SSAFR

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A PARETO FRONTIER DECOMPOSITION APPROACH TO ADDRESS MULTIPLE CRITERIA FOREST ECOSYSTEM MANAGEMENT

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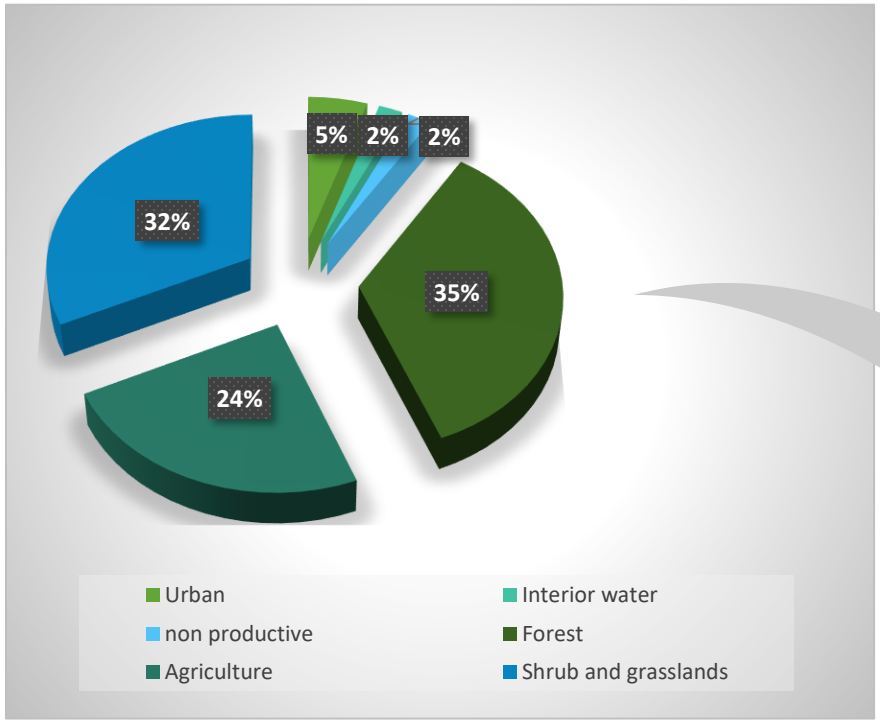
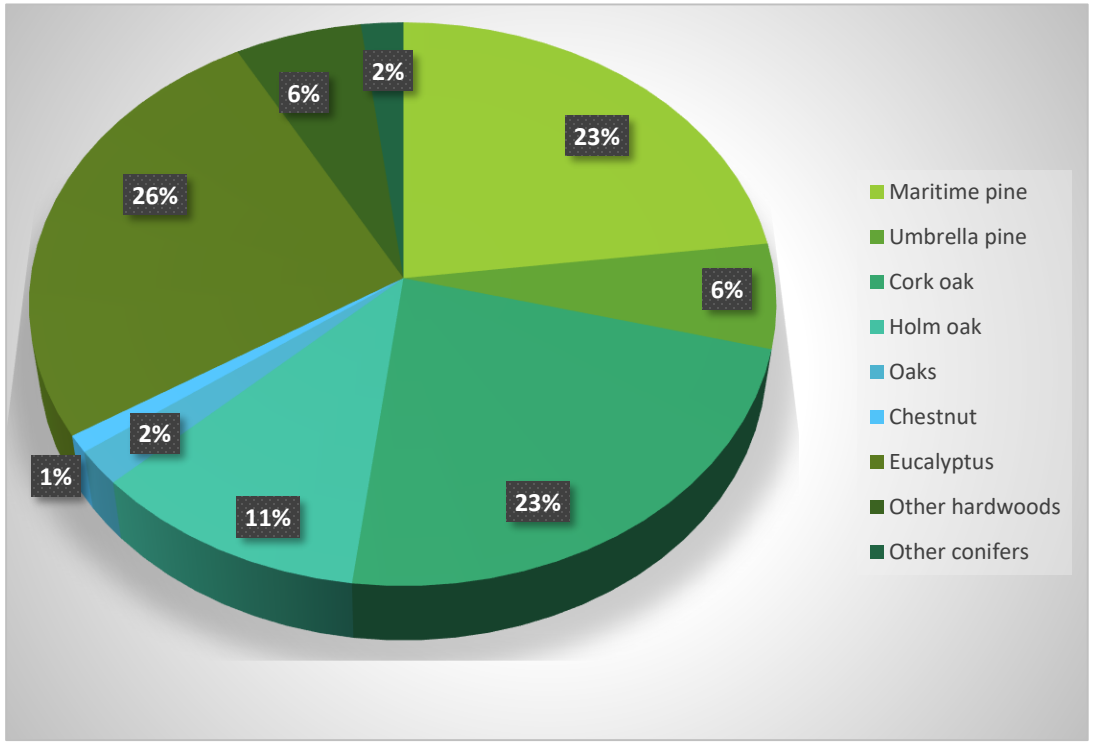
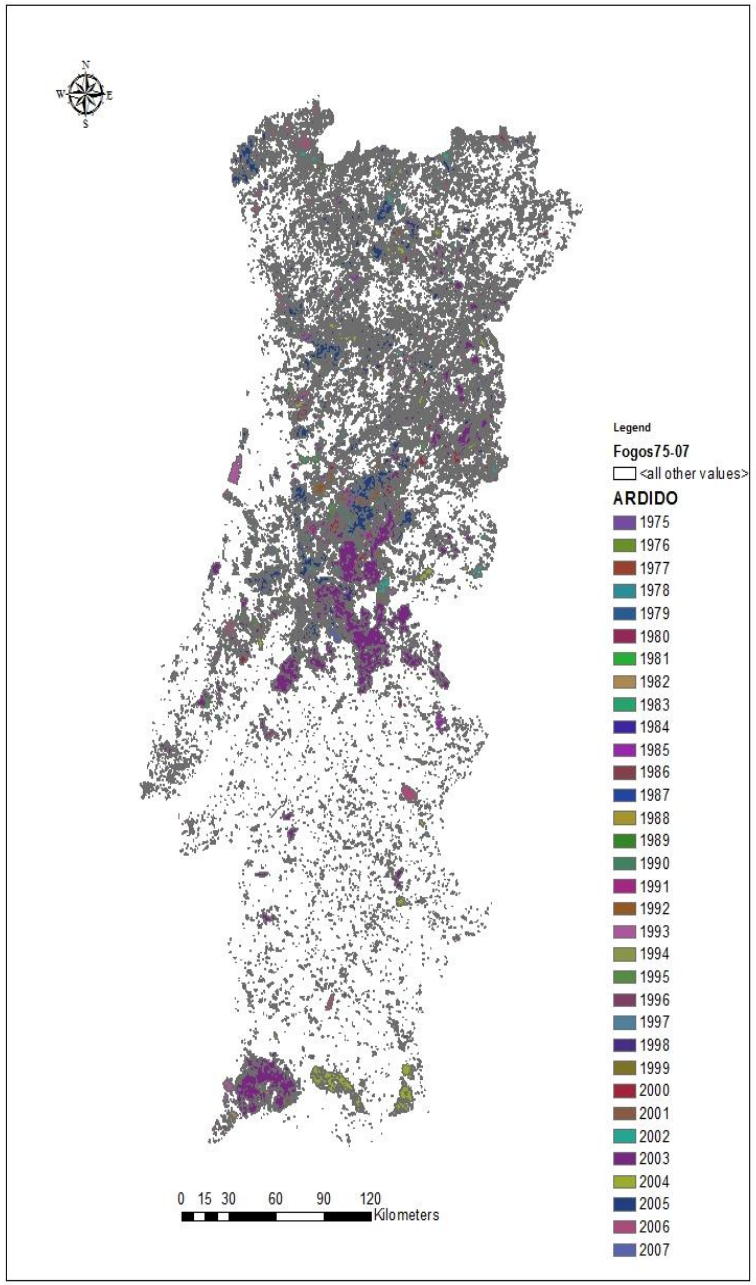
Portuguese Forest in numbers…





