Methods and tools to support forest management planning in Portugal

SuFoRun

Models and decision SUpport tools for integrated FOrest policy development underglobal change and associated Risk and UNcertainty

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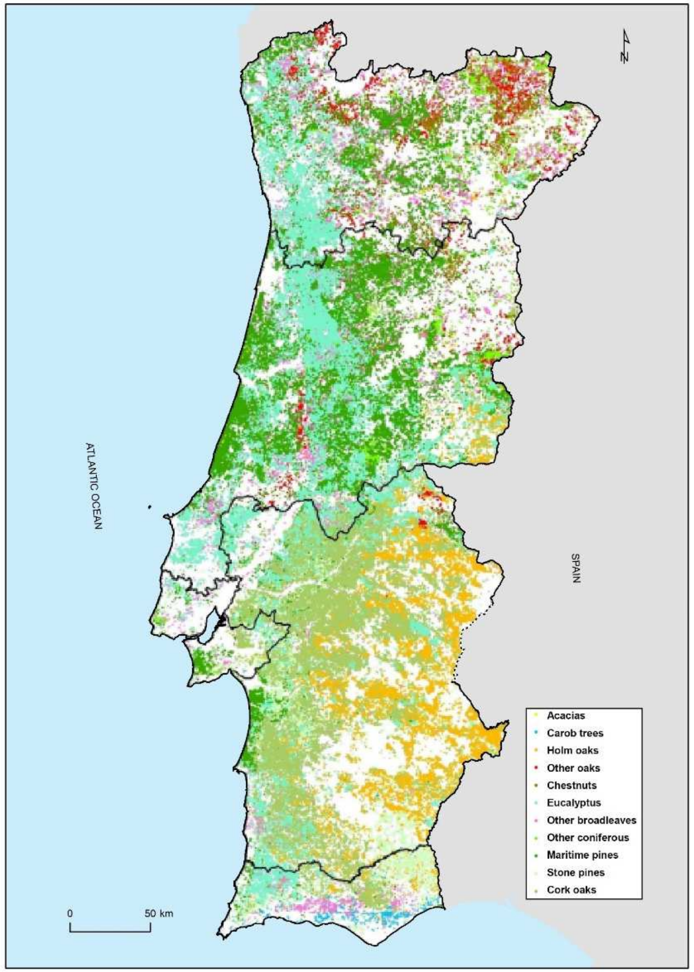
School of Agriculture - Forest Research Center

- **The largest and most qualified school of graduate and post-graduate degrees in the Agricultural Sciences, in Portugal.**
- **It has about 1900 students in graduate and undergraduate programmes, a faculty of 116 teachers and 70 Researchers.**
- **Located in the heart of Lisbon, Tapada da Ajuda – an Environmental and Botanical Park with about 100 ha**
- **Amphitheatre of Stone, the Belvedere, the Garden of the Parada, the Rugby field, the Astronomical Observatory, the Exhibition Pavilion, the Auditorium of Lagoa Branca, among others.**

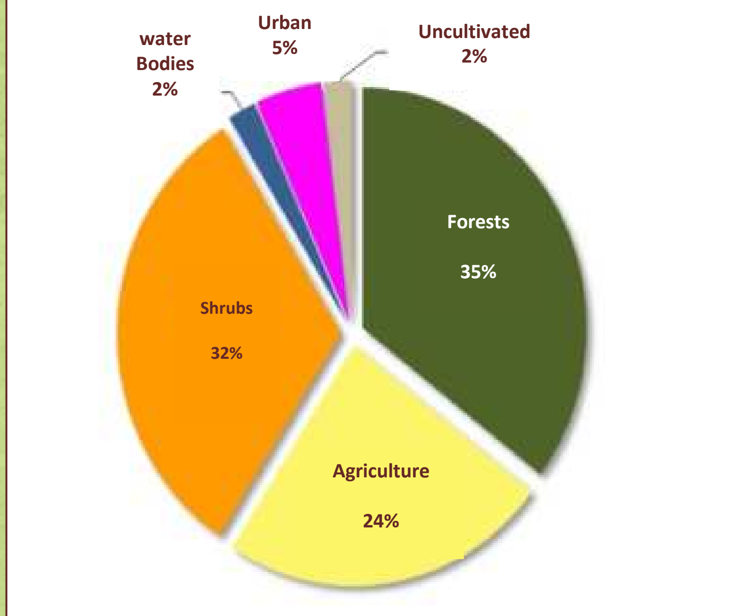
- **Forest Research Centre (CEF)** is a research unit of the ISA, and a FCT - funded member of the national R&D system.
- **CEF** has 95 researchers, 43 doctoral students and 10 research assistants.
- The research is organized in four Research Groups:
  - **ForEco**: Forest ecology
  - **ForBio**: Sustainable management of biotic resources, ecosystem quality and services
  - **ForChange**: Forest ecosystem management under global change
  - **ForTec**: Forest products and biorefineries

http://www.isa.ulisboa.pt/cef/apresentacao

Forest in Portugal



Land cover (%)



