Multicriterial optimization of forest thinnings ?

Interactive decision maps – a simple solution to a complicated problem

Vladimír A. Bushenkov – Róbert Sedmák

Main research question

How to optimize thinnings in even-aged stands in order to simultaneously attain:

- **maximum of cumulative thinning revenues over the premature stage AND**
- **maximum of financial value of growing stock value at the beginning of regeneration AND**
- **maximum of stand static stability expressed by minimal height to diameter ratio (H/D) AND**
- **preserve maximal biodiversity of the thinned stand ?**

Case study – example of real application

Simulation study of multicriterial optimization of thinnings for 3 representative even-aged stands differenced by species composition – growth region Poľana

Stand species composition	Altitude m. a. s.	Age yr	Aspect	Slope °	Species	Species comp. %	Site index – mean height m
Changed	850	20	NW	35	Spruce	70	42
					Beech	30	30
Partially changed	925	20	SE	35	Spruce	60	36
					Fir	10	34
					Beech	25	28
					Maple	5	26
Natural	880	20	SE	40	Spruce	40	36
					Fir	5	34
					Beech	40	32
					Maple	10	30
					Ash	5	28

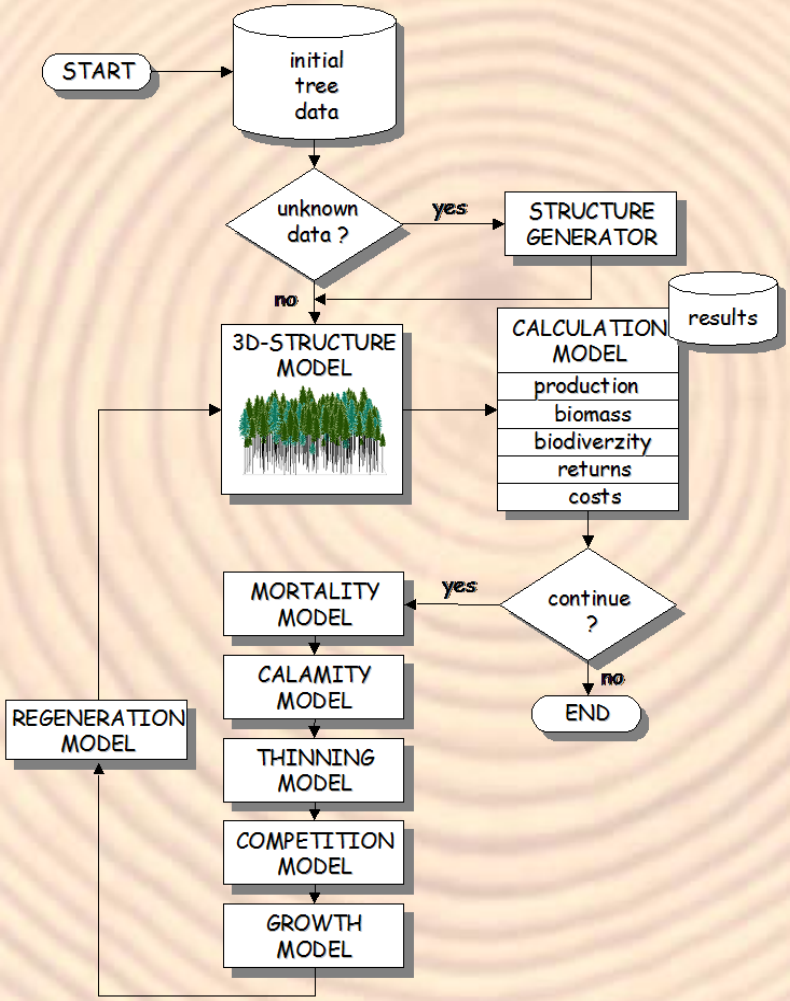
Simulation-optimization case study

Simulation in a dual sense:

- **the simulation of growth trajectories of the representative stands influenced by different thinnings by individual tree growth simulator Sibyla (Fabrika 2005)**

- **the simulation of thinking and behaviour of different types of decision makers (eg. different forest owners, managers, planners, stakeholders, etc.)**

Growth simulator Sibyla – simulation part of optimization process



30 stochastic growth projections from age 20 to age 90 years averaged for each stand and thinnig variant