The forest, multiple use and ecosystem services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Portugal in mourning as fires kill dozens
Many were burned to death in their cars as they tried to flee the fires in central Portugal.
7m
Europe
'Oh my house, my house'
In pictures: Portugal forest fire


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sustainability

MDPI

Article

Addressing Wildfire Risk in Forest Management Planning with Multiple Criteria Decision Making Methods

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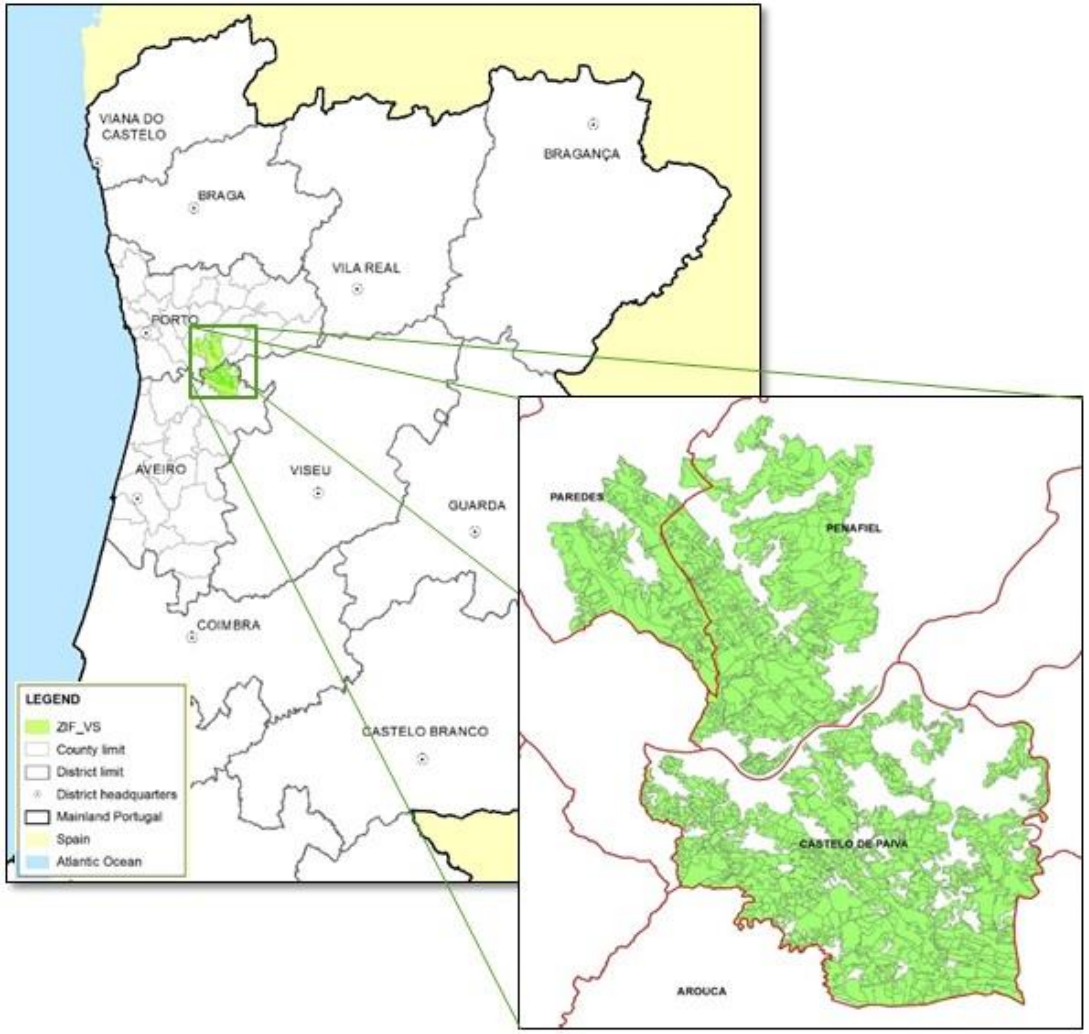
Case study

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**.

