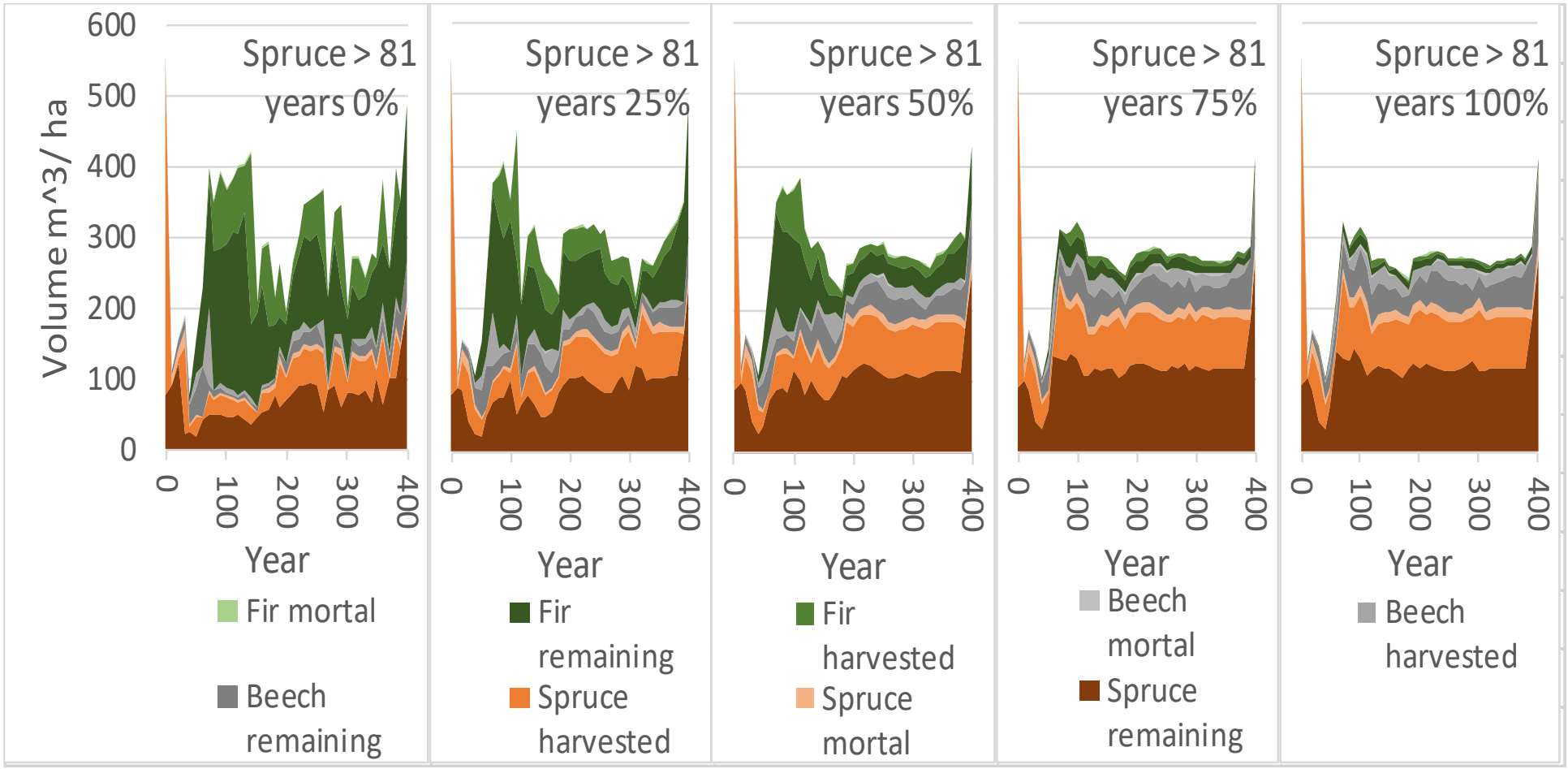
How initial stand impacts on the transition to the next stand generation? (Example: CF 50%)
Clearing and young mixed: Starting from a low volume level and increase their volume
Older and spruce stands: Overaged stand parts are harvested within 10 years to avoid financial losses by high spruce mortality, followed by a cycle dominated by fir, before stabilising in an equilibrium