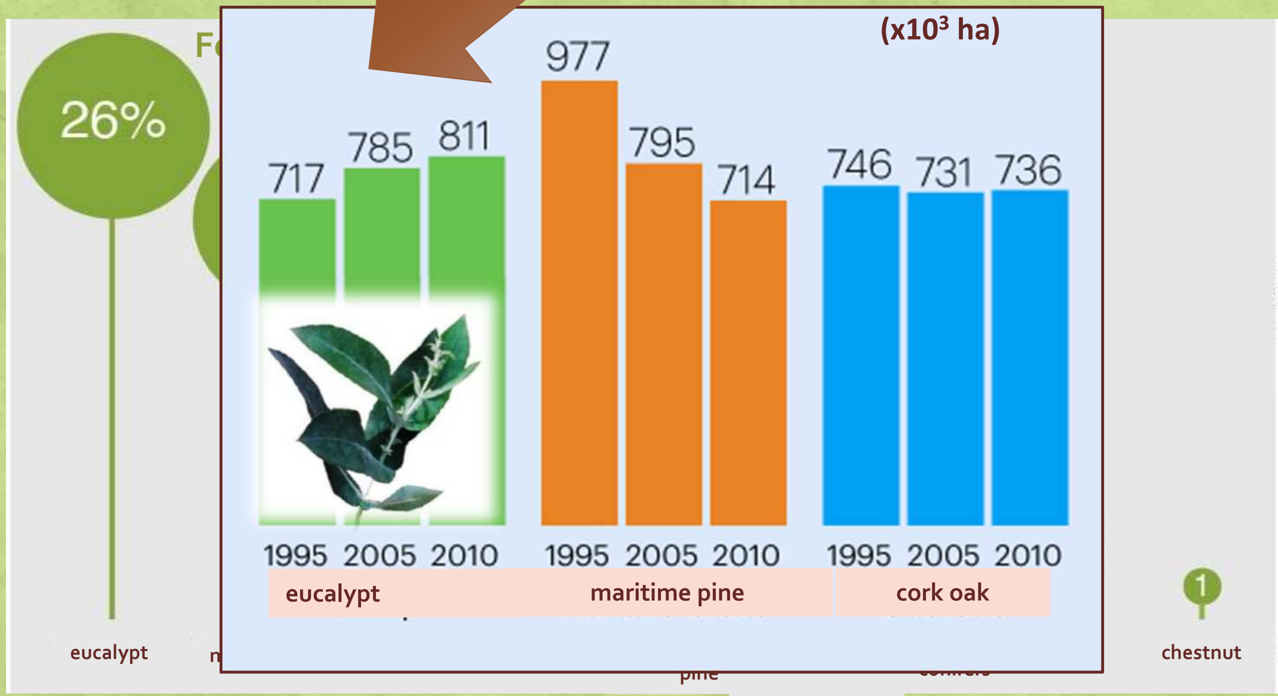
(Source: DGCI, 2006 in ENF, 2015)

Over 85% of the forest area is privately owned

Only 3% of forests are in state hands!

Forest in Portugal

- 35 % Portuguese mainland covered by forest
- 3 major tree species
  - Eucalypts encompass 811 thousand hectares
- Mostly plantations



Multiple use of the forests and Ecosystem services

Management of forests and other natural resources

- "Forest management involves the **use of forests** to meet the **objectives of landowners and society**. A forest manager is the cathalist of this effort." (Davis et al 2001)
- "Forest management can involve the application of **silvicultural practices** so that a forest **remains healthy and vigorous**. Choosing the **timing and placement of activities** is the main task of forest planning" (Heiligmann, 2002)
- "Forest management is **identifying and selecting management alternatives** for forested areas, large and small, to **best achieve the objectives** of the landowner or landowners, given their resource **constraints** and within the constraints of the law and the ethical obligations of the landowner and the forester to be responsible stewards of the land" (McDill, 2012).
- "Forest management involves the integration of silvicultural practices and **business concepts (e.g., analyzing economic alternatives)** in such a way as to best achieve a landowner's objectives. Management of forests requires a plan (however developed), and an assessment of the activities necessary to meet the objectives. **In addition, a recognition of the important ecological and social concerns associated with a forest may influence the character and depth of a plan."** (Bettinger et al 2009)

Management of forests and other natural resources

Management plans are driven by the goal of a person or a group (a "decision maker") working within a legal or political context.

Who is the "decision maker"?

- Landowner
- Forest owners association
- Companies
- Forest authorities (in PT , ICNF)
- ...

Goals

- Income
  - timber harvest (€)
  - NWFP (cork, resin, mushrooms, fruits...)
- Reduction of costs
- Forest regulation
- Provision of wildlife habitat
- Maintenance of late-successional forests
- Reduction of the likelihood of a severe fire (fire risk)
- Carbon sequestration
- Recreation areas
- Biodiversity...

Management of forests and other natural resources

Management requires a plan and an assessment of the activities necessary to meet the objectives.

- Tree planting,
- Herbaceous weed control,
- Fertilization,
- Precommercial/commercial thinning,
- Final harvests, preservation,
- Road construction
- Prescribed fire
- …

Challenges related to the management of forests

- Economic
  - Make profit,
  - Budget limitations,
  - Income generation,
  - Generation of competitive financial return, …
- Environmental
  - Wildlife habitat maintenance and development,
  - Water quality, biological diversity…
- Social
  - Air quality
  - Prescribed burning
- Techonological

Why Plan?