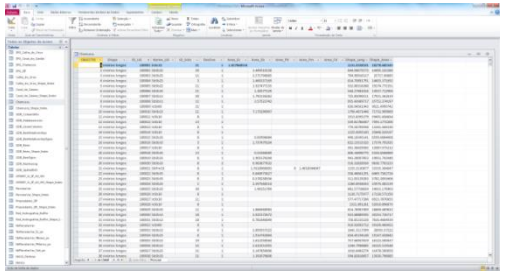
- Ecosystem services:
  - Eucalypt pulpwood,
  - Maritime pine saw logs;
  - Chestnut saw logs ;
  - Carbon storage and
  - Volume of ending inventory.
  - Fire Resistance



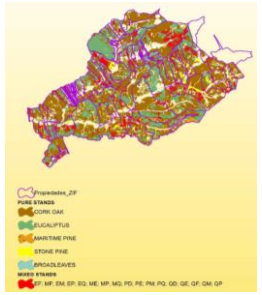
Workflow

Forest inventory: Original state of the forest

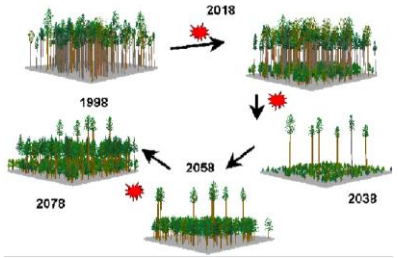
Data processing



Stand characterization



FMA simulation for all stands in each county (block)



Forest evolution scenarios, ES provision

Mathematical model building

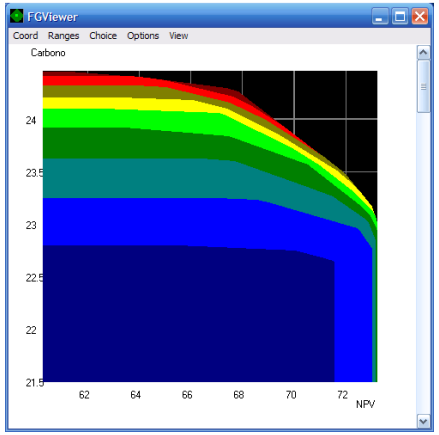
$$\sum_{j=1}^{M_i} x_{ij} = a_i,\ i = 1,\ldots,N$$

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

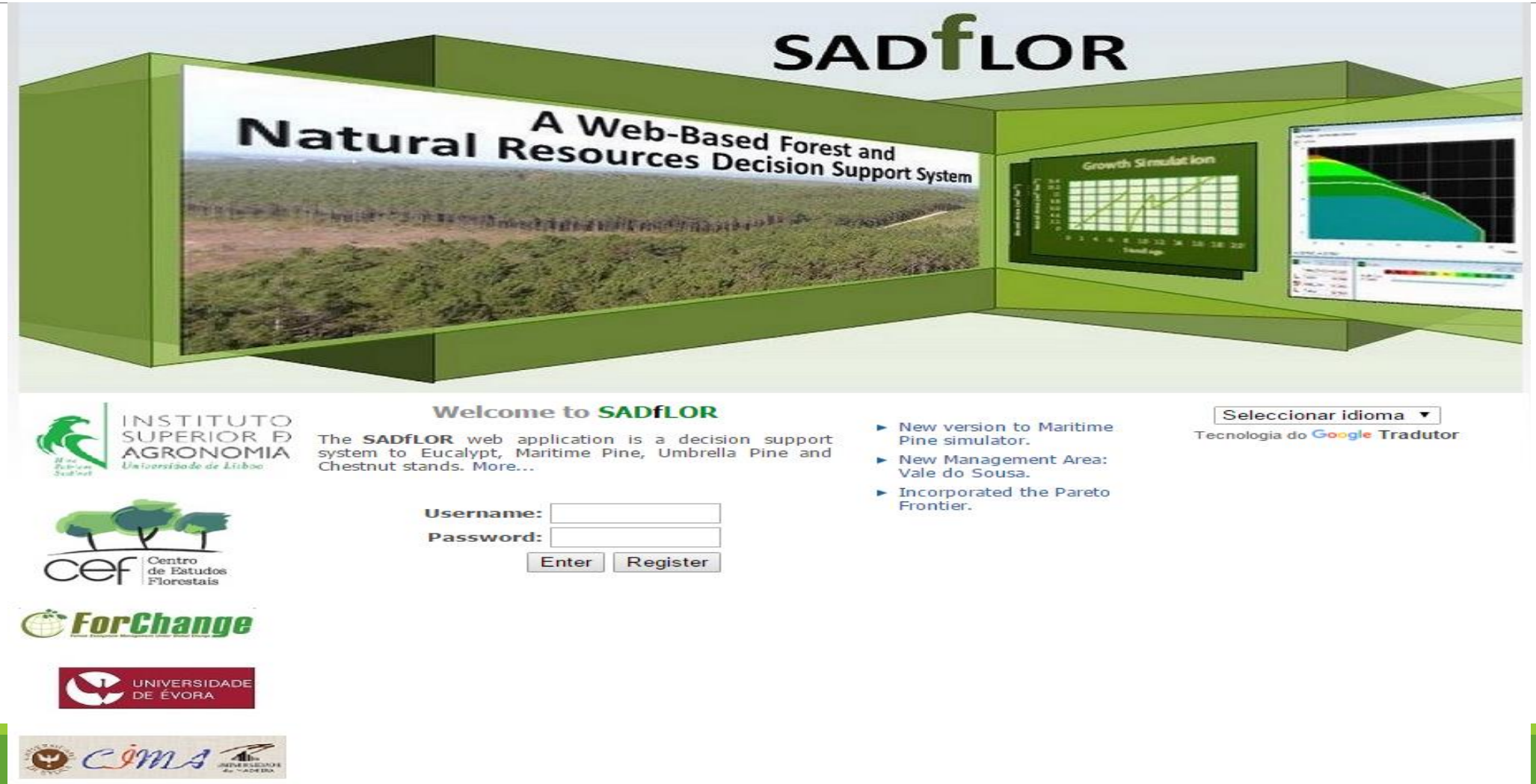
$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} eucalyptw_{ij} x_{ij} = EucalyptW_t,\ t = 1,\ldots,T$$