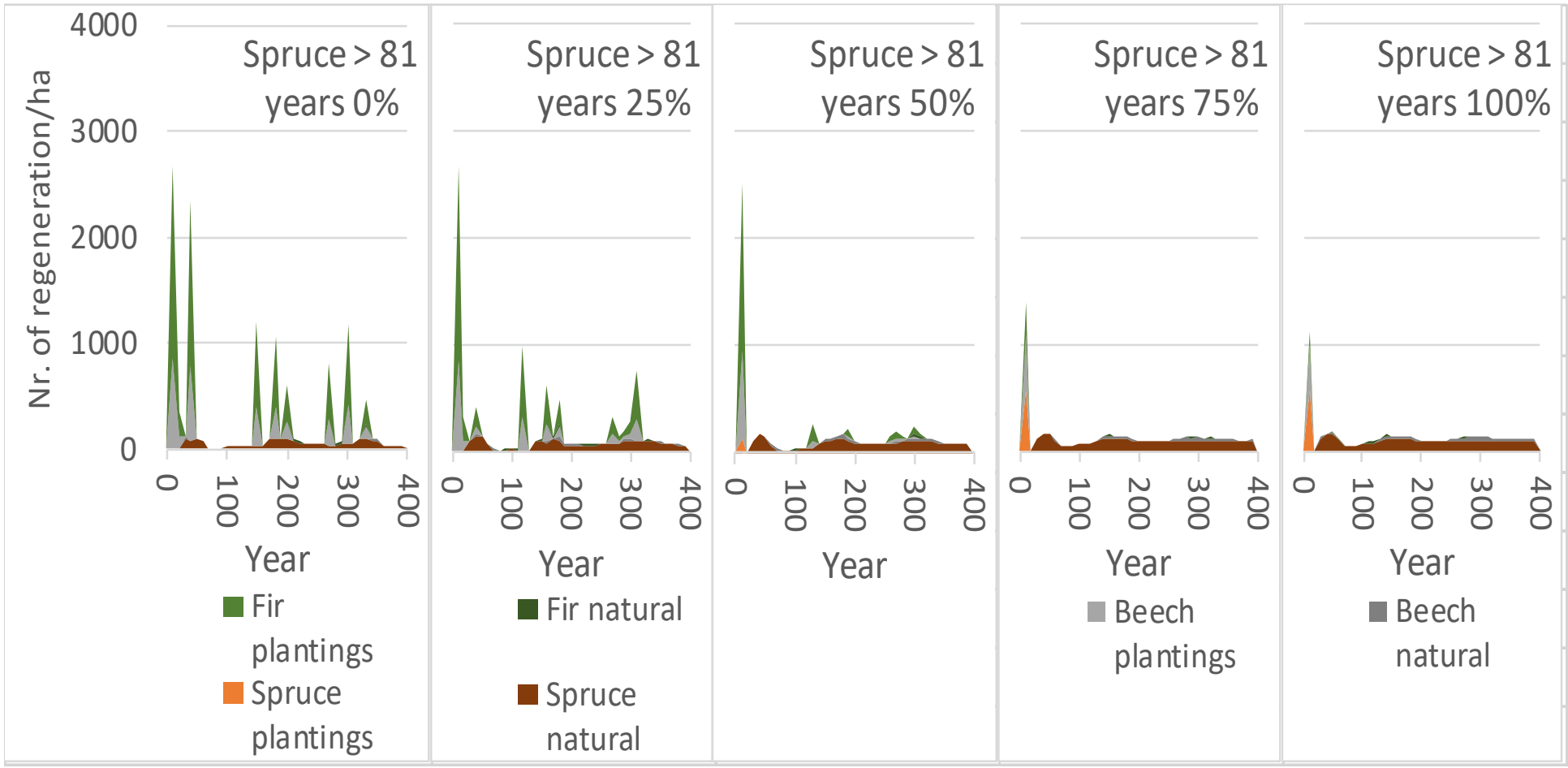
How many trees have to be planted to establish a new mixed stand generation? (Example CF 50%)
Clearing and young mixed already consist of a young stand generation: No requirement for a high amount of planting
Older stands, maily spruce stands: Require a fast planting to allow for a stand generation change



