Searching for an optimal harvest-regeneration system using multi-criteria analysis

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Research question

To search for management scenarios

to be applied in a secondary spruce forest of central Europe

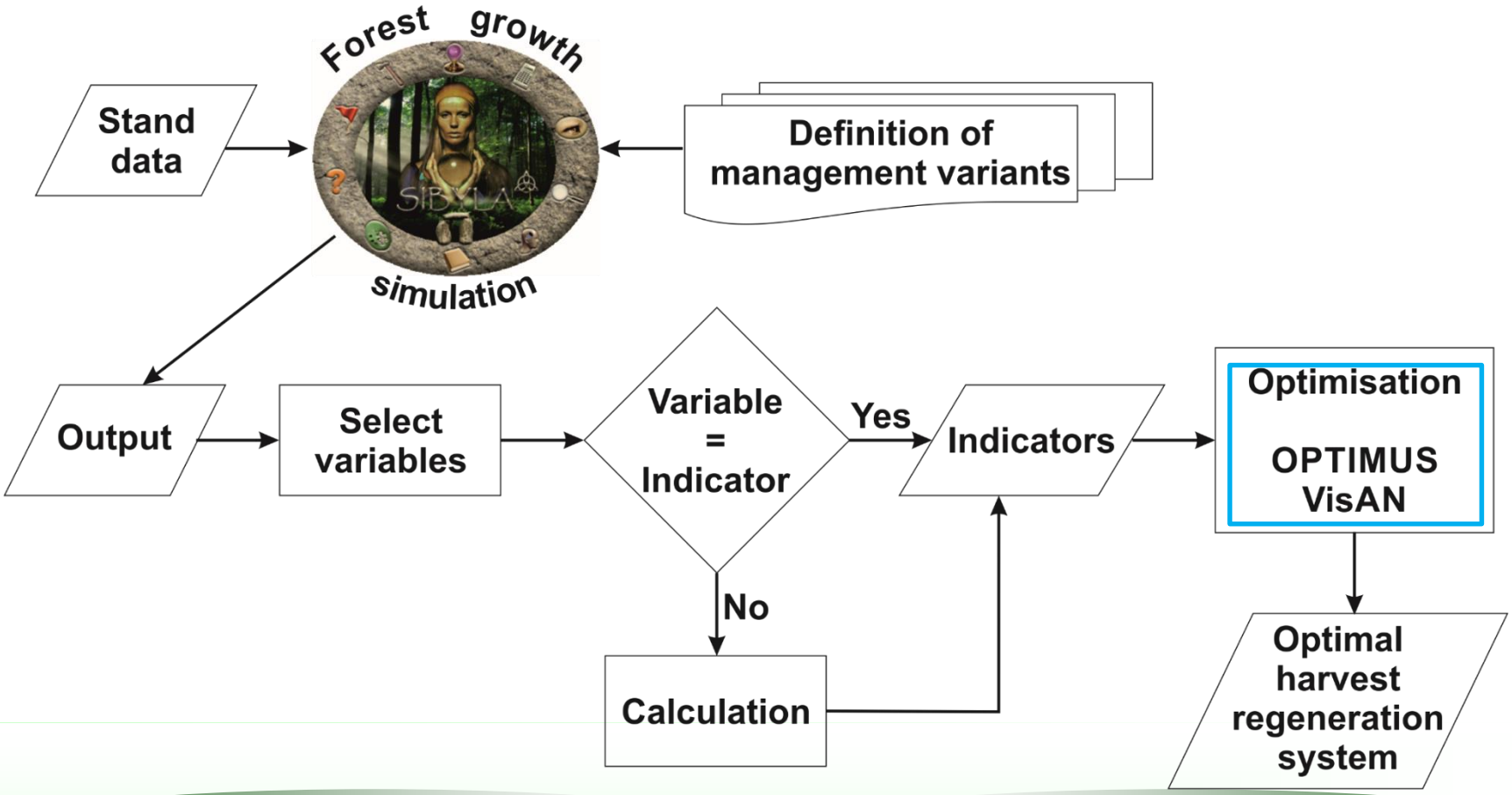
that would optimise

Wood production,

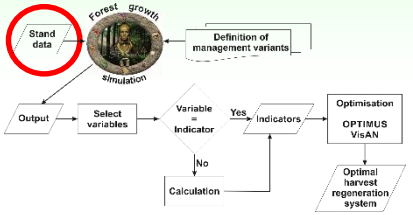
Stand stability,

Tree species diversity

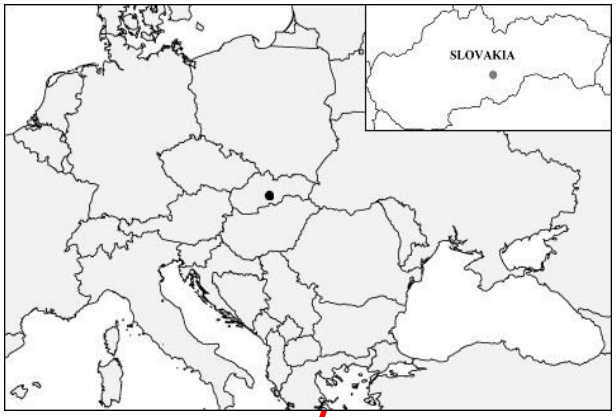
Decision analysis chart



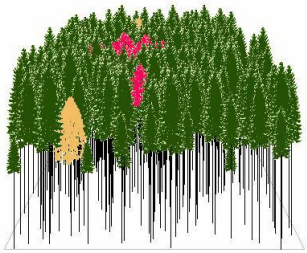
Stand data



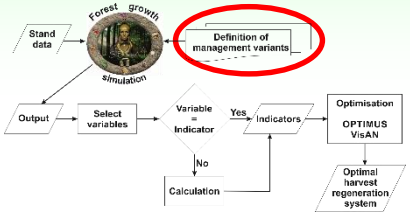
Secondary spruce stand in central Slovakia



Stand age	60 years
Species composition	Norway spruce (Picea abies) 80% European larch (Larix decidua) 10% Maple (Acer sp.) 5% Common beech (Fagus sylvatica) 5%
Elevation	430 - 470 m a.s.l.
Longitude	E 19°54´33.89
Latitude	N 48°32´55.09
Climatic region	slightly warm, and slightly moist climate
Mean air temperature in growing season	15.4°C
Mean precipitation total in growing season	600 mm



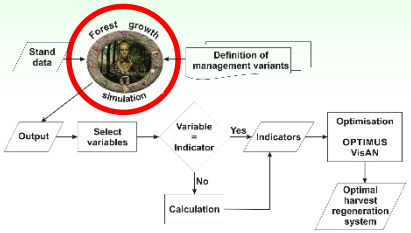
Management variants



- defined by treatment type, intensity, frequency

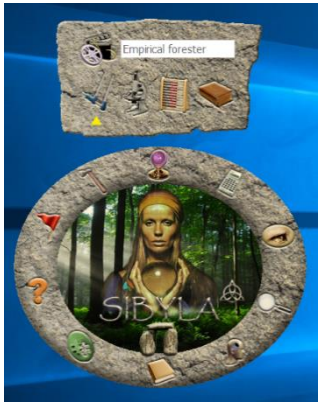