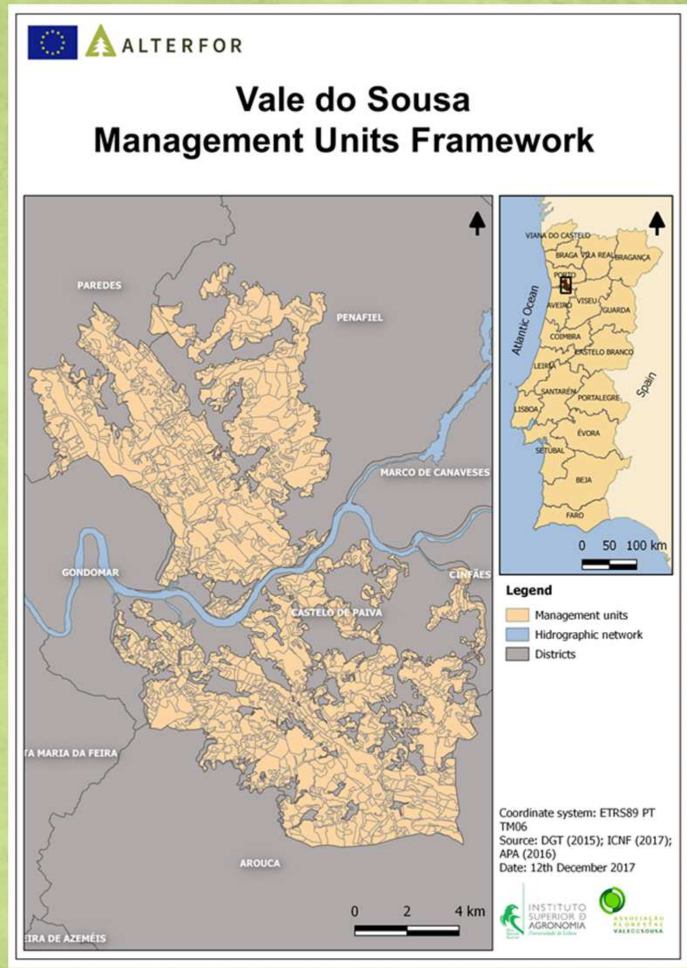
- It’s simple: You should think before you act!
  - Set priorities
  - Evaluate trade-offs
- Plans communicate what you’re going to do
  - Provide an opportunity for interaction among everyone involved
  - Communication between administrators and field personnel
  - Communication between agencies and the public
- Plans establish credibility
  - Demonstrate that you have thought about what you are doing
    - Demonstrates sustainability (for certification)
- Plans provide a framework for accountability
  - Without a plan there is nothing to be accountable for

Planning Process

1) Identify landowner objectives
    - Vague objectives not easy to quantify
2) Inventory resources; identify management constraints
3) Identify potential management activities
    - including what, where and when
4) Evaluate and select management activities; write plan
    - Goals are quantified
5) Implement management activities
6) Monitor implementation and outcomes
7) Periodically re-evaluate/revise the plan

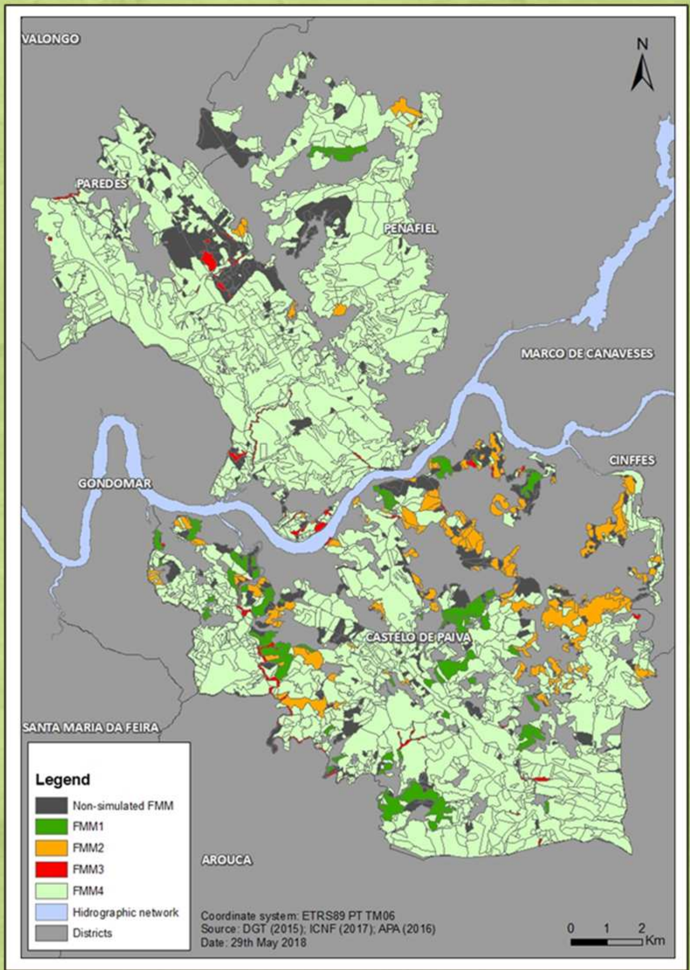
Study Area: Vale do Sousa

- Located in Northwest Portugal and covers the southern part of the Sousa Valley;
- Extents over **14 837** ha - **1373** stands;
- Separated by the **Douro river**;
- Contains: ZIF Entre Douro e Sousa, and ZIF Paiva;
- 360 forest owners (members of ZIF);
- Representative of Portuguese conditions
  - ownership type,
  - structure,
  - species composition



