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PUERTO VARAS, CHILE

A PARTICIPATORY FOREST MANAGEMENT PLANNING APPROACH SUPPORTED BY MULTICRITERIA DECISION METHODS

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THE NEED TO DECOMPOSE THE PROBLEM…

- LANDSCAPE LEVEL MANAGEMENT PLANNING OF FOREST AREAS TYPICALLY INVOLVES SEVERAL STAKEHOLDERS WITH MULTIPLE INTERESTS, WHICH COMPLICATES THE DEVELOPMENT OF JOINT LANDSCAPE LEVEL MANAGEMENT PLANS AND THE PROVISION OF ECOSYSTEM SERVICES.

- THE DECOMPOSITION TECHNIQUE IS APPLIED IN FOREST OPTIMIZATION PROBLEMS, WITH LARGE NUMBER OF DECISION VARIABLES.

- IT'S USED TO SUPPORT AN ECONOMIC PLANNING PROCESS AT DISTINCT LEVELS: PLANNING ENTITIES (UPPER LEVEL) AND OTHER STAKEHOLDERS (LOWER LEVEL).

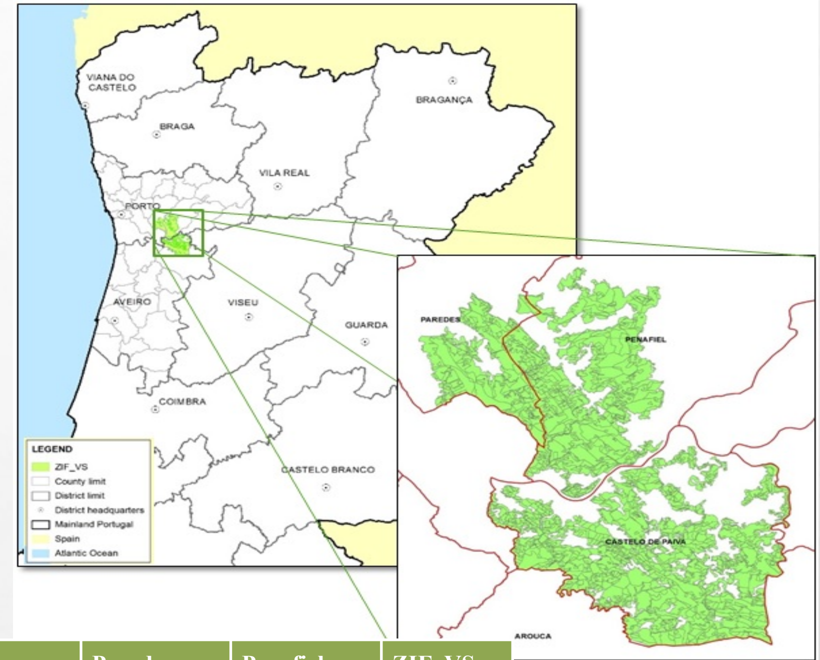
- THUS, MULTIOBJECTIVE OPTIMIZATION TOOLS (EG. PARETO FRONTIER VISUALIZATION TECHNIQUES) ARE USED TO SUPPORT NEGOTIATIONS.

CASE STUDY

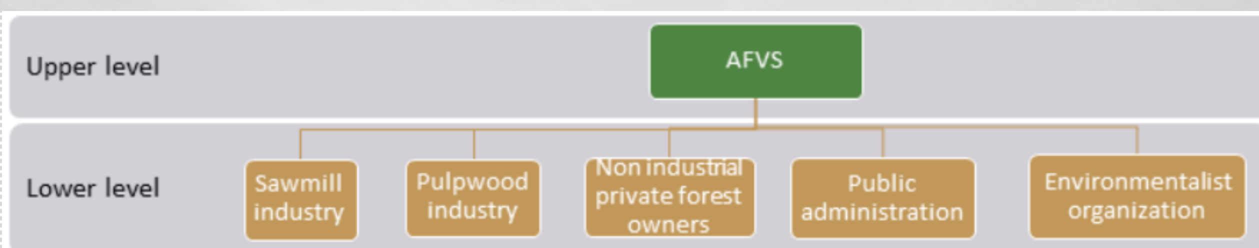
About 14 388 ha with 1976 management units and 330 landowners,

Dominated by eucalypt pure stands (66%) and mixed stands of eucalypt and maritime pine (33%). The remaining area is occupied by hardwoods, specially chestnuts.

- Ecosystem services:
  - Eucalypt pulpwood,
  - Maritime pine saw logs;
  - Chestnut saw logs ;
  - Carbon storage and
  - Volume of ending inventory.