Harvest-regeneration system		Regeneration form	Specification of regeneration variants				Number of variants
			No. of cuttings per decade	No. of phases per decade	Regeneration period [years]	Rotation period [years]	
Even-aged	Clearcutting	Large scale (area > 2ha, cutting width > 2 x stand height)	1		20, 30, 40, 50, 60		40
			2		10, 20, 30, 40		32
		Small scale (area = 1 ha, cutting width < 2 x stand height)	2	2	20, 30, 40, 50, 60	90, 100, 110, 120, 130, 140, 150, 160	40
			3	3			40
	Shelterwood	Large scale (area > 2ha, cutting width > 2 x stand height)	2	2			40
			3	3			40
		Small scale (area = 1 ha, cutting width < 2 x stand height)	2	2			40
			3	3			40
		Expanding small scale (area = 1 ha, cutting width < 2 x height)	2	2			40
			3	3			40
		Target diameter (area = 1 ha, cutting width > 2 x stand height)	Spruce = 50 cm, Larch = 40 cm, Maple, Beech = 45 cm		20, 30, 40, 50, 60		40
Uneven-aged	Selection	Single tree cutting	Target diameter for all tree species: 60 cm, 65 cm, 70 cm, 75 cm, 80 cm				10
	No cutting		Number of target trees: 1 per hectare, 2 per hectare Age: 90, 100, 110, 120, 130, 140, 150, 160 years				8
							∑ 450