Study Area: Vale do Sousa

Current Forest Management Models (cFMM)



FMM1 | Mixed maritime pine and eucalyptus

✓4% of forest area

✓**FMM2 |** Mixed eucalyptus and maritime pine

✓6% of forest area

FMM3 | Chestnut forest system for saw logs production

✓1% of forest area

FMM4| Eucalyptus forest system for pulpwood production

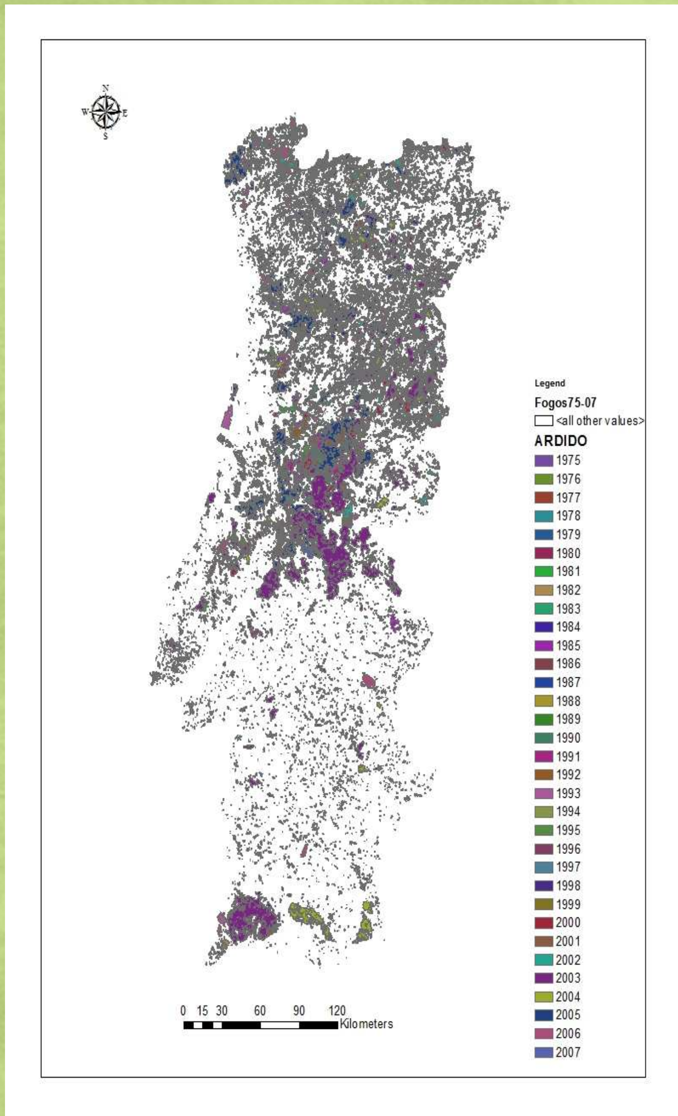
✓89% of forest area

Vale do Sousa - Ownership

- Most forest owners prefer high harvesting intensities
- tree species selection based on the demand by timber industries

Vs

- Nature conservation and environmental groups aims to protect forest resources
- interested in the supporting and regulating forest ecosystem services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PORTUGAL
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Castelo Branco
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Business
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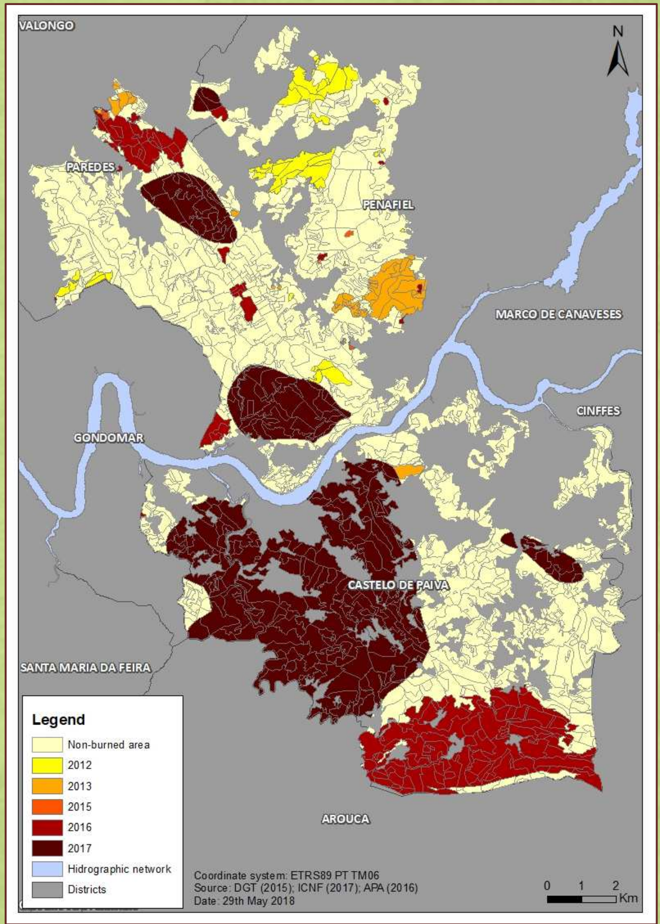
Entertainment & Arts
Portugal in mourning as fires kill dozens
Many were burned to death in their cars as they tried to flee the fires in central Portugal.
7m Europe
'Oh my house, my house'
In pictures: Portugal forest fire