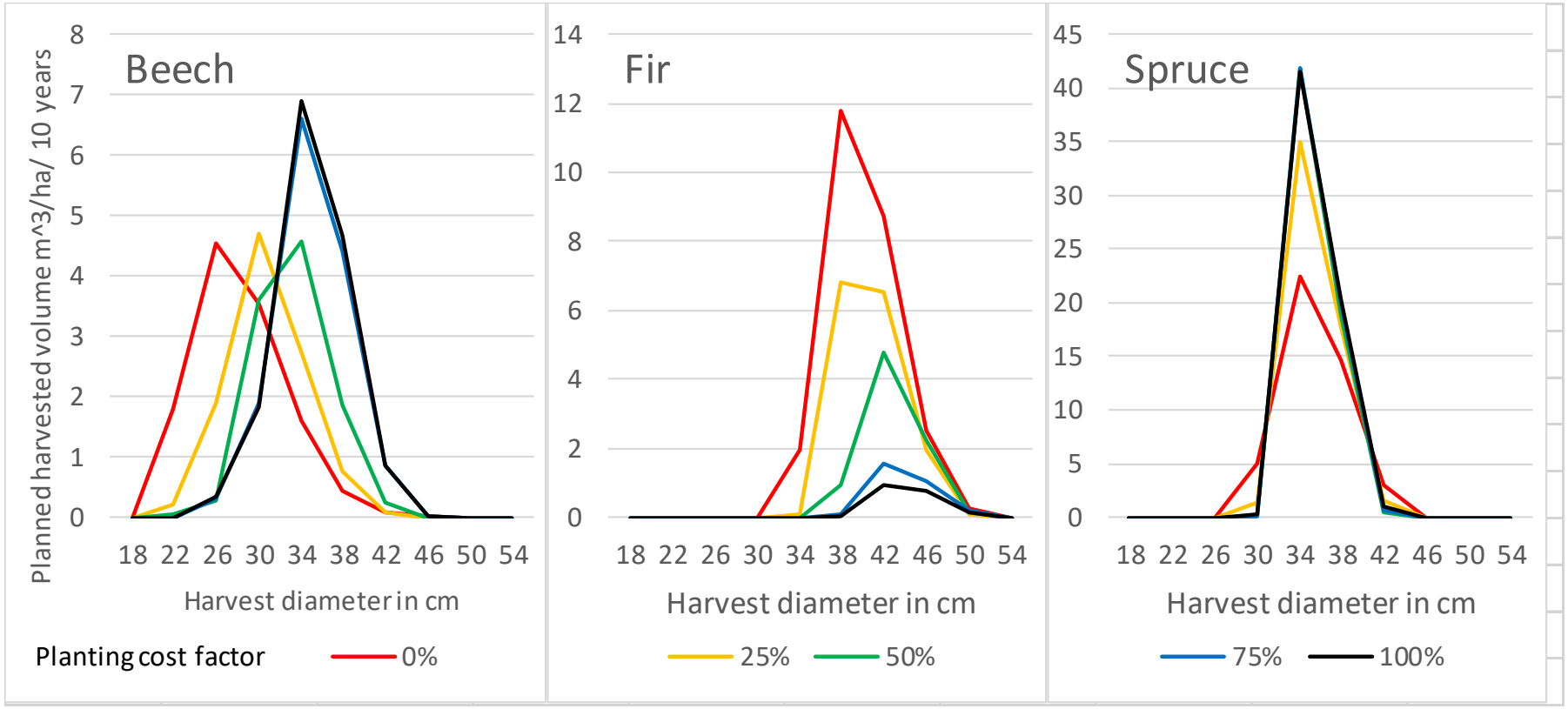
How reduction of planting costs of beech and fir by funding impacts on the long-term equilibrium?
(Example: Initial pure even-aged spruce stand older than 81 year)
Only funding of 50% and more causes long-lasting increase of volume, but its interrupted by temporal reductions of volume to initiate new regeneration and to allow for planting and causes strong fluctuations in stand density



