ONEforest

WP8: Multi-Criteria Decision Support System

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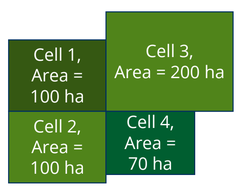
Introduction

WP8 develops a Multi-Criteria Decision Support System (MCDSS), which provides information to stakeholders on the forest-wood value chain based on a combination of (stakeholder) objectives and quantified impacts. The aimed solutions will harmonize the interests of all stakeholders by assuming a virtual superior decision maker who is optimizing an overall objective (sum of all stakeholder objectives). The MCDSS serves to achieve resilient forest production systems. Actors will be empowered to understand the far-reaching consequences of their decisions in a multicriteria decision-making environment.

Initial stand	Species 1	Species 2	...	...
	share	share	share	
1	10	10	...	...
2	10	10	...	...
3	50	50	...	...
...	...	...	...	...
	0	100	...	...

Initial Stand	Management option	Indicators ≈ 20				
		0	1	2	...	8
1	*A*	0	1	1	...	5
1	*B*	1	0	1	...	0
1	*C*	1	1	1	...	1
1	*D*	1	2	0	...	0
2	*A*	...	...	...	...	...
2	*B*	...	...	...	...	...
2	*C*	...	...	...	...	...
2	*D*	...	...	...	...	...
...		...	...	...	...	...
	A	...	...	...	...	...
	B	...	...	...	...	...
	C	...	...	...	...	...
	D	...	...	...	...	...



Cell	Management option
1	A
2	B
3	A
4	D

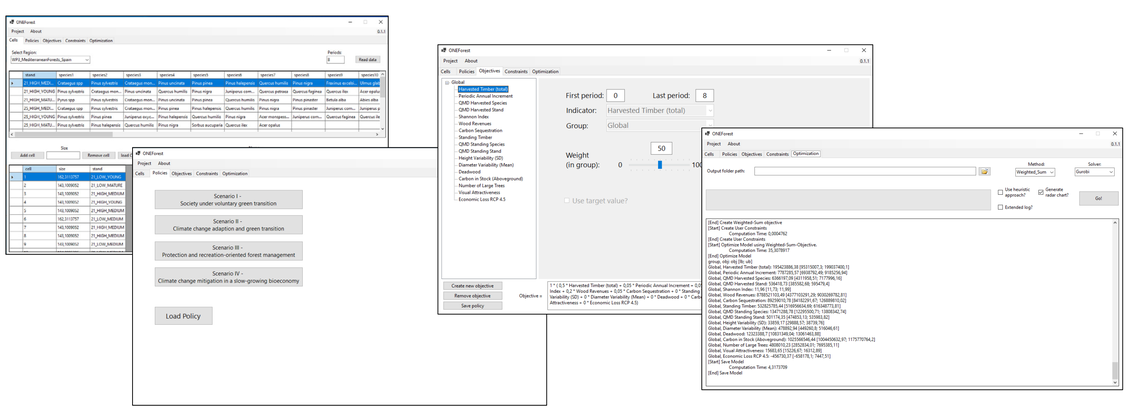
Management options:

A: low intensity
B: business as usual
C: climate adapted forestry
D: intensified management

Prototype of the MCDSS

Main features:

- Replication of forest areas on the basis of four representative case study regions (Estonia, Switzerland, Spain, Germany)
- Consideration of up to 20 indicators, which can be weighted individually in a weighted sum objective
- Utilization of user constraints and target values
- Optimization based on a Mixed Integer Linear Program (MILP)
- Extensive numerical output and graphical analysis with radar charts