Wildfires since 2012

About 43% of the total CSA area was burned (6 422 ha)

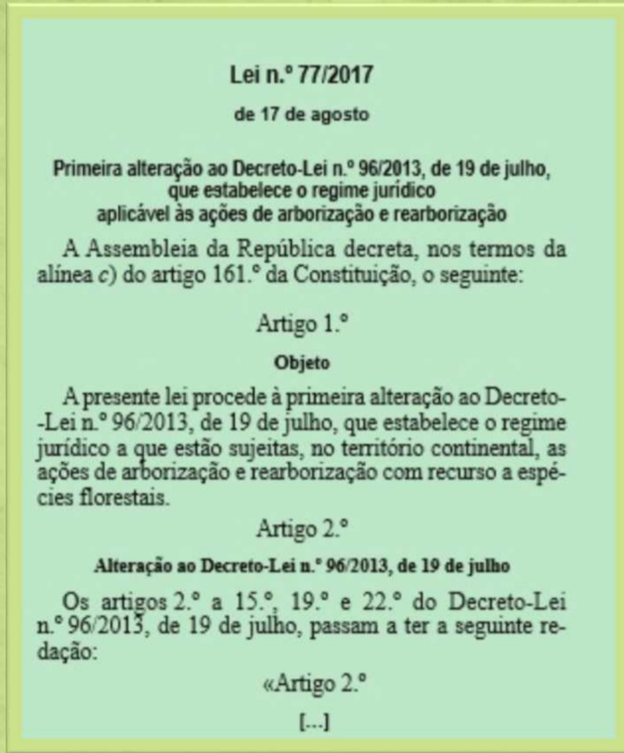


Fire year	Area (ha)	Area (%)
2012	421	2,84
2013	322	2,17
2015	11	0,07
2016	1706	11,50
2017	3963	26,71
Total	6422	43,29

aFMM - Motivation

Alternative Forest Management Models

- Stronger planting restrictions on eucalyptus, and thus the forest owners are looking for **native alternative species for wood production**
- Forest mosaics diversification with **natives species broadleaves** could be a positive **contribution/help to reduce fire and diseases risks.**
- Interested in the **supporting and regulating forest ecosystem services**



Lei n.º 77/2017

de 17 de agosto

Primeira alteração ao Decreto-Lei n.º 96/2013, de 19 de julho, que estabelece o regime jurídico aplicável às ações de arborização e rearborização

A Assembleia da República decreta, nos termos da alínea *c*) do artigo 161.º da Constituição, o seguinte:

Artigo 1.º

Objeto

A presente lei procede à primeira alteração ao Decreto-Lei n.º 96/2013, de 19 de julho, que estabelece o regime jurídico a que estão sujeitas, no território continental, as ações de arborização e rearborização com recurso a espécies florestais.

Artigo 2.º

Alteração ao Decreto-Lei n.º 96/2013, de 19 de julho

Os artigos 2.º a 15.º, 19.º e 22.º do Decreto-Lei n.º 96/2013, de 19 de julho, passam a ter a seguinte redação:

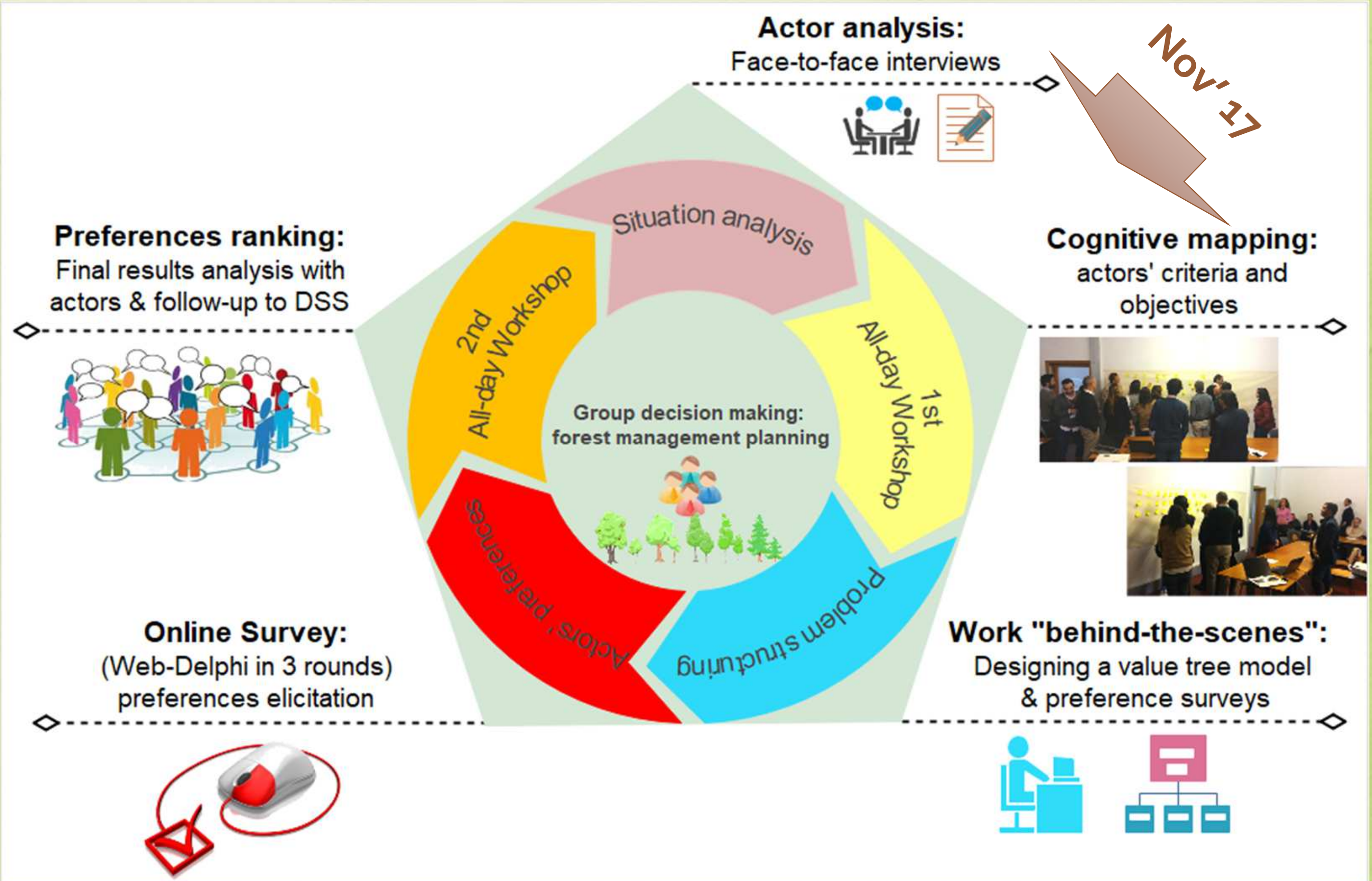
«Artigo 2.º

[...]

The 2017 catastrophe prompted policy decisions to address prevention

aFMM – motivation : Stakeholders

Group decision making process



FMM5 – Povoamentos puros de Pinheiro bravo

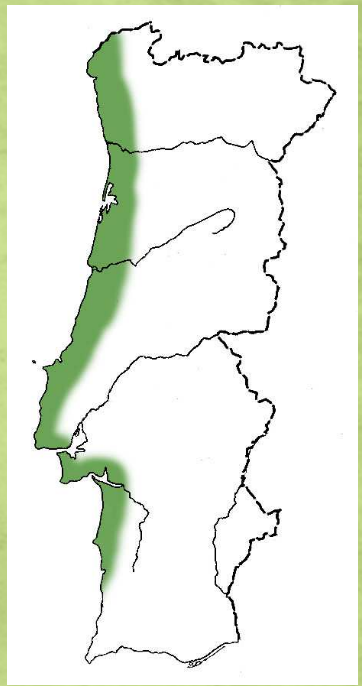
The main reasons

- There's a little area in the case study that is occupied by pure stand but there's no management;

- Large demand of maritime pine wood;

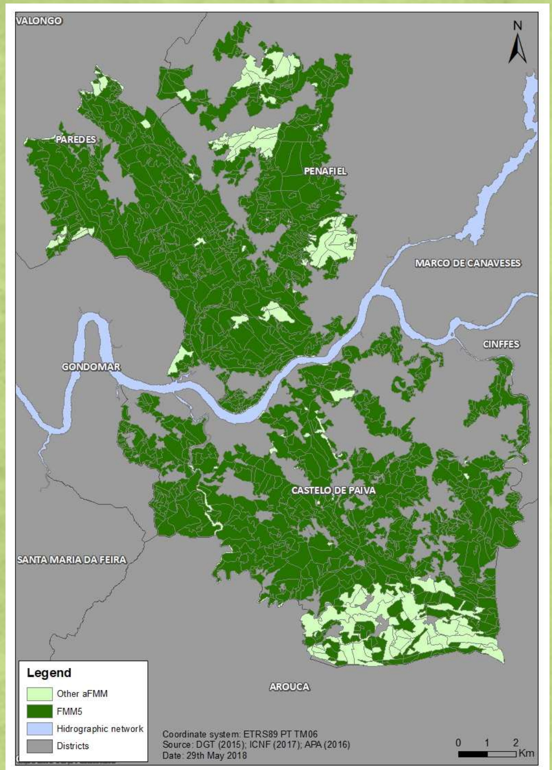
- The CSA has excellent technical conditions and there a lot of technical knowledge available;

- Provides incomes resulting from thinnings.