Forest growth simulation



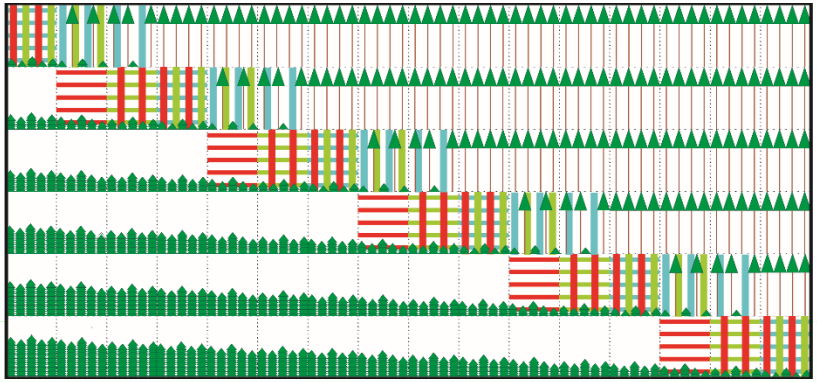
SIBYLA

= a simulator of forest biodynamics (Fabrika, 2005)
- an individual tree distance dependent empirical model
- concept based on SILVA 2.2 (Pretzsch et al., 2002)
- climate and site sensitive
- parameterised for spruce, fir, pine, beech, and oak

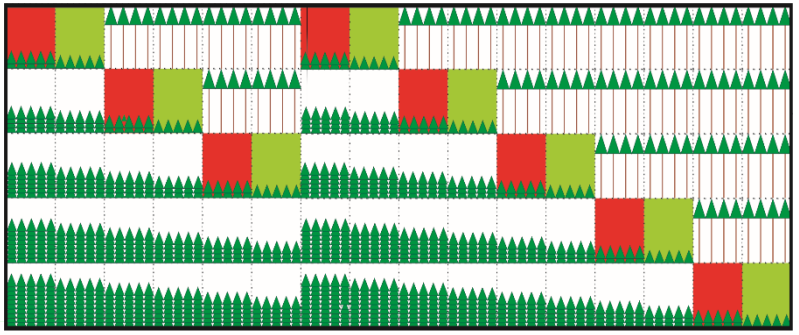


Cultivator = a module of thinning and felling

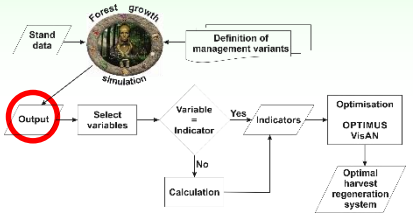
Expanding small-scale shelter-wood with 3 phases per decade