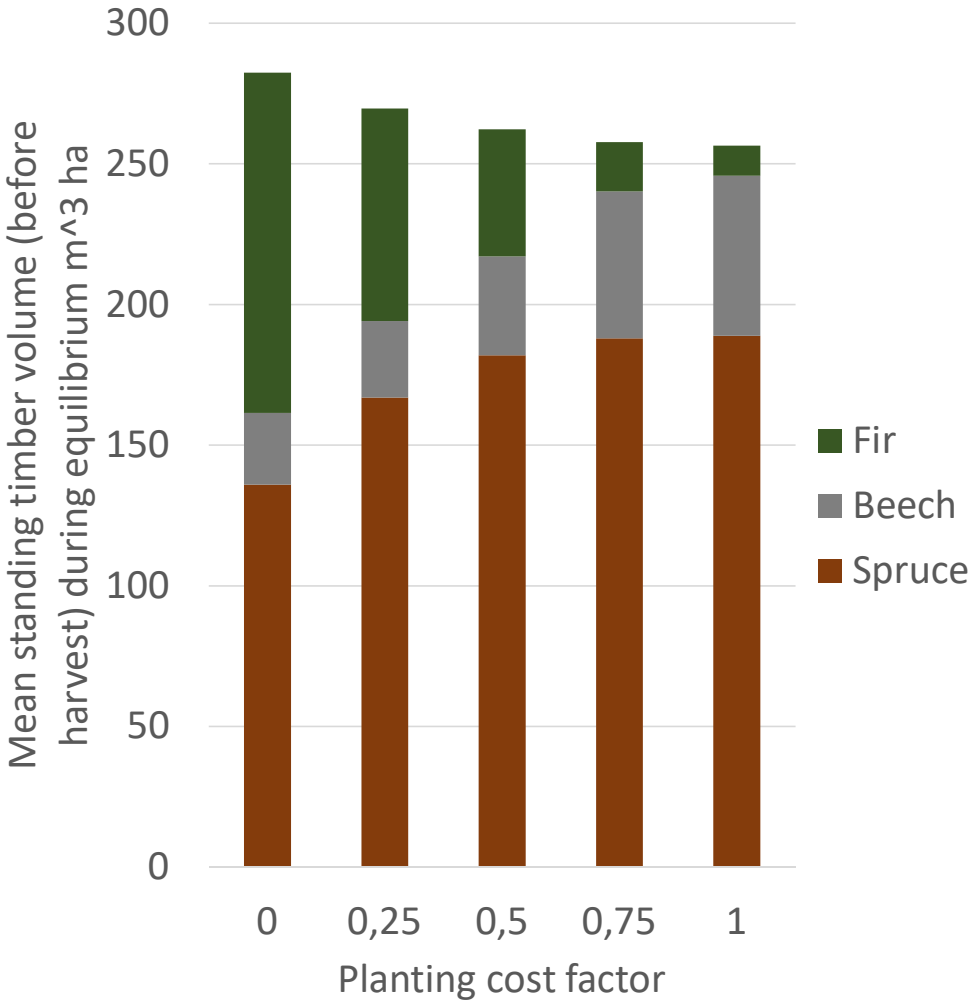
How funding for planting of beech and fir impacts on planting activity?
(Example: Initial pure even-aged spruce stand older than 81 year)
Only funding of 50% and more causes continuously repeated plantings
No or low funding allows only for one planting including spruce because of its cheepest planting cost