(*florestar.net, 2018*)

FMM5 – Pure stands of maritime pine



- N. of simulated MU's: 1 176;
- Area: 13 040 ha;

✓ Growth model PINASTER (even-aged and 1-year time step) implemented in StandsSIM-MD (Barreiro et al. 2016)

Ecosystem services targets

- Native species
- Timber
- Resin (non-wood product)
- Biodiversity
- cultural services
- Recreational areas

Plantation	**1111 trees/ ha (3 x 3)**
Pre-commercial thinning	15 years (remove 30-40% of trees)
Commercial thinning (periodicity)	Each 10 years (25 – 45) based on wilson factor = 0.27
Tappin resin	dbh > 20 cm
Clearcut (age)	35, 40, 45, 50 years

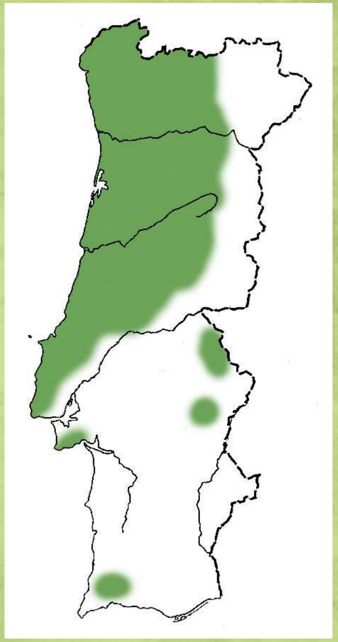
FMM6 – Pure pedunculate oak

The main reasons

- Pedunculate oak is a good alternative for abandoned agricultural land, where the soils are fertile and deep with good water availability;

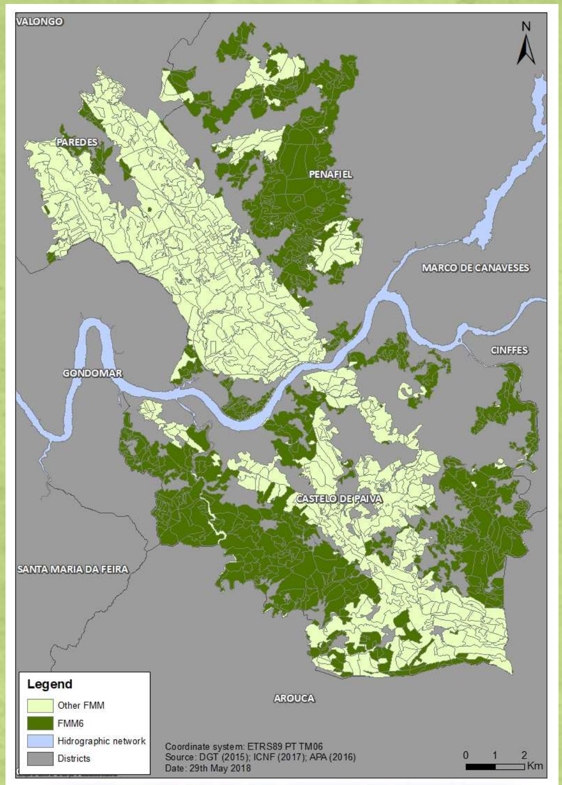
- Stronger planting restrictions on eucalyptus, and thus the forest owners are looking for native alternative species for wood production;

- Forest mosaics diversification with pedunculate oak and other broadleaves could be a positive contribution/help to reduce fires and diseases risks.



(*florestar.net, 2018*)

FMM6 – Pure pedunculate oak



- Number of simulated MUs: 701;
- Area: 6784.86ha;
- Selection of MU with fertile and deep soils;

✓Empirical growth and yield models integrated in SimGaliza, developed in Spain for Galicia (Gómez-García et al. 2015, 2016)

Ecosystem services targets

- Native vegetation
- High qualitity timber
- biodiversity
- cultural services
- Resistance to wildfires

Plantation	1600 trees/ ha (3 x 2)
Pruning	23 years
Pre-commercial thinning	18 - 22 years
Commercial thinning (periodicity)	13 m (25 – 29 years) 16 m (35 – 39 years) 18 m (43 – 47 years)
Clearcut (age)	40, 50, 60 years

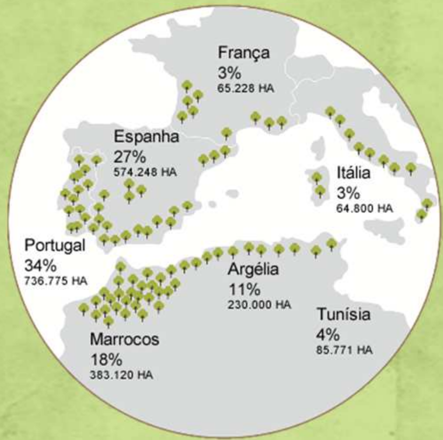
FMM7 – Pure cork oak

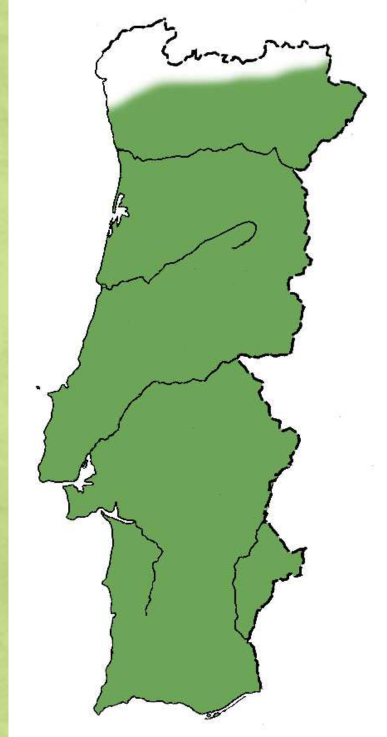
The main reasons

- Existence of several spots with spontaneous regeneration of the two climax oak species (*Q. robur* and *Q. suber*), suggesting that with proper guidance they could succeed and gradually replace mixed stands with pine and eucalyptus;