Small-scale clearcutting scenario with 2 cuttings per decade



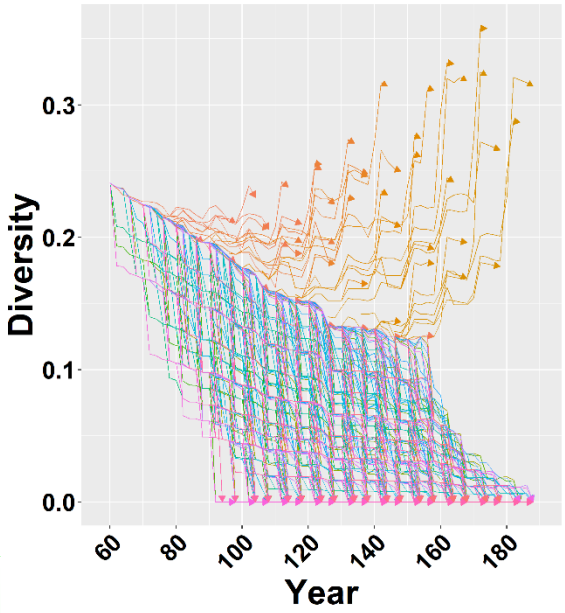
Simulation output

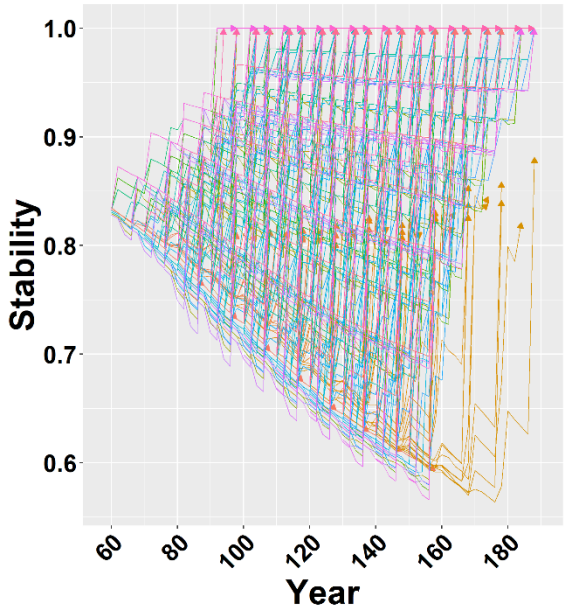


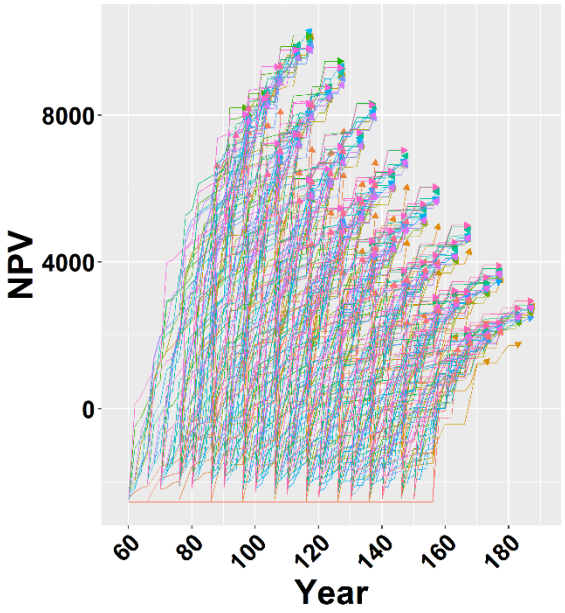
Diversity

Stand stability

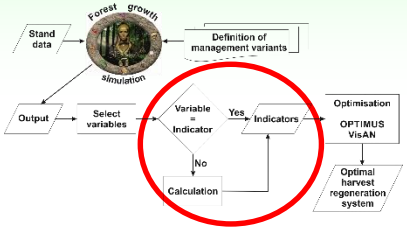
Wood production







Multicriteria optimisation



Optimisation with regard to maximising

Wood production = NPV

$$NPV = \sum_{y=0}^{n} \left[\frac{R_y}{(1+r)^y} - \frac{C_y}{(1+r)^y} \right]$$

Stability = *h/d* ratio

Diversity = Shannon's H´ index

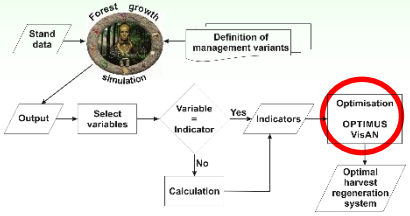
$$H' = -\sum_{i=1}^{N} p_i \,.\, log_2\,(p_i)$$

Testing impact of different combinations of weights on the selection of optimal variants