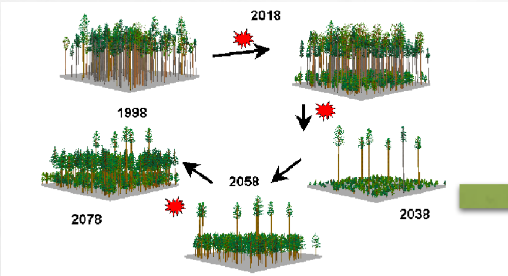


	Paiva	Paredes	Penafiel	ZIF_VS
Forested area (ha)	7626.27	2138.74	5085.38	14832
Number of management units	1293	235	654	2182
MU average area (ha)	5.9	9.1	7.8	6.8
MU max area (ha)	100.2	99.5	97.47	100.2
MU min area (ha)	0.5	0.5	0.5	0.5



WORKFLOW

FMA simulation for all stands in each county (block)



Forest evolution scenarios, ES provision

Mathematical model building

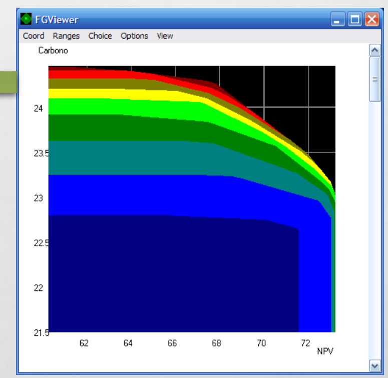
$$\sum_{j=1}^{M_i} x_{ij} = a_i,\ i=1,\dots,N$$

$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} pinew_{ijt} x_{ij} = PineW_t,\ t=1,\dots,T$$

$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} eucalyptw_{ijt} x_{ij} = EucalyptW_t,\ t=1,\dots,T$$

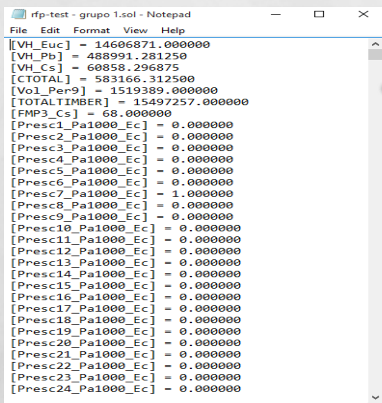
$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} chestnutw_{ijt} x_{ij} = ChestnutW_t,\ t=1,\dots,T$$

Ecosystem services tradeoffs analysis



Negotiation process

Forest Management Plan



rfp-test - grupo 1.sol - Notepad

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[VH_Pb] = 488991.281250
[VH_Cs] = 60858.296875
[CTOTAL] = 583166.312500
[Vol_Per9] = 1519389.000000
[TOTALTIMBER] = 15497257.000000
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SADFLOR - A WEB-BASED FOREST AND NATURAL RESOURCES DSS

ForChange

UNIVERSIDADE DE ÉVORA

CIMA

- 84000 stand-level prescriptions
- 90-year planning horizon
- 1 year periods

LP PROBLEM FORMULATION

1st step

LOWER LEVEL

$$\left.\begin{array}{l}(Wood_{Paiva},\ Carb_{Paiva},\ VEI_{Paiva})\\ (Wood_{Paredes},\ Carb_{Paredes},\ VEI_{Paredes})\\ (Wood_{Penafiel},\ Carb_{Penafiel},\ VEI_{Penafiel})\end{array}\right\} \rightarrow \max$$

LOWER AND UPPER LEVEL

$$\sum_{j=1}^{M_i} x_{ij} = a_i,\ i \in I_k$$

$$W_{kt} = \sum_{i \in I_k} \sum_{j=1}^{M_i} w_{ijt} x_{ij},\quad t = 1,\ldots,T$$

$$Wood_k = \sum_{t=1}^{T} W_{kt}$$

$$CARB_{kt} = \sum_{i \in I_k} \sum_{j=1}^{M_i} carb_{ijt} x_{ij},\quad t = 1,\ldots,T$$

$$Carb_k = \sum_{t=1}^{T} CARB_{kt} \ / T$$

$$VEI_k = \sum_{i \in I_k} \sum_{j=1}^{M_i} vei_{ij} x_{ij}$$

$$x_{ij} \geq 0,\quad \forall i, j$$

2nd step

UPPER LEVEL

$Wood_{VS} \rightarrow \max$, $Carb_{VS} \rightarrow \max$, and $VEI_{VS} \rightarrow \max$