Methodology

Mathematical Model

Maximize weighted sum objective:

$$\max y^*_{o,g} = \frac{y_{o,g} - \underline{Y_{o,g}}}{\overline{Y_{o,g}} - \underline{Y_{o,g}}} \qquad \forall\, g \in G, o \in O_g$$

$$y_{(i,free),g} = v_{i,g} \qquad \forall\, g \in G, i \in I_g^{free}$$

Indicator constraints:

harvested timber
$$v_{(harvested\ timber),g} = \sum_{t\in T}\sum_{c\in C_g}\sum_{m\in M} x_{c,m} \cdot B^{HarvestedTimber}_{c,m,t} \cdot F_c \qquad \forall\, g \in G$$

periodic annual increment
$$v_{(periodic\ annual\ increment),g} = \sum_{t\in T}\sum_{c\in C_g}\sum_{m\in M} x_{c,m} \cdot B^{PeriodicAnnualIncrement}_{c,m,t} \qquad \forall\, g \in G$$

Carbon-sequestration
$$v_{(c-sequestration),g} = \sum_{t\in T}\sum_{c\in C_g}\sum_{m\in M} x_{c,m} \cdot B^{Carbon}_{c,m,t} \cdot F_c \qquad \forall\, g \in G$$

Standing timber
$$v_{(standing\ timber),g} = \sum_{t\in T}\sum_{c\in C_g}\sum_{m\in M} x_{c,m} \cdot B^{Standing}_{c,m,t} \cdot F_c \qquad \forall\, g \in G$$

Large trees
$$v_{(large\ trees),g} = \sum_{t\in T}\sum_{c\in C_g}\sum_{m\in M} x_{c,m} \cdot B^{Trees}_{c,m,t} \cdot F_c \qquad \forall\, g \in G$$

... ...

Shannon Index
$$v_{(shannon\ index),g} = -\sum_{t\in T}\sum_{c\in C_g}\sum_{m\in M}\sum_{s\in S} x_{c,m} \cdot F_{c,m,s,t} \cdot \ln\left(x_{c,m} \cdot F_{c,m,s,t}\right) \qquad \forall\, g \in G$$

=> Approximation through linearization necessary!

Assumption: shannon index reaches the maximum if following statement applies:

$$\sum_{c\in C_g}\sum_{m\in M} x_{c,m} \cdot F_{c,m,s,t} = \frac{1}{|S|} \qquad \forall t \in T, s \in S$$

$$\min \hat{y} = \sum_{t\in T}\sum_{s\in S}(u_{t,s} + o_{t,s})$$

s.t.:
$$\sum_{c\in C_g}\sum_{m\in M} x_{c,m} \cdot F_{c,m,s,t} + u_{t,s} - o_{t,s} = \frac{1}{|S|} \qquad \forall s \in S, t \in T$$
$$u_{t,s} \le s_{t,s} \qquad \forall s \in S, t \in T$$
$$o_{t,s} \le 1 - s_{t,s} \qquad \forall s \in S, t \in T$$
$$0 \le o_{t,s}, u_{t,s} \le 1 \qquad \forall s \in S, t \in T$$
$$s_{t,s} \in \{0;1\} \qquad \forall s \in S, t \in T$$

Selecting one management option for each cell

$$\sum_{m\in M} x_{c,m} = 1 \qquad \forall c \in C$$

$$x_{c,m} \in \{0;1\} \qquad \forall c \in C, m \in M$$

Hard constraints, e.g.

$$\sum_{c\in C_g}\sum_{m\in M} x_{c,m} \cdot B^{Trees}_{c,m,t} \begin{matrix}\le \\ \ge\end{matrix} Limit \qquad \forall\, t \in T$$

...