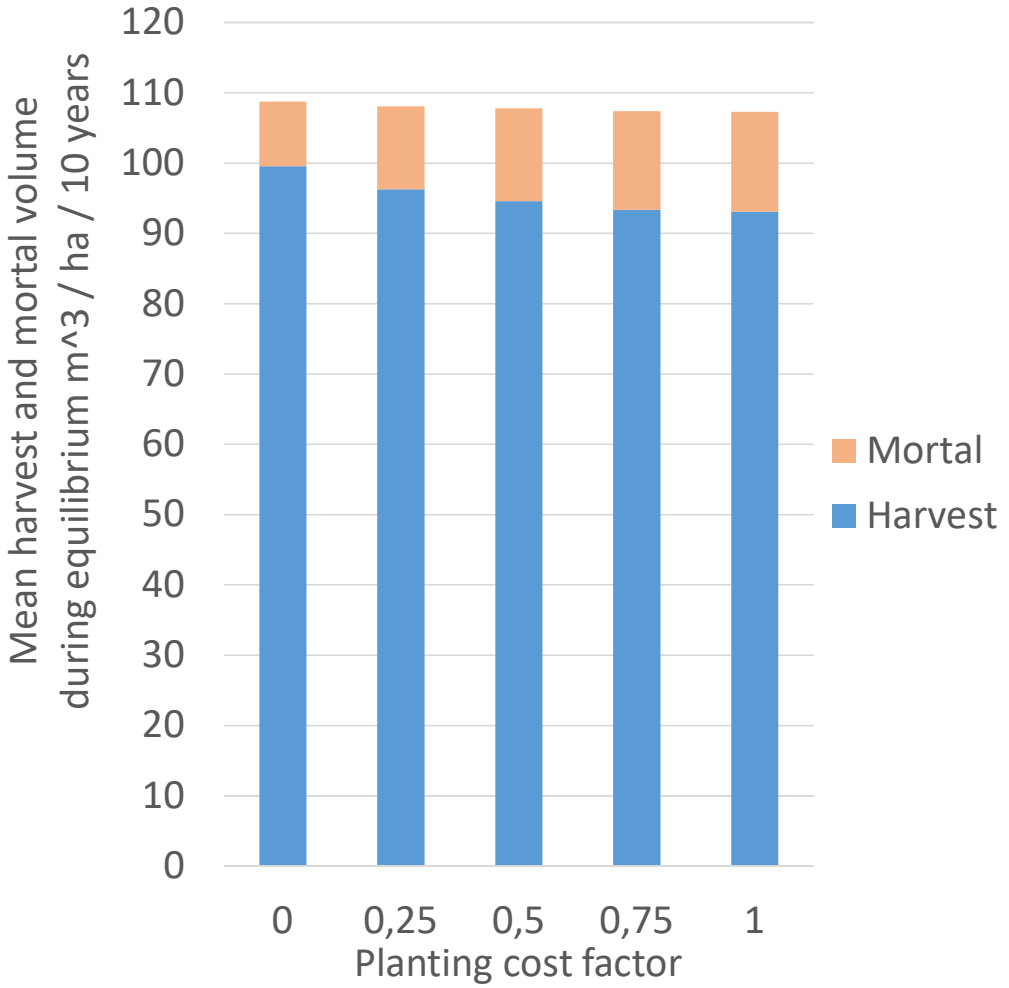
How funding for planting impacts on target diameter during the equilibrium?
Funding limits diversity of tree sizes by reducing mean target diameter of fir and beech to enable a higher and more frequent planting intensity
Spruce target diameter remains stable as it benefits from reduced mortality in mixture



Funding supports biodiversity: Fir proportion increases; Proportion of ecologically valueable beech reduces (lower profitability)



Funding reduces volume failed by mortality by stand stabilisation by a lower spruce proportion and mitigates climate change by higher harvest



Conclusion: Funding for planting

- establishes a mixed, uneven-aged, stable, continuous-cover forest able to better resist against climate change
- is an adequate and immediate measure to support forest owners who are willing to improve forest stand stability by species mixture
- must cover majority of planting costs and must be specificly adjusted for a near natural tree species composition
- Negative effects on biodiversity might be solved by a further funding for
  - remaining of thick but unprofitable beech and fir habitat trees and
  - to not indirectly punish owners who already invested in biodiversity in the past and not require planting and funding
- Nonlinear optimisation of harvesting and planting within a matrix model extended by an option for planting is a planning tool allowing to determine optimal transformation pathes to a near-natural forest management and equilibrium

References, Acknowlegement, Database

References

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