1-0-0
0.9-0.1-0
0.9-0-0.1
....
0-0-1

63 combinations

Multicriteria optimisation

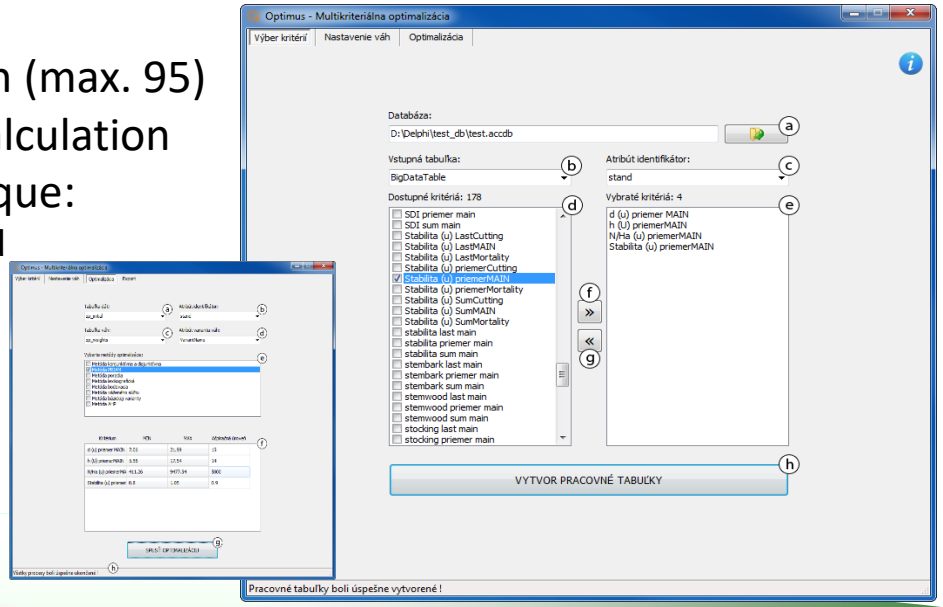


OPTIMUS = an optimisation tool

- developed at Technical University Zvolen
- enables user-specified optimisation based on multiple criteria, optimisation techniques and different approaches of weight calculation

Steps:

1. Selection of criteria for optimisation (max. 95)
2. Selection of a method for weight calculation
3. Selection of an optimisation technique:
    - Conjunctive and disjunctive method
    - PRIAM method
    - Order method
    - Lexicographical method
    - Score method
    - <u>Weighted summation</u>
    - Basic variant
    - Analytic Hierarchy Process (AHP)



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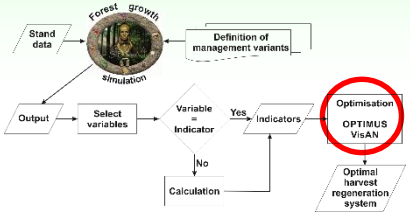
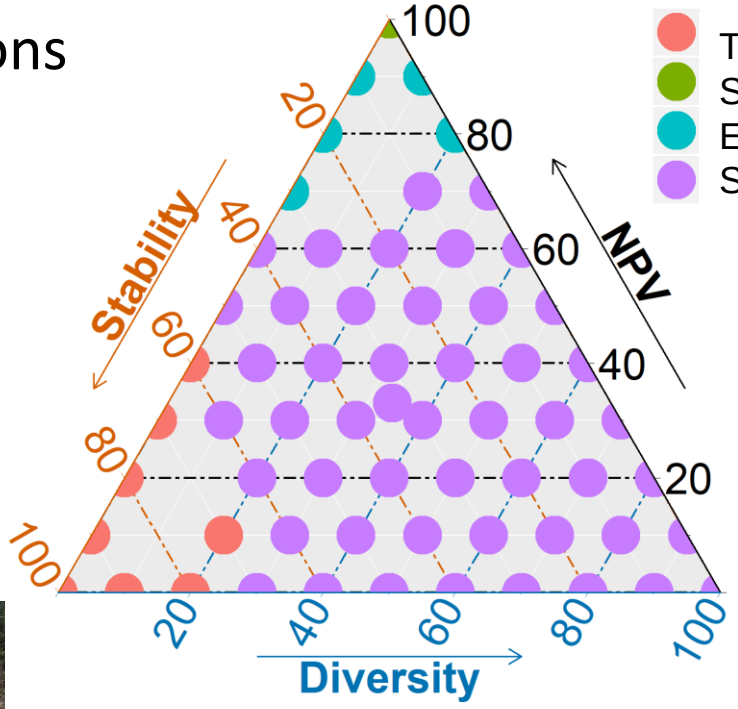