$$Wood_{VS} = \sum_{k=1}^{K} Wood_k$$

$$Carb_{VS} = \sum_{k=1}^{K} Carb_k$$

$$VEI_{VS} = \sum_{k=1}^{K} VEI_k$$

3rd step

UPPER LEVEL USING DECOMPOSITION METHOD

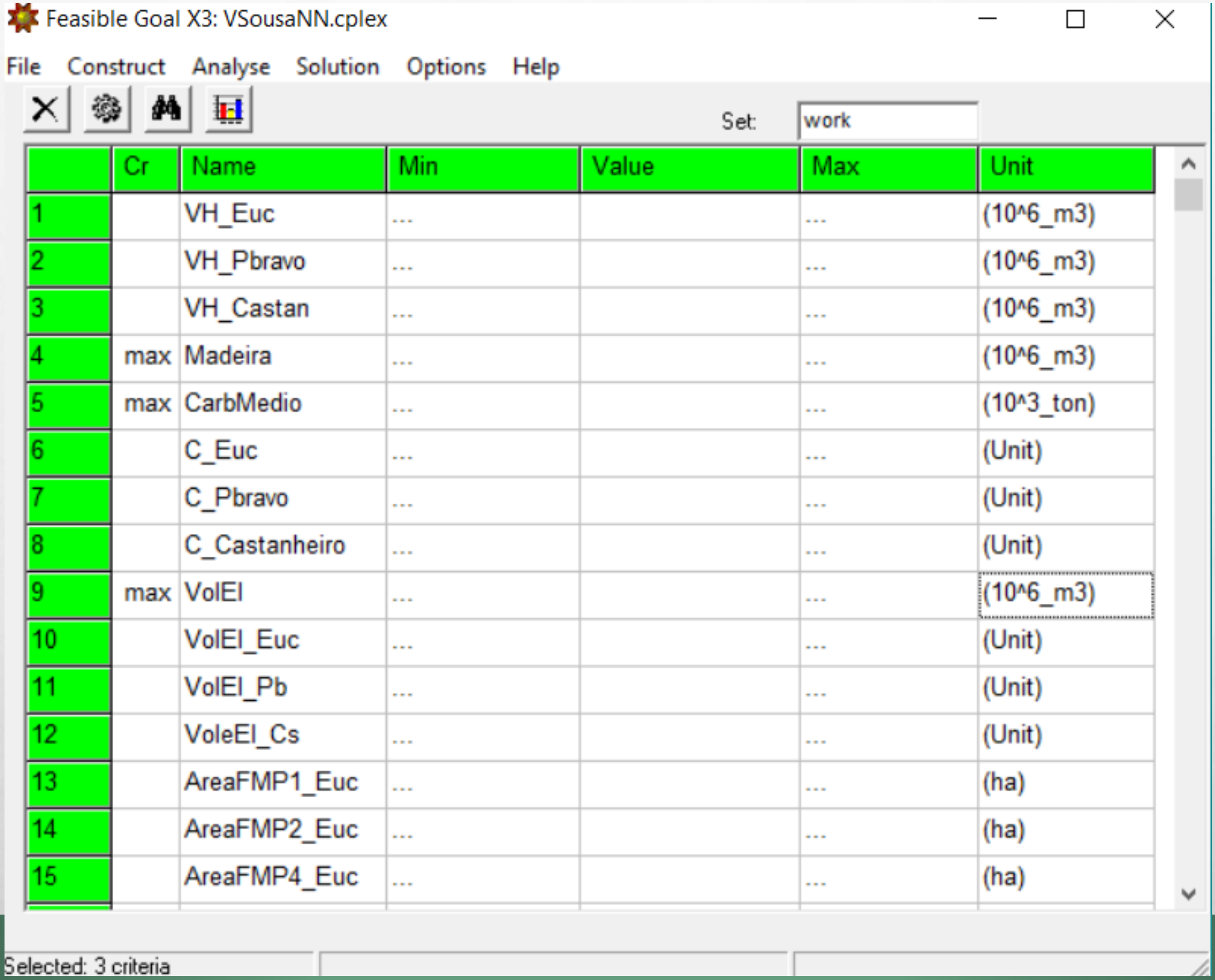
$$a_i^{Paiva} Wood_{Paiva} + b_i^{Paiva} Carb_{Paiva} + c_i^{Paiva} VEI_{Paiva} \leq d_i^{Paiva},\quad i = 1,\ldots,m^{Paiva},$$

$$a_i^{Pared} Wood_{Paredes} + b_i^{Pared} Carb_{Paredes} + c_i^{Pared} VEI_{Paredes} \leq d_i^{Pared},\quad i = 1,\ldots,m^{Pared},$$

$$a_i^{Penaf} Wood_{Penafiel} + b_i^{Penaf} Carb_{Penafiel} + c_i^{Penaf} VEI_{Penafiel} \leq d_i^{Penaf},\quad i = 1,\ldots,m^{Penaf},$$

where a_i^k, b_i^k, c_i^k and d_i^k stand for the coefficients and the independent term of linear constraint i used to approximate the Pareto frontier of the sub area k problem, while m^k stands for the number of linear constraints used for this approximation. In this application a total of 142 linear inequations was used to approximate the Pareto frontier of the 3 sub problems.