330 thinning variants were explored for each stand

Thinnigs – subject optimization

3 thinning methods – understorey, overstorey and target trees
5-12 variants of thinning volumes
15 variants of different number and time arrangement of interventions

Variant	Intervention age															Total N
I	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	15
II	20	25	30	35	40	45	50	55	60	65	70	75	80		90	14
III	20	25	30	35	40	45	50	55	60	65	70		80		90	13
IV	20	25	30	35	40	45	50	55	60		70		80		90	12
V	20	25	30	35	40	45	50		60		70		80		90	11
VI	20	25	30	35	40		50		60		70		80		90	10
VII	20	25	30		40		50		60		70		80		90	9
VIII	20		30		40		50		60		70		80		90	8
IX	20		30		40		50		60		70		80			7
X	20		30		40		50		60				80			6
XI	20		30		40				60				80			5
XII	20				40				60				80			4
XIII	20				40				60							3
XIV	20				40											2
XV	20															1

3 methods x 15 arrangements x 5-12 volumes = 330 different thinnig variants

Types of decision makers (DM)

(I) Economic oriented DM – focused on timber and biomass production and trade, other non-production ecosystem services (ES) taking into account only to a limited extent

(a) concerning regard to ecological stability

(b) not concerning regard to ecological stability

(II) Environment oriented DM – aimed to ecological stability and sustainability of forest in order to assure the environmental protection (water and soil protection, carbon sequestration, etc.) considering the timber and biomass production as secondary ES

(a) concerning regard to ecological stability

(b) not concerning regard to ecological stability

(III) Nature conservation oriented DM – concentrated on forest protection, biodiversity and nature conservation considering the timber and biomass production as almost completely irrelevant ES

(a)concerning regard to ecological stability

(b)not concerning regard to ecological stability

Interactive Decision Maps (IDM) – How it works ?

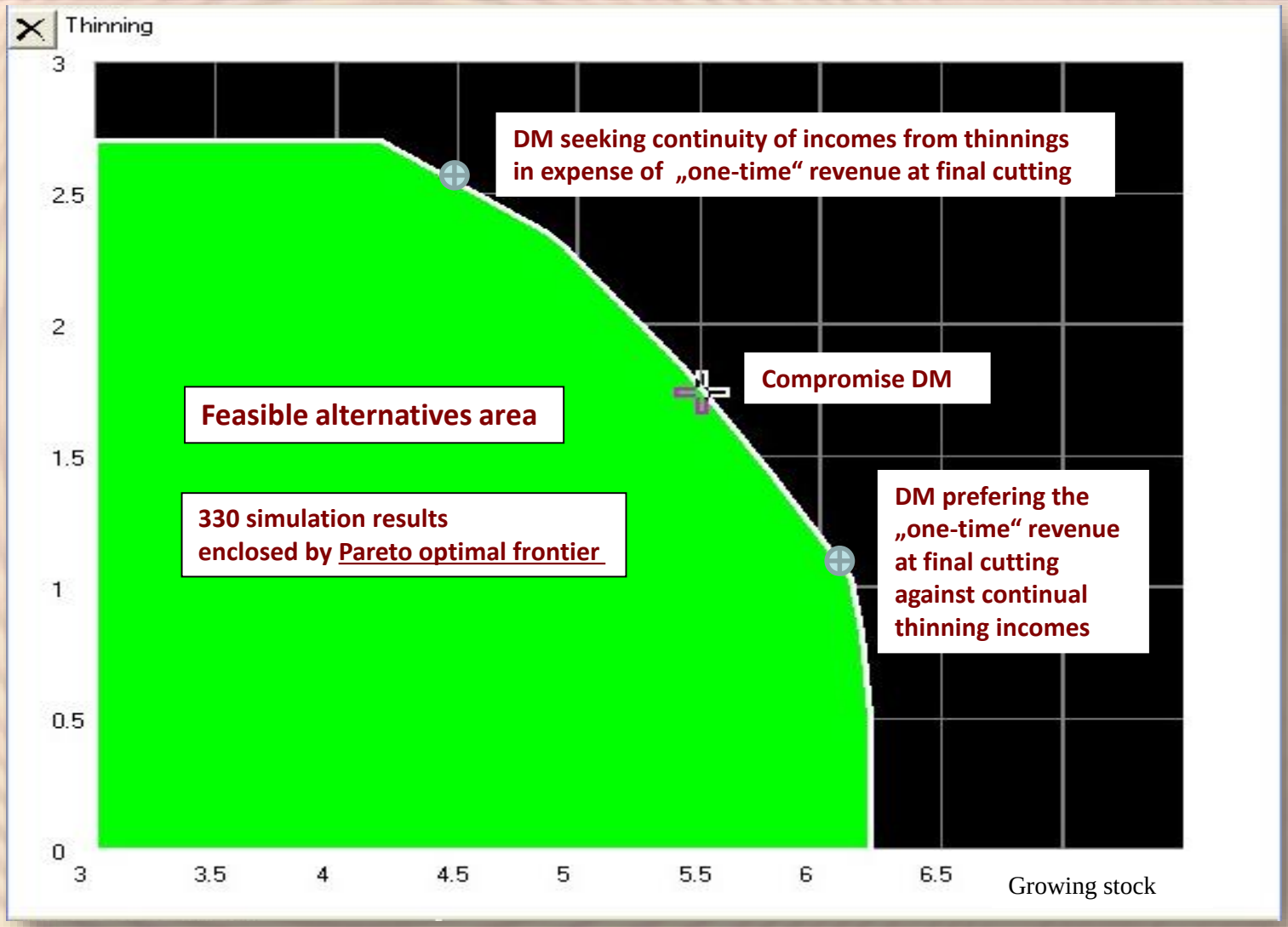
Three main steps:

1. **Generation of decision maps** = defining the Pareto optimal frontier of feasible solutions = defining a set of possible reasonable goals in multidimensional space for rationally based DM

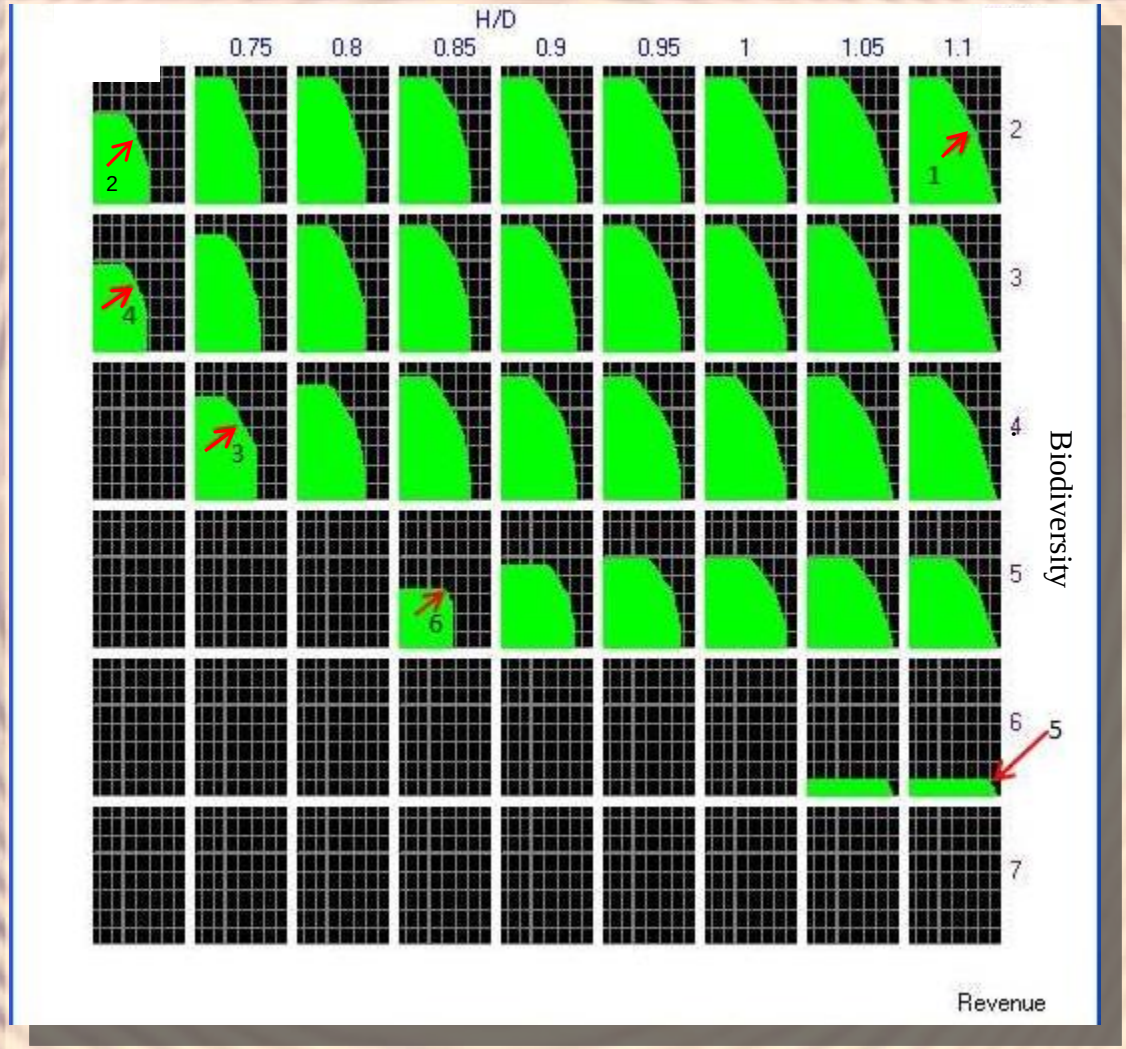
2. **Setting single the most prefered goal on Pareto frontier** based on additional knowledge about the solved problem and personal preferences of particular DM