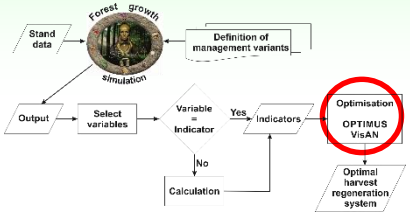
Impact
of
63 combinations
of
weights

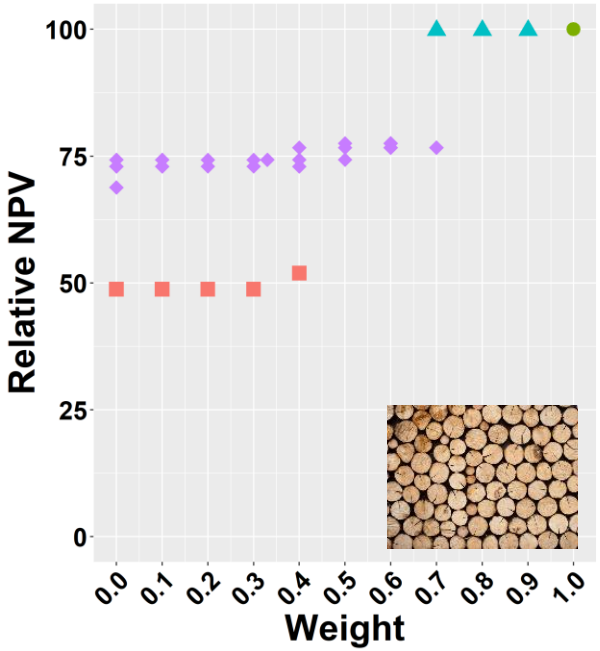


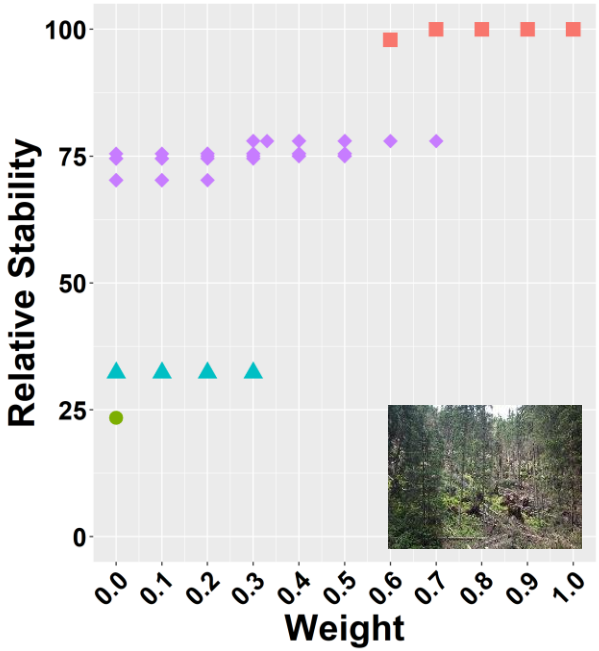
RegSystem

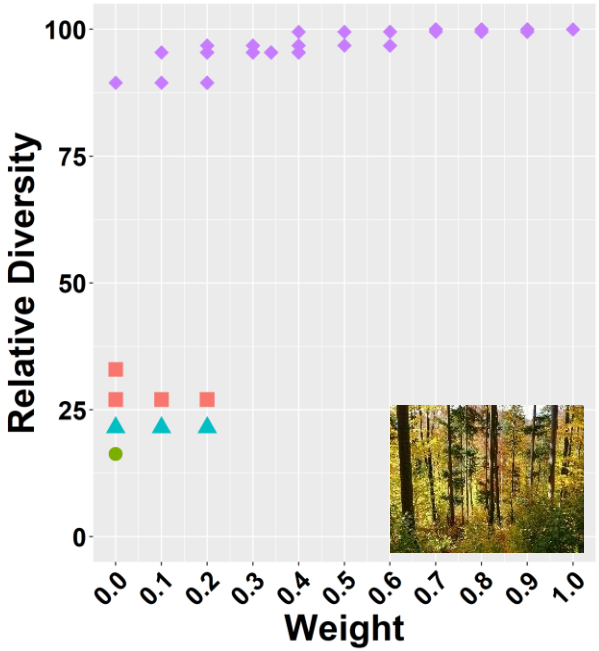
- Target diameter
- Small-scale clearcut
- Expanding small-scale shelterwood
- Selection cut