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

Ecosystem services tradeoffs analysis



SADfLOR - a web-based Forest and Natural Resources **DSS**



The LP model

$$\sum_{j=1}^{M_i} x_{ij} = a_i \; \mathrm{i} = 1, \ldots, N \tag{1}$$

$$\sum_{j=1}^{M_i} x_{ij} = a_i \; \mathrm{i} = 1, \ldots, N \tag{2}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{Mi} eucalyptw_{ijt} x_{ij} = EucalyptW_t \quad t = 1, \ldots, T \tag{3}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{Mi} chestnutw_{ijt} x_{ij} = ChestnutW_t \quad t = 1, \ldots, T \tag{4}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{Mi} carb_{ijt} x_{ij} = Carb_t \quad t = 1, \ldots, T \tag{5}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{Mi} npv_{ij} x_{ij} = NPV \tag{6}$$

Understory fuel reduction
(0,1,5,10,15 Years)

$$\sum_{i=1}^{N} \sum_{j=1}^{Mi} cs_{ij} x_{ij} = C \tag{7}$$

$$\sum_{t=1}^{T} PineW_t = PineSawlogs \tag{8}$$

$$\sum_{t=1}^{T} EucalyptW_t = EucalyptPulpwood \tag{9}$$

$$\sum_{t=1}^{T} ChestnutW_t = ChestnutSawlogs \tag{10}$$

$$\sum_{t=1}^{T} \frac{Carb_t}{T} = CARB \tag{11}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{Mi} vei_{ij} x_{ij} = VEI \tag{12}$$

The LP model (cont.)

$$\sum_{i=1}^{N}\sum_{j\in FMP_{if}} x_{ij} = A_{FMP_f} \quad f = 1,\ldots,4 \tag{13}$$

$$\sum_{j=1}^{M_i} \frac{r_{ijt}x_{ij}}{a_i} = R_{it} \quad i = 1,\ldots,\mathrm{N},\ t = 1,\ldots,T \tag{14}$$

