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
- Definition of management variants
- Forest growth simulation
- Select variables
- Variable = Indicator
  - Yes → Indicators
  - No → Calculation
- Output
- Optimisation
  - OPTIMUS VisAN
- Optimal harvest regeneration system
Stand data

Secondary spruce stand in central Slovakia

<table>
<thead>
<tr>
<th>Stand age</th>
<th>60 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species composition</td>
<td>Norway spruce (Picea abies) 80% European larch (Larix decidua) 10% Maple (Acer sp.) 5% Common beech (Fagus sylvatica) 5%</td>
</tr>
<tr>
<td>Elevation</td>
<td>430 - 470 m a.s.l.</td>
</tr>
<tr>
<td>Longitude</td>
<td>E 19°54′33.89</td>
</tr>
<tr>
<td>Latitude</td>
<td>N 48°32′55.09</td>
</tr>
<tr>
<td>Climatic region</td>
<td>slightly warm, and slightly moist climate</td>
</tr>
<tr>
<td>Mean air temperature in growing season</td>
<td>15.4°C</td>
</tr>
<tr>
<td>Mean precipitation total in growing season</td>
<td>600 mm</td>
</tr>
</tbody>
</table>
Management variants
- defined by treatment type, intensity, frequency

<table>
<thead>
<tr>
<th>Harvest-regeneration system</th>
<th>Regeneration form</th>
<th>Specification of regeneration variants</th>
<th>Number of variants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of cuttings per decade</td>
<td>No. of phases per decade</td>
</tr>
<tr>
<td>Even-aged</td>
<td>Clearcutting</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Small scale</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td></td>
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<tr>
<td></td>
<td>Large scale</td>
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<tr>
<td></td>
<td>Shelterwood</td>
<td>Large scale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small scale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expanding small scale</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Target diameter</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Selection</td>
<td>Single tree cutting</td>
<td></td>
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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

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Simulation output

Diversity

Stand stability

Wood production

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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

\[ H´ = -\sum_{i=1}^{N} p_i \cdot \log_2(p_i) \]

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
   - Weighted summation
   - Basic variant
   - Analytic Hierarchy Process (AHP)
Multicriteria optimisation

Impact of 63 combinations of weights

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Red = Production
Blue = Stability
Green = Diversity
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

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Thank you for your attention

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