Multicriteria optimisation









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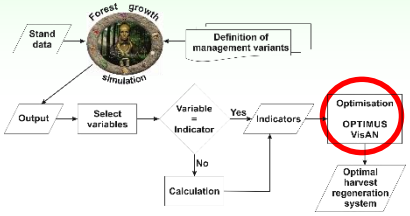

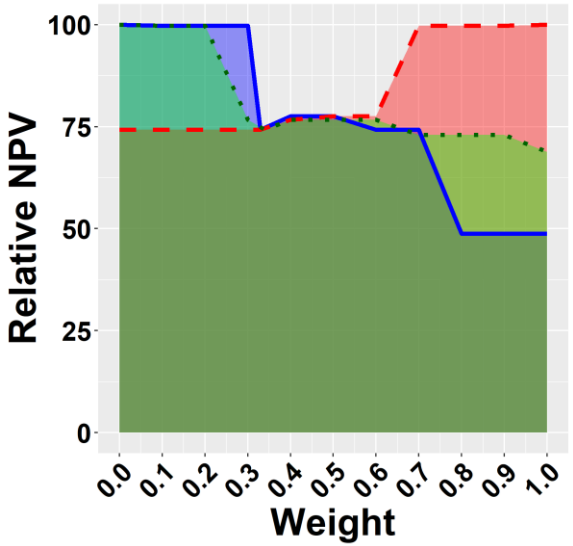

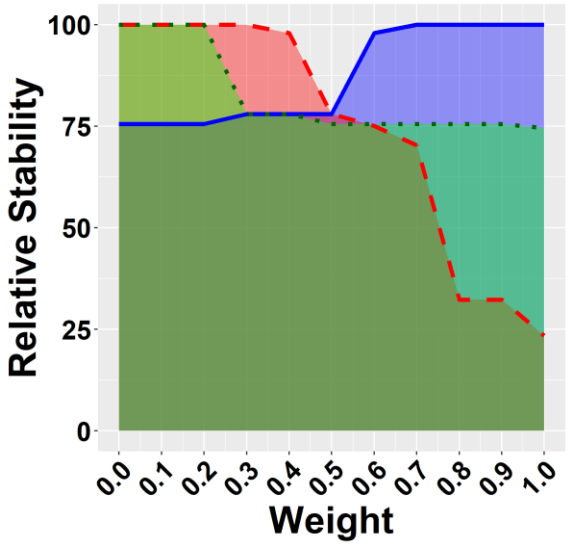

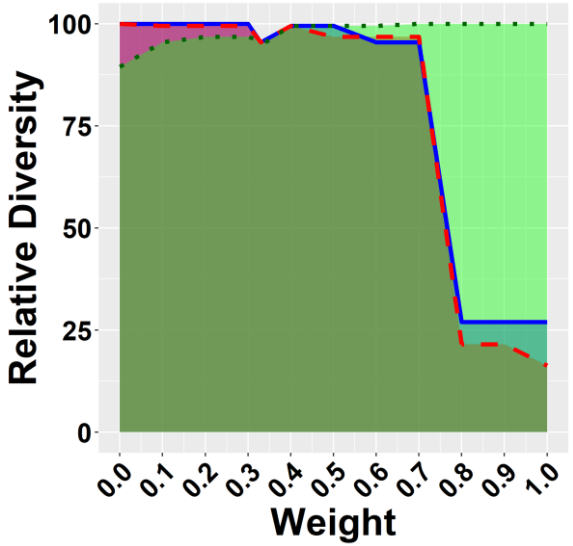

Red = Production
Blue = Stability
Green = Diversity

Merganičová et al. 2020: Searching for an optimal harvest-regeneration system using multi-criteria analysis. EFI FORMASAM Conference: Managing forests in the 21st century, March 03-05, 2020

Conclusion

Different management systems are preferable to maximise different forest functions

Optimisation of contradictory goals is required

Our optimisation tool enables us to analyse trade-offs between different forest functions and the impact of their weights on decision

Methods based on close-to-nature management systems were found most suitable for fulfilling the ensemble of selected functions in a secondary spruce forest

Thank you for your attention

This work was financed by the EFI FORMASAM 01/2018, and the Slovak Research and Development Agency under contracts No. APVV-15-0265, APVV-18-0305, APVV-16-0325, APVV-15-0714.