$$\sum_{i=1}^{N} \frac{a_i R_{it}}{FA} = WF_T \quad t = 1,\ldots,T \tag{15}$$

$$\sum_{t=1}^{T} \frac{WF_T}{T} = WF \tag{16}$$

$$\sum_{t=1}^{T} \frac{WF_T}{T} = WF \tag{17}$$

$$\sum_{i=1}^{N} \frac{a_i Ra_{it}}{FA} = WFa_t \quad t = 1,\ldots,T \tag{18}$$

$$\sum_{t=1}^{T} \frac{WFa_t}{T} = WFa \tag{19}$$

$$x_{ij} \geq 0,\ \forall i,\ j \tag{20}$$

Fire Resistance indicator

Pareto frontier module

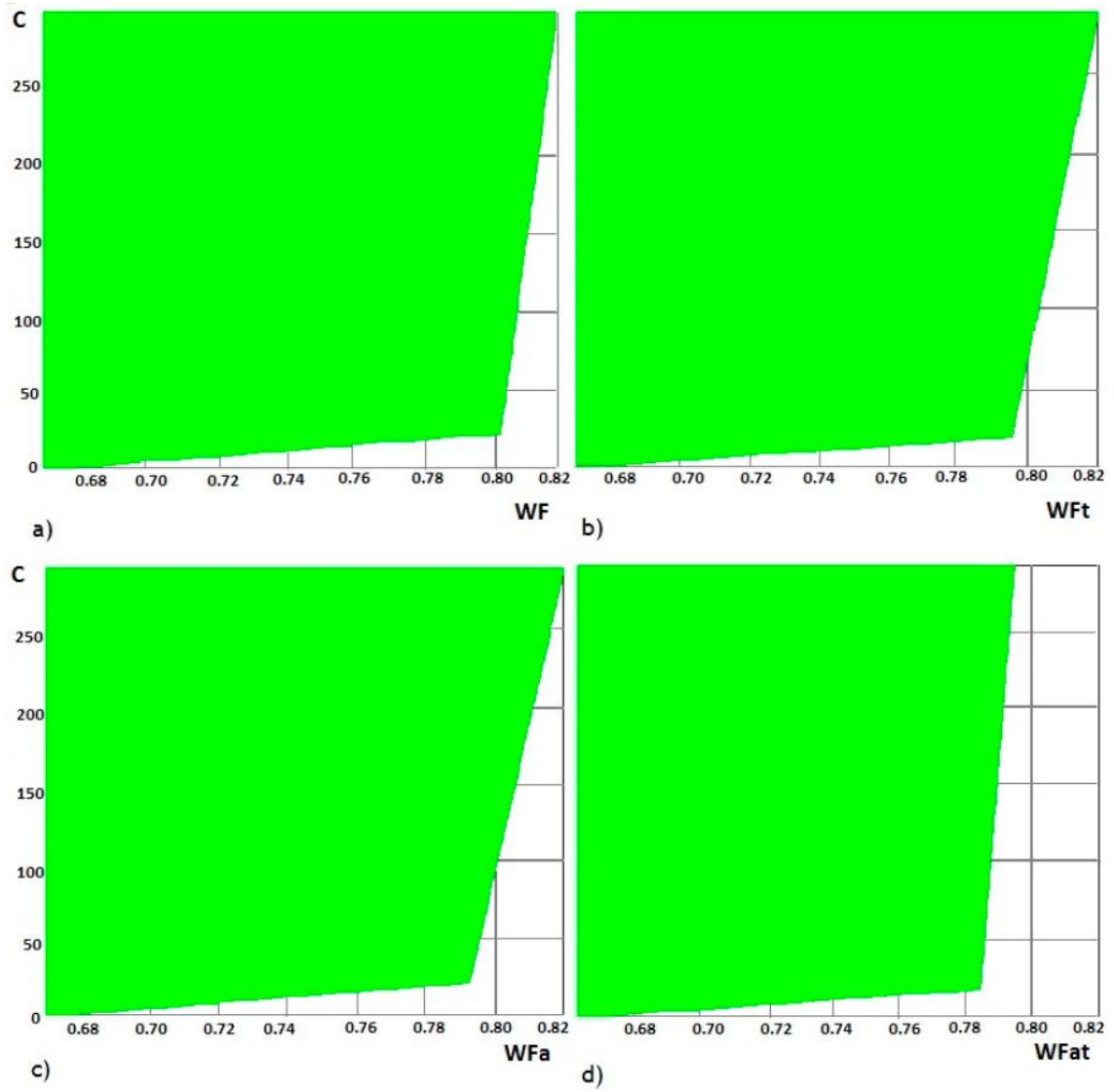


Figure 2. Trade-offs between fuel treatment costs (C) and (**a**) the non-adjusted average resistance wildfire indicator (WF); (**b**) the non-adjusted resistance wildfire indicator at the end of the planning horizon (WFT); (**c**) the non-adjusted average resistance wildfire indicator (WFa); and (**d**) the non-adjusted resistance wildfire indicator at the end of the planning horizon (WFaT).

rfp-test - grupo 1.sol - Notepad

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[VH_Euc] = 14606871.000000
[VH_Pb] = 488991.281250
[VH_Cs] = 60858.296875
[CTOTAL] = 583166.312500
[Vol_Per9] = 1519389.000000
[TOTALTIMBER] = 15497257.000000
[FMP3_Cs] = 68.000000
[Presc1_Pa1000_Ec] = 0.000000
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Fix Point Terminate Choice

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913	[Presc9_Pa219a]	1
953	[Presc9_Pa221a]	1
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993	[Presc9_Pa225a]	1
1031	[Presc99_Pa235a]	1
1032	[Presc9_Pa237a]	1
1052	[Presc9_Pa238a]	1
1091	[Presc98_Pa240a]	0.305941
1093	[Presc8_Pa241a]	1
1132	[Presc9_Pa244a]	1
1161	[Presc100_Pa256a]	1
1171	[Presc100_Pa257a]	1

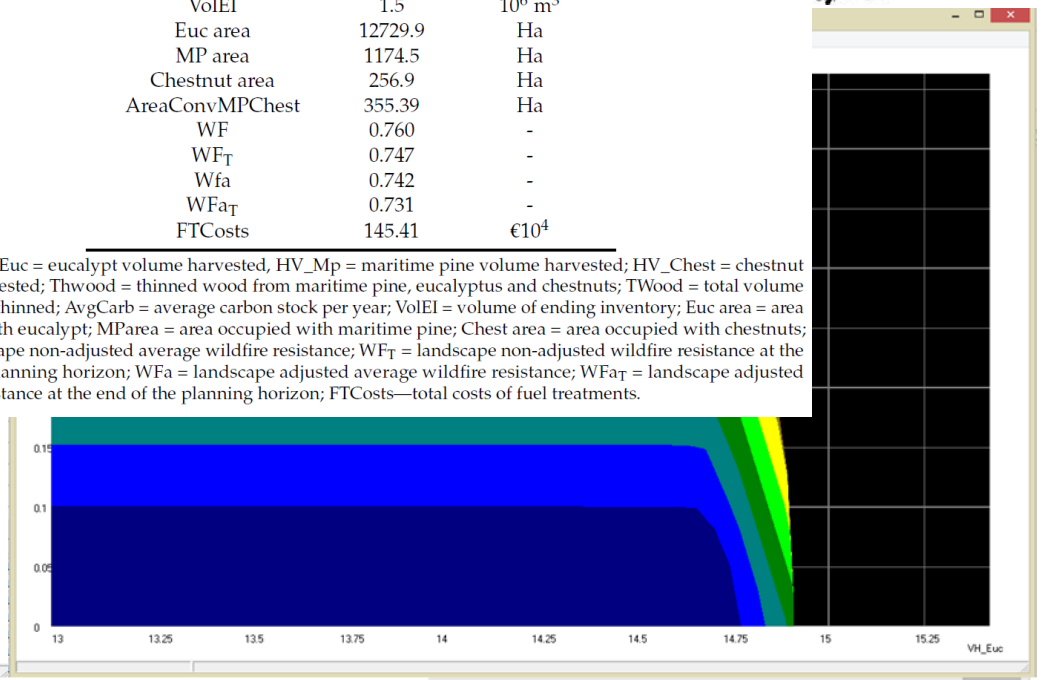
x = 14.7943, y= 0.20372

VH_Euc

VH Castan 0.34375

Ecosystem Service List	Value	Units
HV_Euc	14.72	10^6 m^3
HV_Mp	0.23	10^6 m^3
HV_Chest	0.14	10^6 m^3
Thwood	0.39	10^6 m^3
TWood	15.48	10^6 m^3
AvgCarb	593.47	10^3 Mg·year^{-1}
VolEI	1.5	10^6 m^3
Euc area	12729.9	Ha
MP area	1174.5	Ha
Chestnut area	256.9	Ha
AreaConvMPChest	355.39	Ha
WF	0.760	-
WF_T	0.747	-
Wfa	0.742	-
WFa_T	0.731	-
FTCosts	145.41	€10^4

Where: HV_Euc = eucalypt volume harvested, HV_Mp = maritime pine volume harvested; HV_Chest = chestnut volume harvested; Thwood = thinned wood from maritime pine, eucalyptus and chestnuts; TWood = total volume harvested + thinned; AvgCarb = average carbon stock per year; VolEI = volume of ending inventory; Euc area = area occupied with eucalypt; MParea = area occupied with maritime pine; Chest area = area occupied with chestnuts; WF = landscape non-adjusted average wildfire resistance; WF_T = landscape non-adjusted wildfire resistance at the end of the planning horizon; WFa = landscape adjusted average wildfire resistance; WFa_T = landscape adjusted wildfire resistance at the end of the planning horizon; FTCosts—total costs of fuel treatments.