Indices				
t - index of the period	c – index of the cell	g – index of a group	m – index of management option	s – index of species

Sets					
M	Management options	C	Cells	O_g	objectives o considered in group g
I_g^{free}	indicators i considered as objective in group g	C_g	Cells in group g		
T	Periods	G	Groups		

Input: Parameters	
$\underline{Y_{o,g}}$	lower bound for objective o in group g
$\overline{Y_{o,g}}$	upper bound for objective o in group g
$B^{HarvestedTimber}_{c,m,t,a}$	Harvested amount of timber in m^3 of species s of assortment a in period t if management option m is applied in cell c
$B^{PeriodicAnnualIncrement}_{c,m,t}$	Volume increment per period t for cell c with management option m
$B^{Carbon}_{c,m,t}$	Carbon sequestration in period t if management option m is applied in cell c
$B^{standing}_{c,m,t}$	Standing timber in period t if management option m is applied in cell c
$B^{Trees}_{c,m,t}$	Number of large trees in period t if management option m is applied in cell c
F_c	Size of cell c in hectare

Output: Variables	
$y^*_{o,g}$	normalized value of objective o in group g
$v_{i,g}$	value of indicator i in group g
$x_{c,m}$	=1, if management option m is applied for cell c, otherwise 0

Results

The mathematical model attempts to realize the prioritization of indicators based on the entered weights in the best possible way. As a result of the optimization the user gets an assignment of a management option to each of the cells created. For each indicator the lower and upper bound are calculated and its specific value that results out of the chosen management options. This can be analyzed in a radar chat which is part of the output. For the CSR Catalonia the geo-coordinates of the cells were known, enabling the distribution of the management options to be displayed graphically on a map.

	A	B	C	D	E
1	Objective	0,7553			
2	Computation Time	68,3520616			
3	MIP Gap	NaN			
4					
5	group	obj	lb	ub	obj/value
6	Global	Shannon Index	11,73378668	11,9944512	11,89346649
7	Global	Visual Attractiveness	15226,6713	16312,8882	16265,97758
8	Global	Number of Large Trees	2852834,009	7695385,115	7491898,613
9	Global	Deadwood	10831349,04	13061463,88	12371772,98
10	Global	QMD Standing Stand	474853,1271	535983,8234	507564,084
11	Global	QMD Standing Species	12295500,71	13808342,74	13413874,71
12	Global	Standing Timber	516956634,7	616348773,8	567409297,4
13	Global	Harvested Timber (total)	95315007,3	199037400,1	165055326,1
14	Global	Periodic Annual Increment	6918751,489	9135256,945	8236665,088
15	Global	QMD Harvested Species	4311958,507	7177996,161	5306642,03
16	Global	QMD Harvested Stand	385582,6796	595479,4034	433882,1608
17	Global	Height Variability (SD)	29888,5675	38739,7614	35898,11194
18	Global	Diameter Variability (Mean)	449260,8015	516046,6055	482516,6468
19	Global	Carbon in Stock (Aboveground)	1004450633	1175770764	1071615319
20	Global	Carbon Sequestration	84182291,67	126889810	99477369,96
21	Global	Economic Loss RCP 4.5	-658178,1021	74472658	-89413,9097
22	Global	Wood Revenues	4377103291	9030269783	6161616134
23					
24	stand	cell	mgmt opt	plot id	
25	21_LOW_YOUNG	1	B	80004	
26	21_LOW_MATURE	2	B	80006	
27	21_HIGH_MEDIUM	3	A	80012	
28	21_HIGH_YOUNG	4	B	80014	
29	21_HIGH_MEDIUM	5	A	80015	
30	21_LOW_MEDIUM	6	A	80019	
31	21_HIGH_MEDIUM	7	A	80020	
32	21_HIGH_MEDIUM	8	A	80021	
33	21_LOW_MEDIUM	9	A	80022	
34	21_LOW_MEDIUM	10	A	80024	
35	21_LOW_MEDIUM	11	A	80025	
36	21_LOW_MEDIUM	12	A	80027	
37	21_LOW_MEDIUM	13	A	80028	
38	21_LOW_MEDIUM	14	A	80029	
39	21_LOW_MEDIUM	15	A	80030	

Numerical output with objective values and assignment of management options to cells

Radar chart with range of indicator values and optimization result

Distribution of management options in the CSR Catalonia

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