PARETO FRONTIER MODULE


Feasible Goal X3: VSousaNN.cplex

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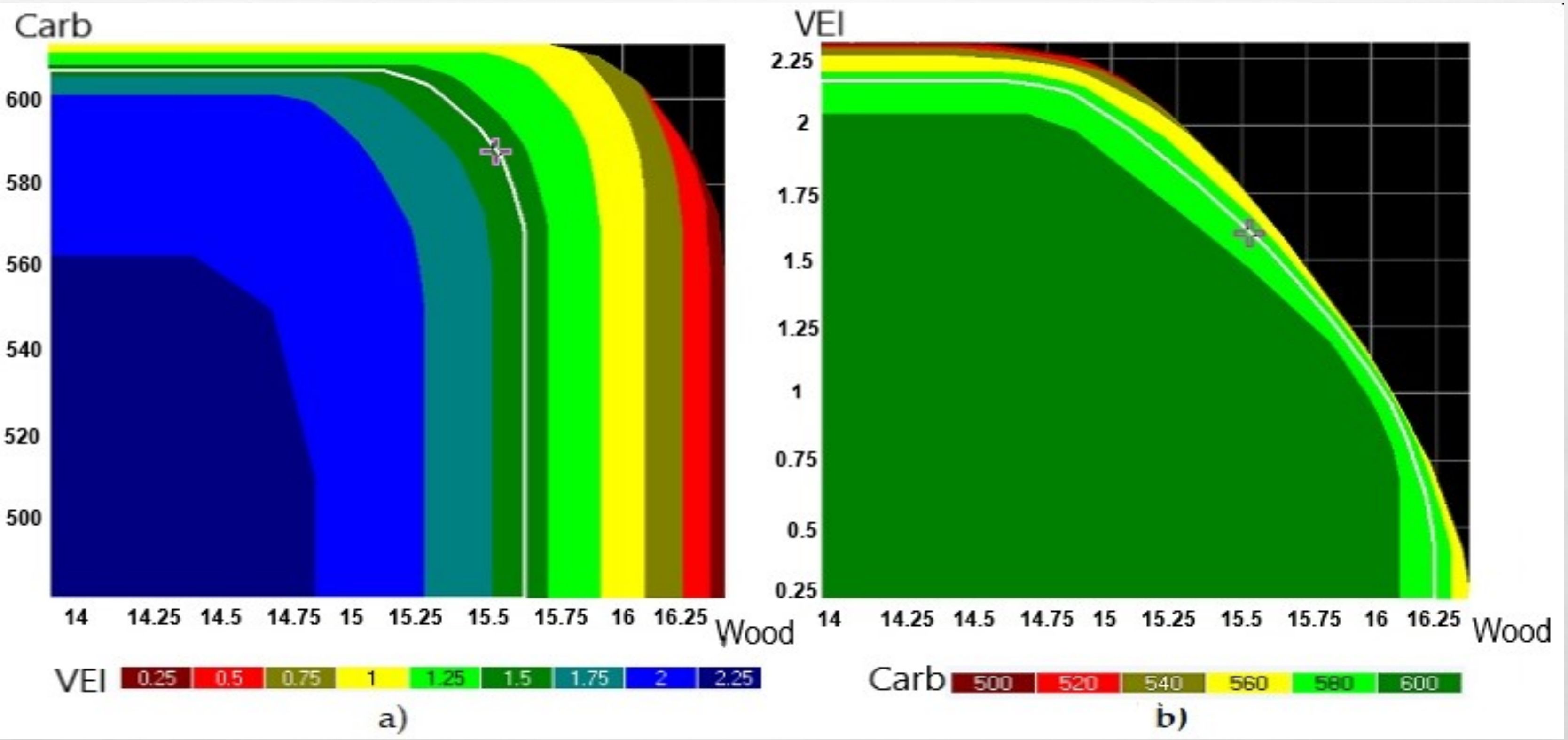
Set: work

