Effect of annual rate on optimisation of harvest-regeneration systems in a mixed temperate forest of Central Europe

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Introduction

Forest ecosystems provide a wide spectrum of different products and services. The most important factor affecting the fulfilment of forest functions is the method of forest management. Several studies show a significant influence of the discount rate on the selection of the appropriate variant of forest management. The presented analysis examines the influence of different harvest-regeneration systems on the fulfilment of selected forest functions with regard to their maximisation in a multi-criteria process and the influence of the discount rate on the optimal harvest-regeneration system.

Study area

The study was carried out in a mixed forest located in the southern part of Central Slovakia.
Forest stand age: 60 years
Tree 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
Average air temperature in growing season	15.4°C
Average precipitation total in growing season	600 mm

Methods

The silvicultural systems arise from the regeneration methods which are broadly classified into two groups:

- even-aged methods (clear cutting, shelterwood)
- uneven-aged methods (selection system).

The forms and the variants of four harvest-regeneration systems applied in this study are described in Table 1.
We simulated the development of the virtual forest stand in SIBYLA (Simulator of Forest Biodynamics) using the predefined regeneration variants for a period equal to the specific regeneration period, i.e. the maximum length of the simulation was 130 years.
Based on the literature survey we selected four indicators for the multi-criteria decision making process aimed at optimising a harvest-regeneration system in the mixed forest with regard to the fulfilment of environmental, ecological and production forest functions:

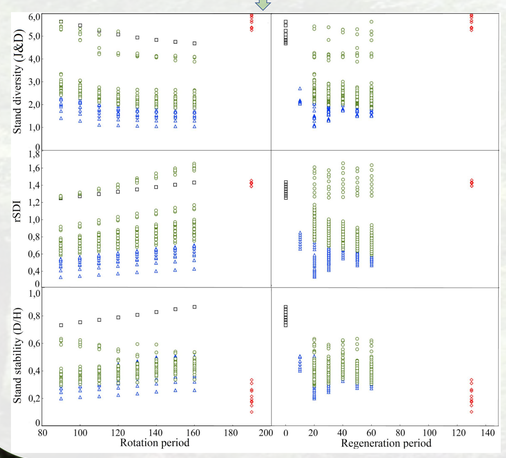
- stand diversity (Jaehne and Dohrenbusch 1997) - J&D,
- relative stand density index (Reineke 1933) - rSDI,
- stand stability (D/H),
- cumulative net present value (NPVC).

Table 1 Forms and variants of regeneration systems considered in the study.
Note: * Target diameter was determined on the base of natural conditions;
** Single tree cutting according to Liocourt´model of selection system;
*** Forest regeneration based on self-development

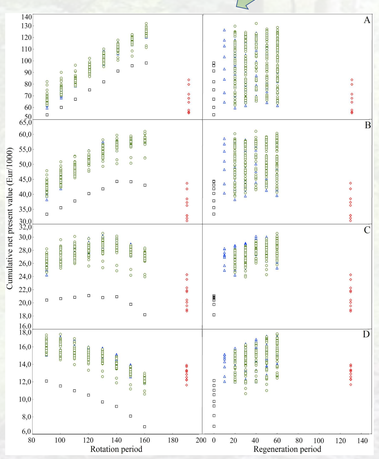
Harvest-regeneration system	Regeneration form	Specification of regeneration variants				Number of variants
		Number of cuttings per decade	Number of phases per decade	Regeneration period [years]	Rotation period [years]	
△ Clearcutting	Large scale (area > 2ha, width of cutting area > 2 mean stand heights)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

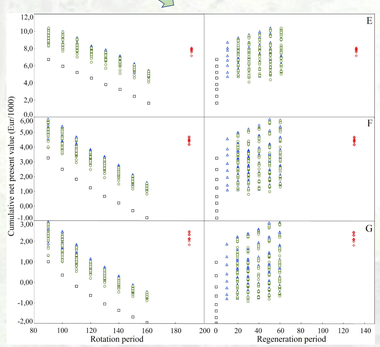
Results

Maximasing non-production function



Maximasing production function

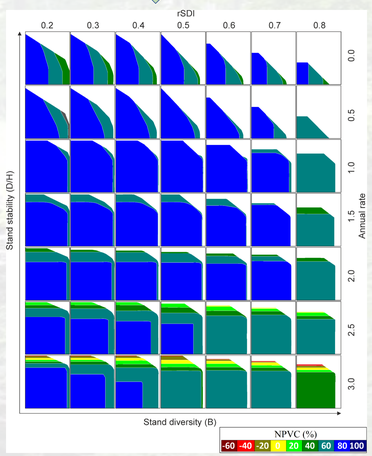




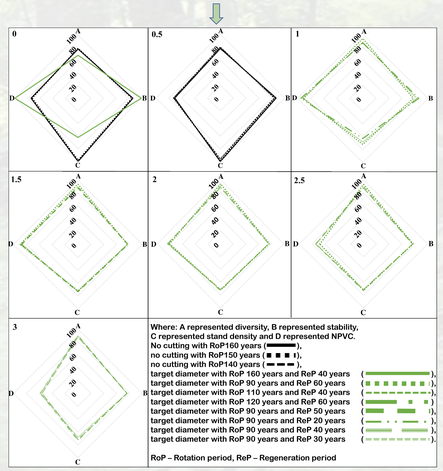
□ no cutting system, ○ shelterwood system, ◊ selection system, △ clearcutting system

Where following letters express the relationship between:
A: NPVC at a discount rate 0 % and RoP and ReP,
B: NPVC at a discount rate 0.5 % and RoP and ReP,
C: NPVC at a discount rate 1 % and RoP and ReP,
D: NPVC at a discount rate 1.5 % and RoP and ReP,
E: NPVC at a discount rate 2 % and RoP and ReP,
F: NPVC at a discount rate 2.5 % and RoP and ReP,
G: NPVC at a discount rate 3 % and RoP and ReP,
RoP – Rotation period, ReP – Regeneration period

Map of feasible goals



Visualisation of multicriteria solution



Where: A represented diversity, B represented stability, C represented stand density and D represented NPVC.
No cutting with RoP160 years ( ),
no cutting with RoP150 years ( ),
no cutting with RoP140 years ( ),
target diameter with RoP 160 years and ReP 40 years ( ),
target diameter with RoP 90 years and ReP 60 years ( ),
target diameter with RoP 110 years and ReP 40 years ( ),
target diameter with RoP 120 years and ReP 60 years ( ),
target diameter with RoP 90 years and ReP 50 years ( ),
target diameter with RoP 90 years and ReP 20 years ( ),
target diameter with RoP 90 years and ReP 40 years ( ),
target diameter with RoP 90 years and ReP 30 years ( ).

RoP – Rotation period, ReP – Regeneration period

Conclusions

Maximisation of the selected indicators characterising different forest functions showed that the methods based on close-to-nature harvest-regeneration systems are most appropriate, which is consistent with the statement of Pukkala (2016). In terms of forest stand production expressed by NPVC (cumulative net present value), we proved the significant influence of the discount rate on the fulfilment of this function. With the increasing discount rate, rotation period decreases and preferences of harvest-regeneration systems are oriented more to clearcutting methods. The differences between the optimal harvest-regeneration systems were smaller in multi-criteria synthesis than in maximisation analysis of one main objective represented by the specific indicator.

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