3. **Selection of the Pareto optimal solution** = selection of decision alternative located near identified Pareto optimal goal

Interactive Decision Maps – Biobjective example



Interactive Decision Maps – Four dimensional case



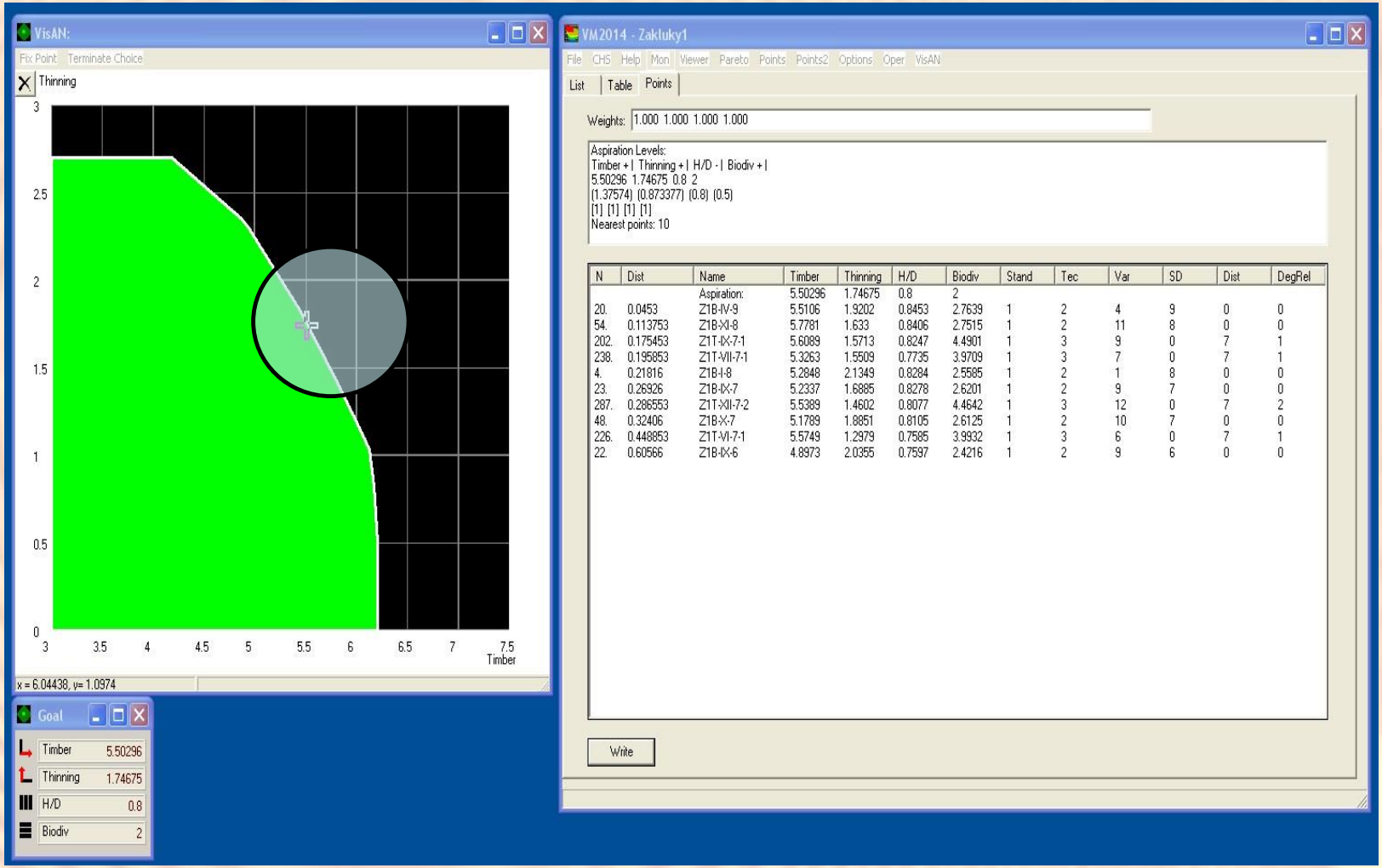
Four objectives:

- **Maximization of growing stock value at age 90 years**
- **Maximization of cumulative thinning incomes over the period 20-90 years**
- **Minimization of H/D ratio = maximization of stand static stability**
- **Maximization of biodiversity index**

Six decision makers

1 - economist without concern
2 - economist with concern
3 - environmentalist without concern
4 - environmentalist with concern
5 - conservationist without concern
6 –conservationist with concern

Interactive Decision Maps – Sample of results – Changed species composition



N	Dist	Name	Timber	Thinning	H/D	Biodiv	Stand	Tec	Var	SD	Dist	DegRel
		Aspiration:	5.50296	1.74675	0.8	2						
20.	0.0453	Z1B-IV-9	5.5106	1.9202	0.8453	2.7639	1	2	4	9	0	0
54.	0.113753	Z1B-XI-8	5.7781	1.633	0.8406	2.7515	1	2	11	8	0	0
202.	0.175453	Z1T-IX-7-1	5.6089	1.5713	0.8247	4.4901	1	3	9	0	7	1
238.	0.195853	Z1T-VII-7-1	5.3263	1.5509	0.7735	3.9709	1	3	7	0	7	1
4.	0.21816	Z1B-I-8	5.2848	2.1349	0.8284	2.5585	1	2	1	8	0	0
23.	0.26926	Z1B-IX-7	5.2337	1.6885	0.8278	2.6201	1	2	9	7	0	0
287.	0.286553	Z1T-XII-7-2	5.5389	1.4602	0.8077	4.4642	1	3	12	0	7	2
48.	0.32406	Z1B-X-7	5.1789	1.8851	0.8105	2.6125	1	2	10	7	0	0
226.	0.448853	Z1T-VI-7-1	5.5749	1.2979	0.7585	3.9932	1	3	6	0	7	1
22.	0.60566	Z1B-IX-6	4.8973	2.0355	0.7597	2.4216	1	2	9	6	0	0