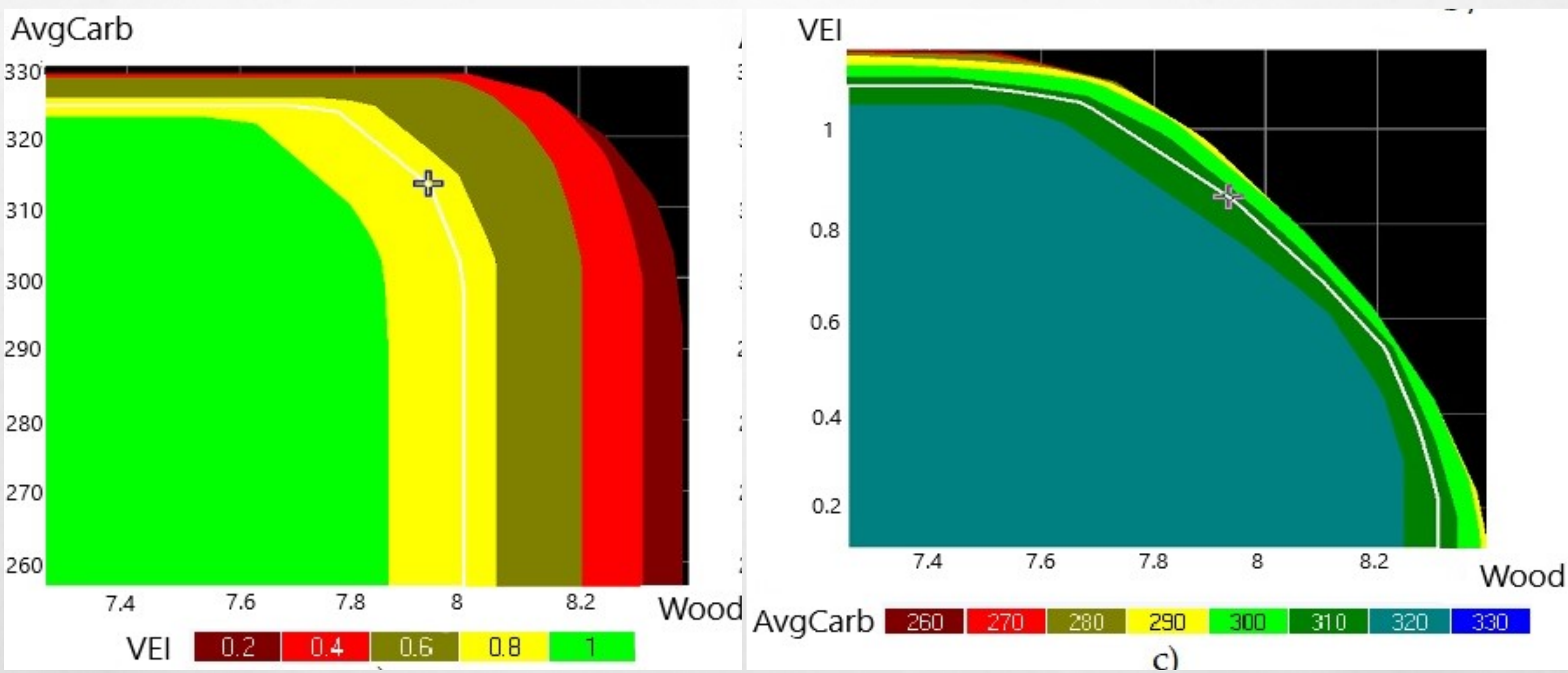
	Cr	Name	Min	Value	Max	Unit
1		VH_Euc	...		...	(10^6_m3)
2		VH_Pbravo	...		...	(10^6_m3)
3		VH_Castan	...		...	(10^6_m3)
4	max	Madeira	...		...	(10^6_m3)
5	max	CarbMedio	...		...	(10^3_ton)
6		C_Euc	...		...	(Unit)
7		C_Pbravo	...		...	(Unit)
8		C_Castanheiro	...		...	(Unit)
9	max	VolEl	...		...	(10^6_m3)
10		VolEl_Euc	...		...	(Unit)
11		VolEl_Pb	...		...	(Unit)
12		VoleEl_Cs	...		...	(Unit)
13		AreaFMP1_Euc	...		...	(ha)
14		AreaFMP2_Euc	...		...	(ha)
15		AreaFMP4_Euc	...		...	(ha)

Selected: 3 criteria

DECOMPOSITION RESULTS – FULL MODEL UPPER LEVEL



DECOMPOSITION RESULTS – LOWER LEVEL (E.G. PAIVA)