Scales

0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45

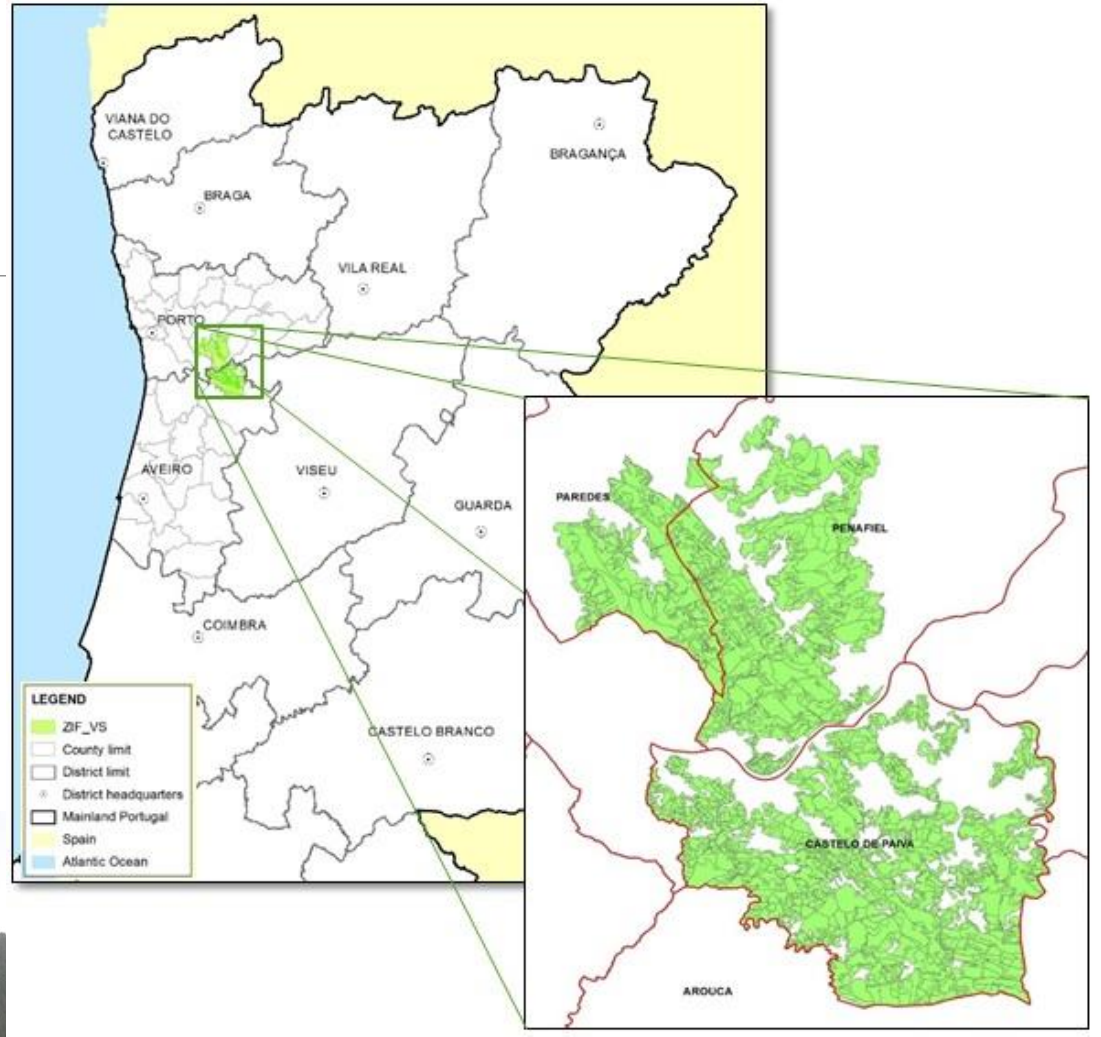
VH Castan 0.294527

The need to decompose the problem…

-
- This technique is applied in forest optimization problem, which large number of decision variables.
- Thus, approximating the EPH is a very complicated problem in this case.
- To solve this problem, its block separable structure is used.

Case study

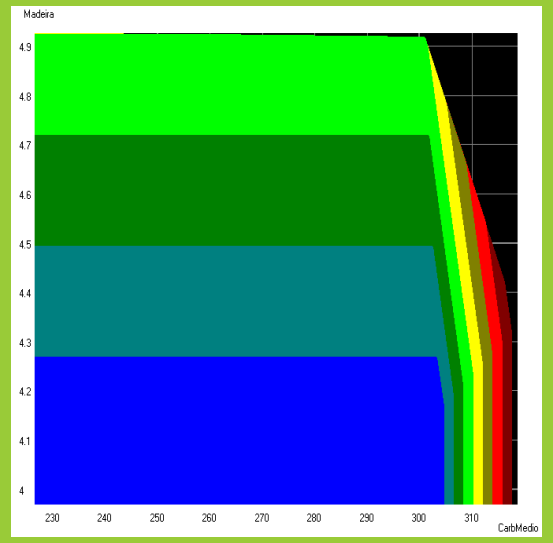
	Paiva	Paredes	Penafiel	ZIF_VS
Forested area (ha)	7626.27	2138.74	5085.38	14832
Number of management units	1293	235	654	2182
MU average area (ha)	5.9	9.1	7.8	6.8
MU max area (ha)	100.2	99.5	97.47	100.2
MU min area (ha)	0.5	0.5	0.5	0.5