Interactive Decision Maps – Sample of results – Changed species composition

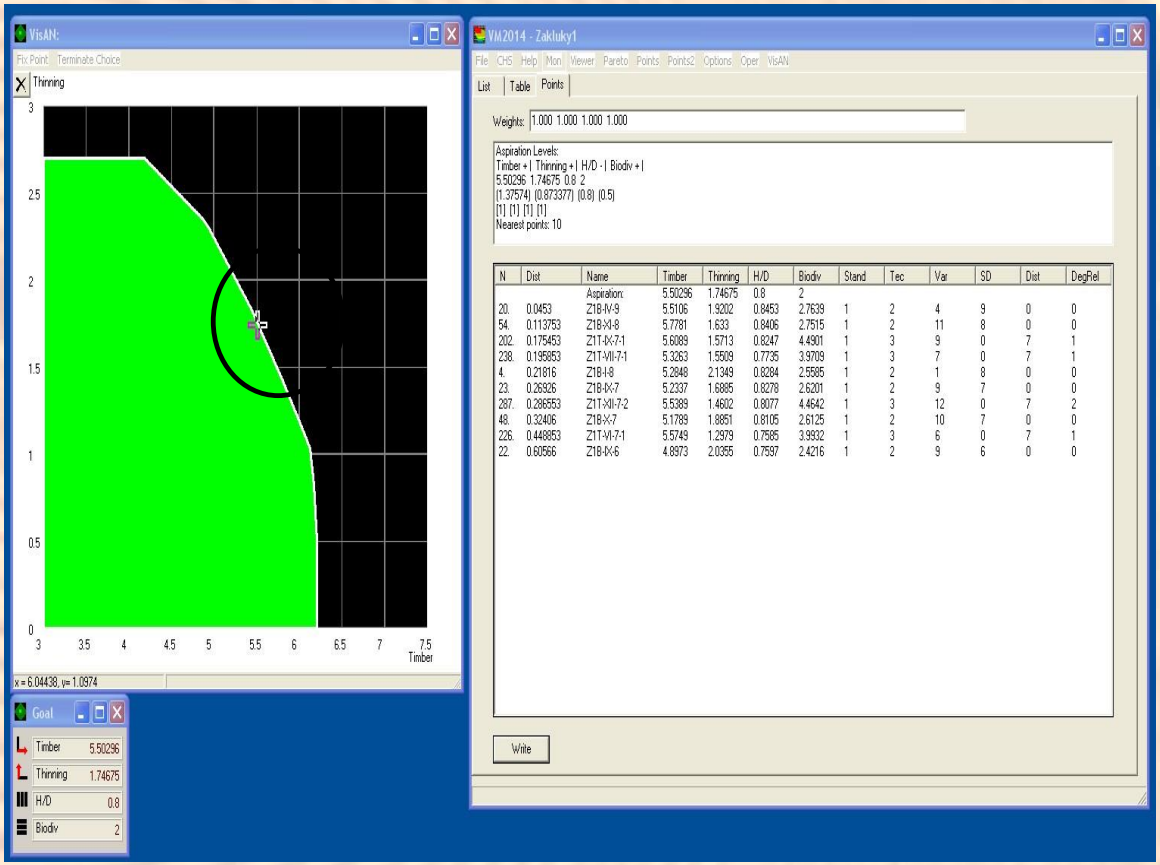
DM type	Forest stability concern	Thinnig method	Timing variant	Target stocking	Target tree spacing	Degree of aid	Silviculture description and recommendations
Economist	no	O	IV-V	0.8	-	-	Overstorey thinning, negative selection, 2x per decade till age 50, then 1x per decade, systematic tending more frequent at younger stages, less frequent at older stages, medium intensity at optimal stocking level
	yes	U	IX-X	0.6-0.7	-	-	Understorey thinning, negative selection,1x per decade, systematic less frequent heavy thinnings at critical stocking level
		U	I-IV	0.8-0.9	-	-	Understorey thinning, negative selection, 2x per decade, systematic frequent slight to optimal thinnings above or at optimal stocking level
Environmentalist	no	T	IX-XII	-	7-8	1,2	Target tree thinning, positive selection, 1x per decade, systematic less frequent interventions, higher number of supported target trees with low or medium degree of aid
	yes	T	I-III	-	8	2	Target tree thinning, positive selection, 2x per decade, systematic very frequent interventions, higher number of supported target trees with medium degree of aid
Conservationist	no	T	XV	-	7	3	Target tree thinning, positive selection, only one extremely heavy intervention at age 20, high number of one-time supported target trees with high degree of aid,
	yes	T	XIII	-	8-10	2,3	Target tree thinnings, positive selection, two interventions at young stage, lower number of target trees supported by higher degree of aid

Interactive Decision Maps – main advantages

Simple
Intuitive
Complex
Feasible
Reasonable
Rational

Easy-to-use

Multiobjective optimization



Thank you for your attention !