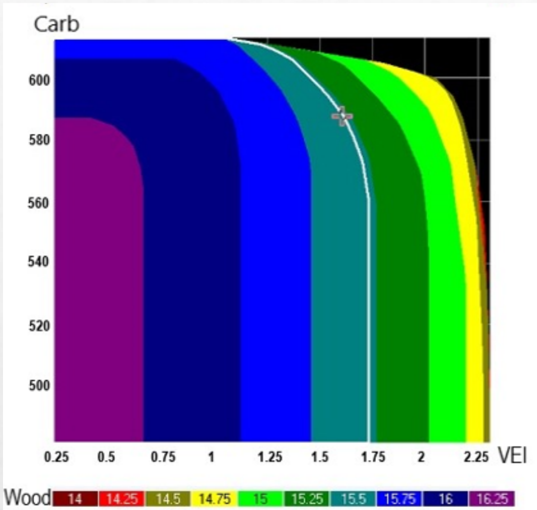


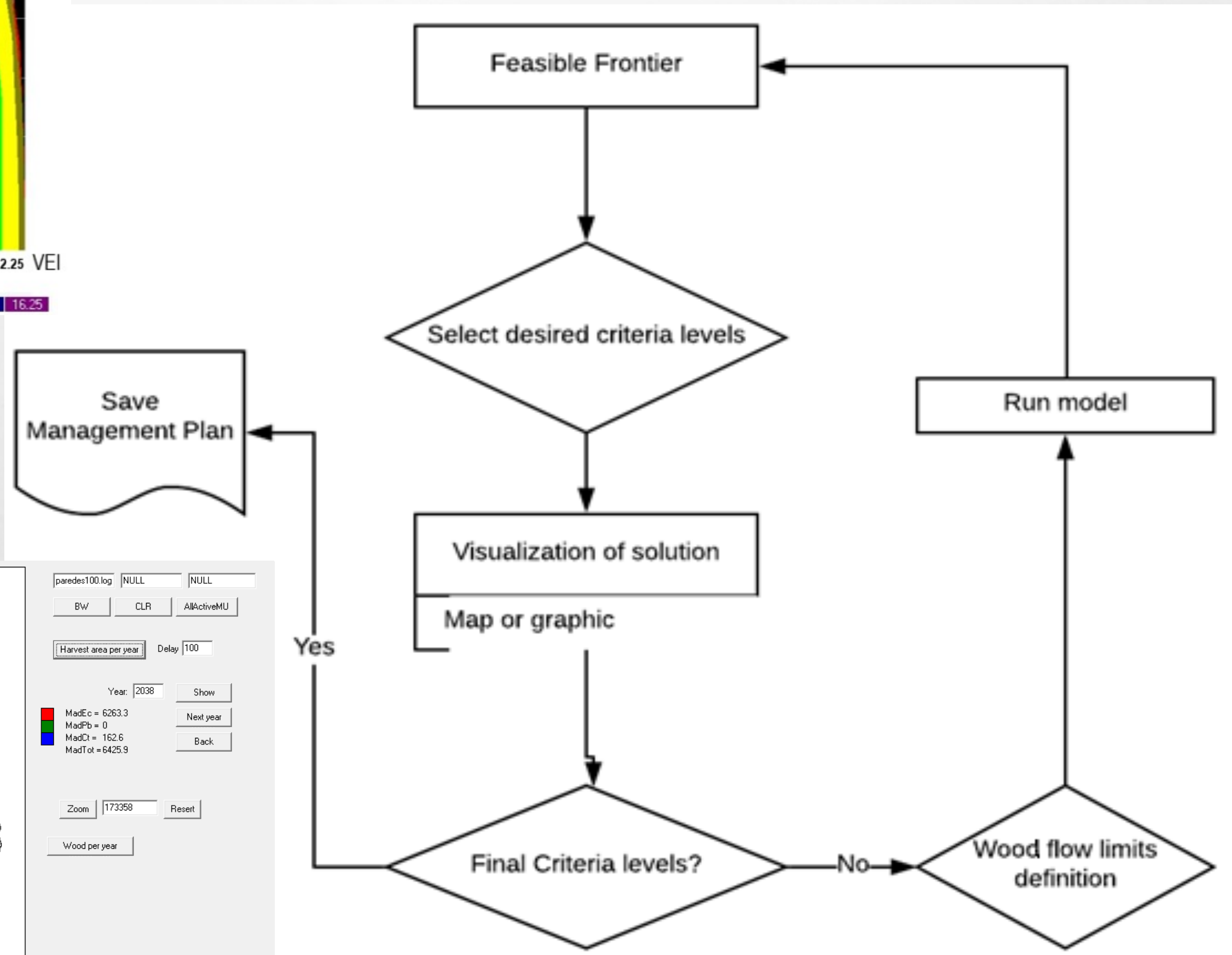
DECOMPOSITION RESULTS

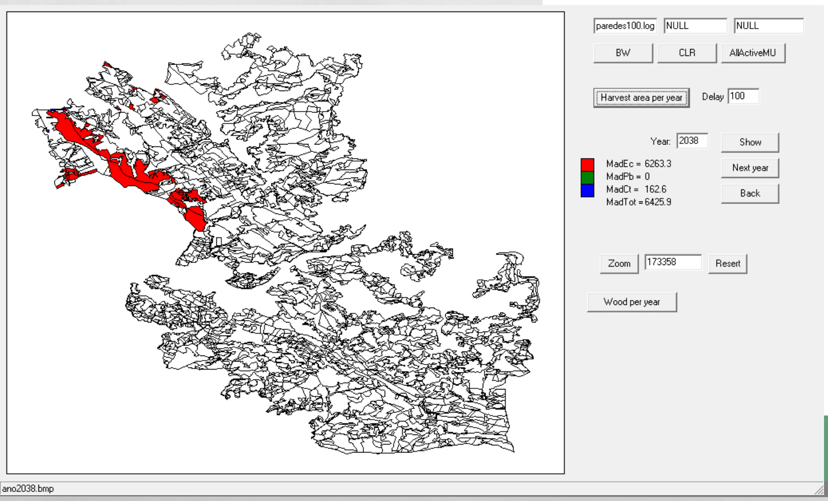
	Computation cost in seconds		Dimension of LP problems		
	CPLEX (10% precision)	CPLEX (1% precision)	Rows	Columns	Non zeros
EPH for Paiva sub-area	119	737	3515	46355	15394015
EPH for Paredes sub-area	16	106	2392	8884	2307164
EPH for Penafiel sub-area	72	417	2790	20844	6504067
Joining separate sub-area's EPH	1	1	-	-	-
Full time for approximating the EPH using the decomposition method	208	1261	-	-	-
Full time for approximating the EPH using the full model	556	3728	8700	76086	24250258