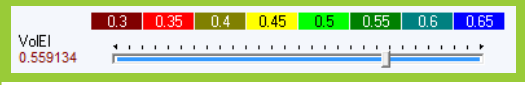


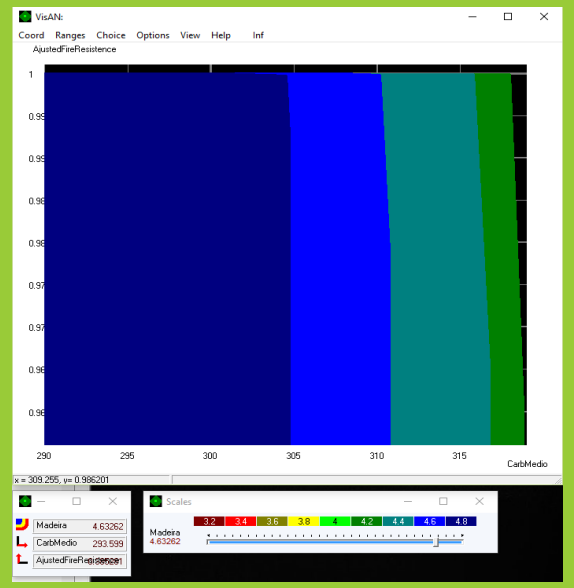
Wood - YY
Carbon - XX
VolEI - Color

Carbon_YY
Fire Resistence -XX
Madeira- Color

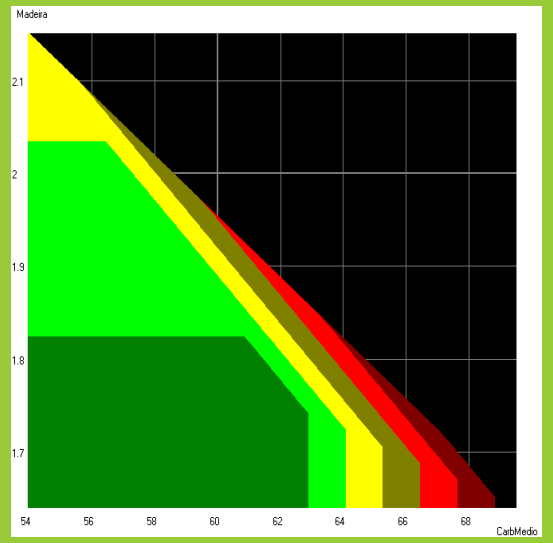
Paiva

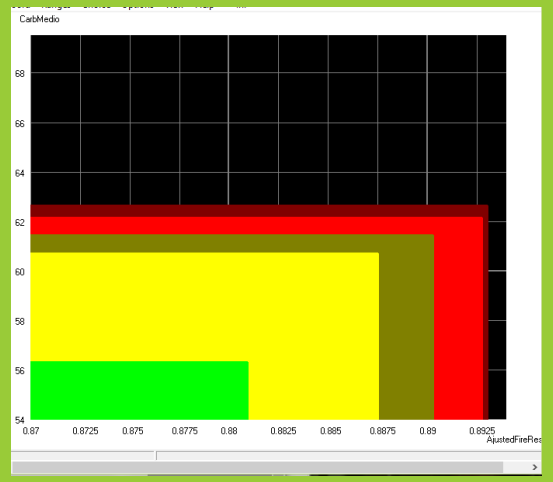




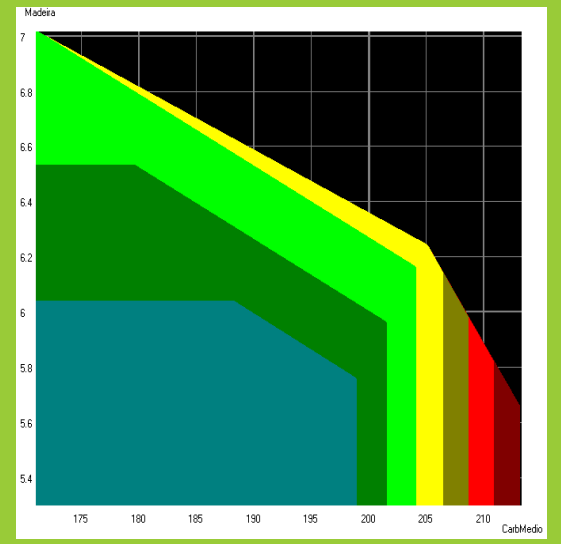


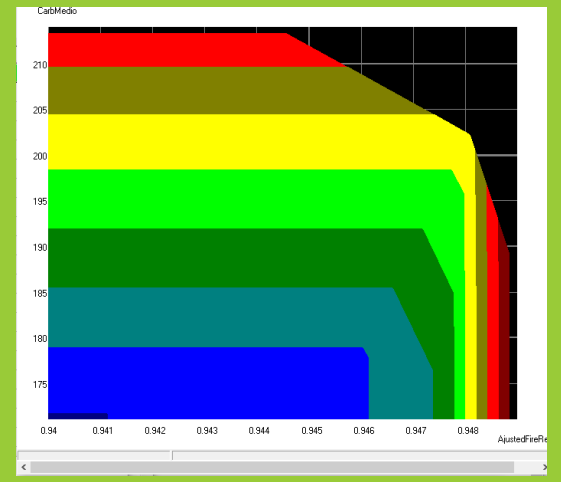
Paredes





Penafiel



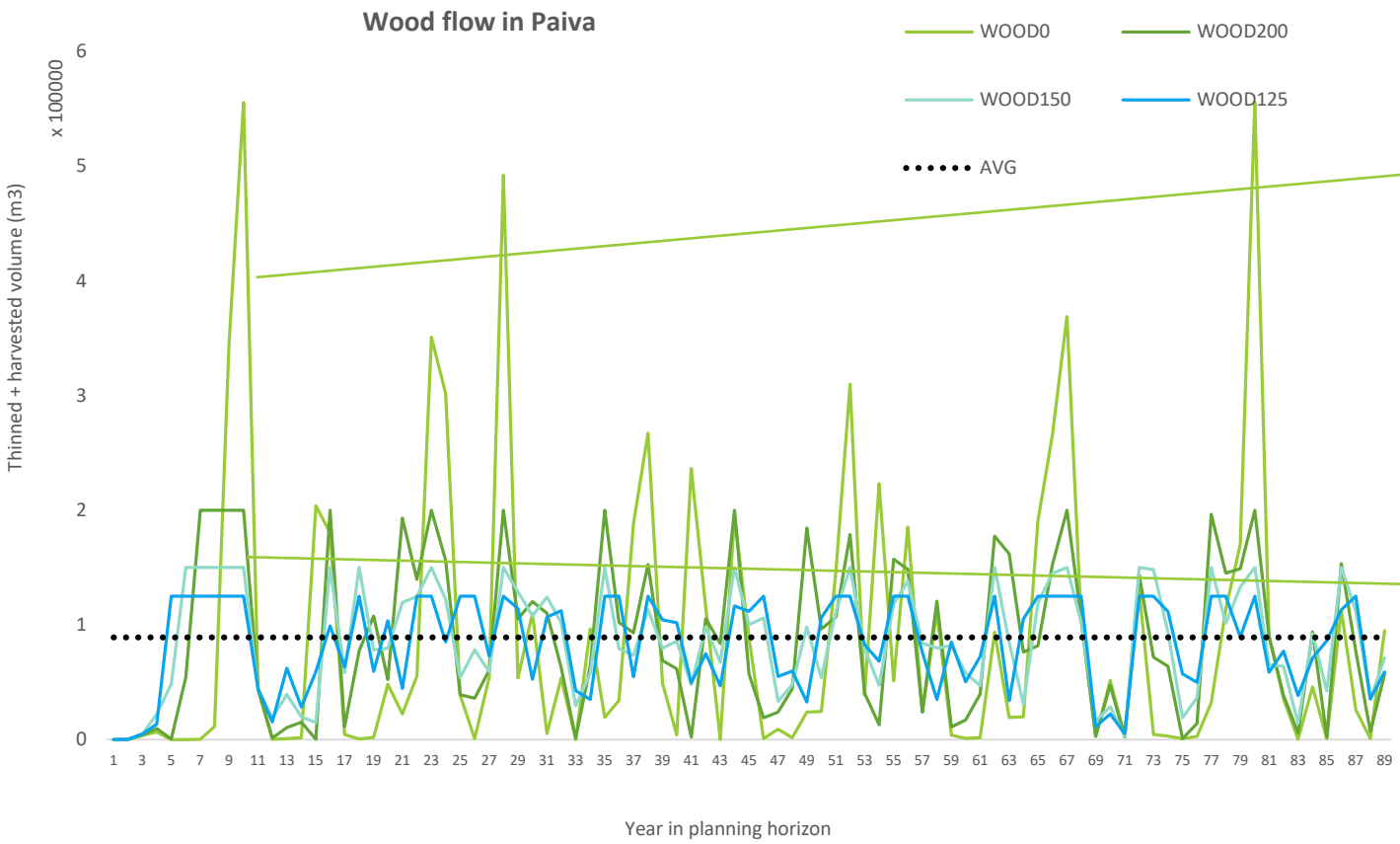


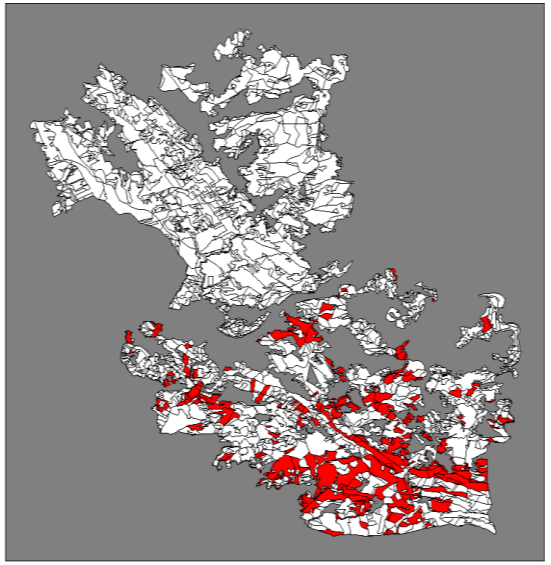
ZIF_VS

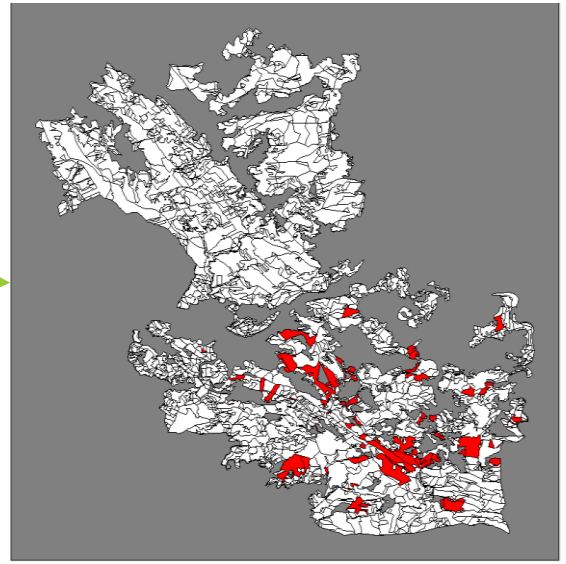
Decomposition results

Area		ZIF_VS		Paiva		Paredes		Penafiel	
ES		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Wood ($m^3 \times 10^6$)	Range	13.88 – 16.38		7.25-8.39		1.71-2.07		4.93 – 5.91	
	Point	15.52	15.45	7.93	7.98	2.01	1.98	5.59	5.55
Carbon Stock ($Mg \times 10^3$)	Range	481.54 - 613.07		256.41 – 328.78		54.02 – 69.82		171.57– 214.48	
	Point	588	550	313.2	303	68.5	67	206.0	204
VolEI ($m^3 \times 10^6$)	Range	0.23 – 2.31		0.12 – 1.17		0.012– 0.28		0.09 – 0.86	
	Point	1.6	1.58	0.86	0.79	0.15	0.18	0.59	0.65

Results visualization module







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