Problem solving considered two linear programing solvers (CPLEX and GLPK) and a personal computer with an Intel Core i7 processor with 1.60 GHz frequency and 8 Gb memory.

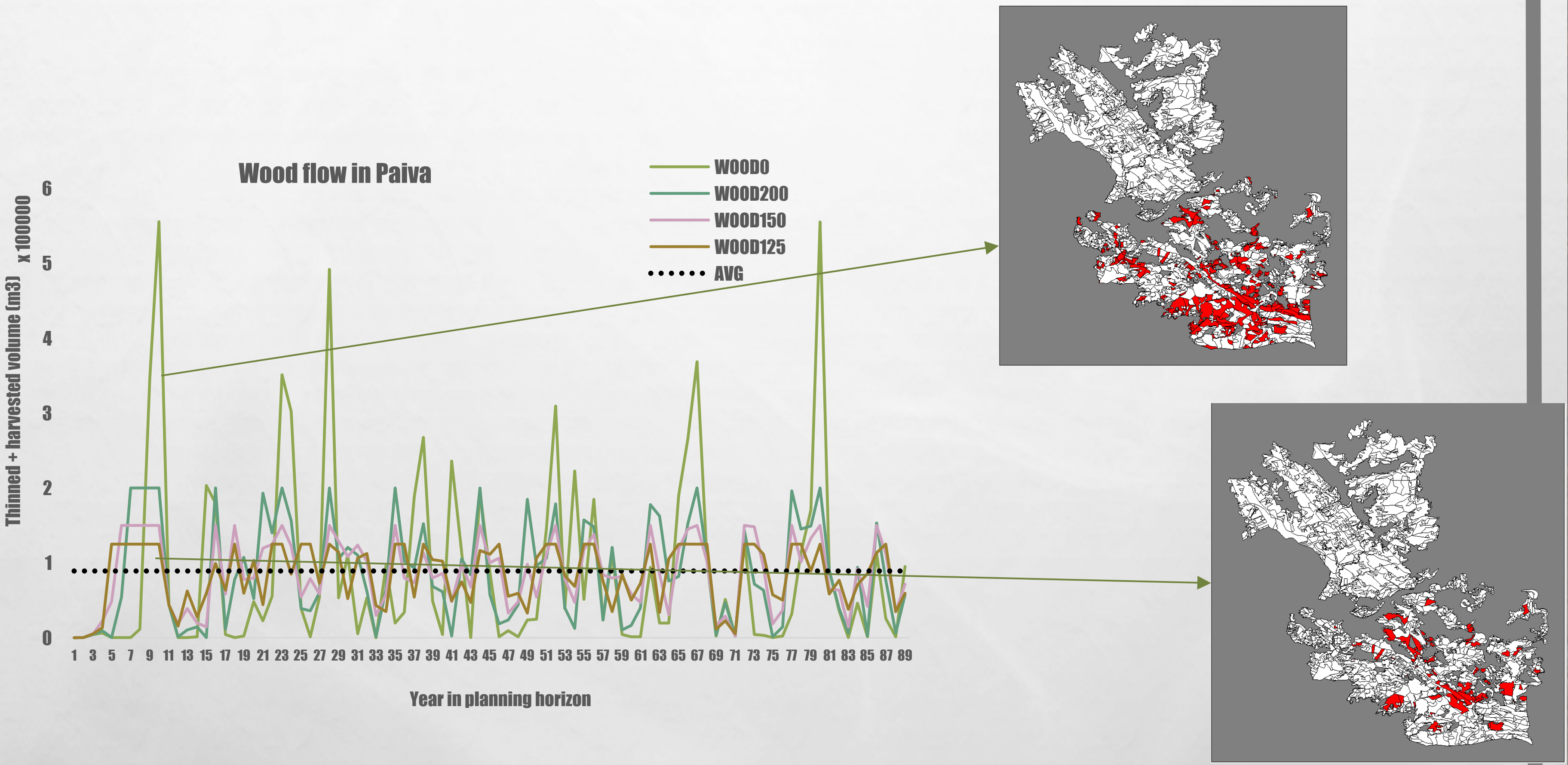
NEGOTIATION PROCESS



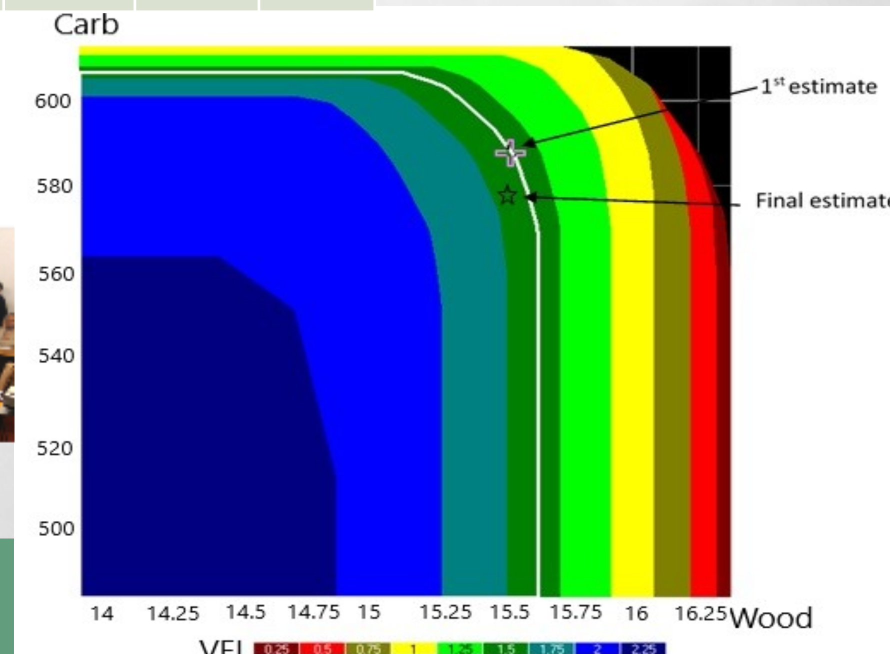




RESULTS VISUALIZATION MODULE



Area		ValeSousa		Paiva		Paredes		Penafiel	
ES		1st	Last	1st	Last	1st	Last	1st	Last
Wood (m^3 x 10^6)	Range	13.88 – 16.38		7.25-8.39		1.71-2.07		4.93 – 5.91	
	Solution	15.53	15.51	7.93	7.98	2.01	1.98	5.59	5.55
Carbon Stock (Mg x 10^3)	Range	481.54 - 613.07		256.41 – 328.78		54.02 – 69.82		171.57– 214.48	
	Solution	588	574	313.2	303	68.5	67	206.0	204
VEI (m^3 x 10^6)	Range	0.23 – 2.31		0.12 – 1.17		0.012– 0.28		0.09 – 0.86	
	Solution	1.6	1.62	0.86	0.79	0.15	0.18	0.59	0.65



REMARKS AND FINAL CONSIDERATIONS

- THIS APPROACH CONTRIBUTES TO ADDRESS COMPUTATIONAL CONSTRAINTS ASSOCIATED TO THE SOLUTION OF COMPLEX FOREST RESOURCES MANAGEMENT PLANNING.

- BI-LEVEL PLANNING MAY HELP DEVELOP SATISFACTORY SOLUTIONS FOR BOTH THE UPPER AND THE LOWER LEVEL DECISIONMAKERS.

- OUR RESULTS DID DEMONSTRATE THE EFFICIENCY OF THE PROCESS FOR BUILDING THE PARETO FRONTIER OF VERY LARGE PROBLEMS FROM THE PARETO FRONTIERS OF SMALLER AND COMPUTATIONAL SIMPLER SUB PROBLEMS.

- THIS WILL BE INFLUENTIAL FURTHER TO ADDRESS MORE COMPLEX PROBLEMS THAT NEED INTEGER SOLUTION APPROACHES.

- THE PROVISION OF SEVERAL ECOSYSTEM SERVICES DOES DEPEND ON THE SPATIAL CONDITIONS GENERATED BY THE HARVEST SCHEDULING PLANS OUR DECOMPOSITION APPROACH MAY CONTRIBUTE TO THE POSSIBILITY OF BUILDING PARETO FRONTIERS OF COMPLEX SPATIAL OPTIMIZATION MODELS.

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Puerto Varas, Chile

S. Marques, V. A. Bushenkov, A. V. Lotov, M. Marto and J. G. Borges 2019. Bi-level participatory forest management planning supported by Pareto frontier visualization. Forest Science, DOI: 10.1093/forsci/fxz014 Accepted (January 11th)

THANK YOU!
GRACIAS!
OBRIGADA!

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