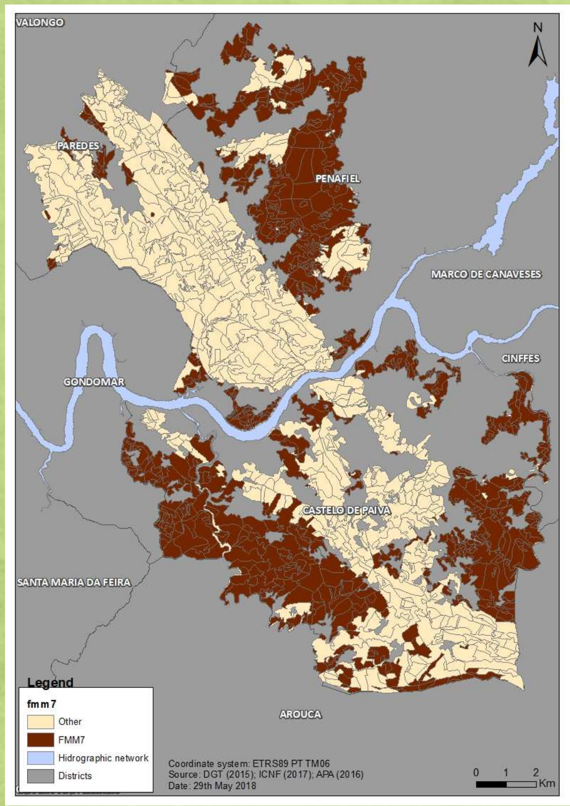
- Stronger planting restrictions on eucalyptus, and thus the forest owners are looking for native alternative species for cork production;

- Forest mosaics diversification with cork oak and other broadleaves could be a positive contribution/help to reduce these fire and diseases risks.





(*florestar.net, 2018*)



FMM7 – Pure cork oak

- Number of simulated MUs: 693;
- Area: 6597.46 ha;
- Selection of MU with fertile and deep soils;

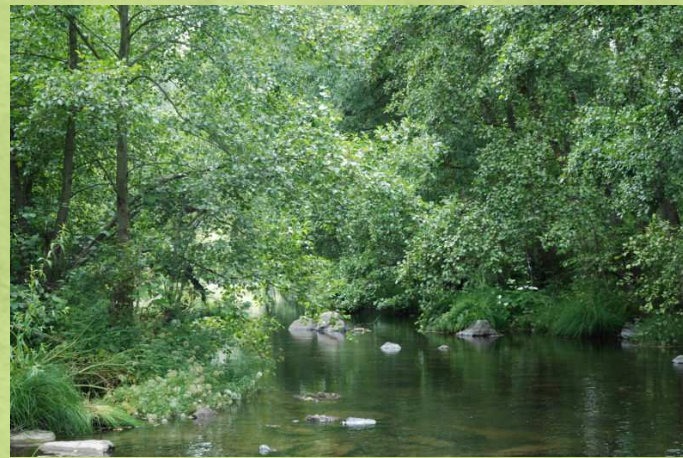
✓Growth and yield model SUBER V5.0 currently available in the sIMfLOR Platform (Faias et al. 2012).

Ecosystem services targets

- Native vegetation
- Cork
- Biodiversity
- cultural services
- Resistance to wildfires

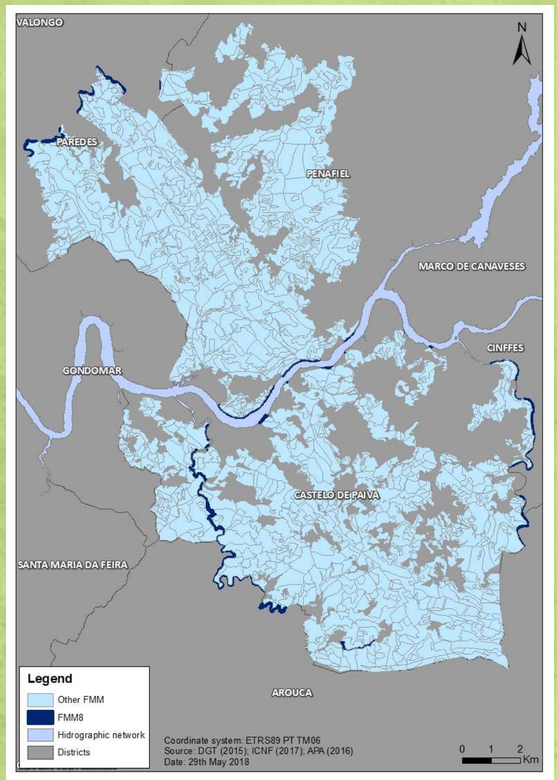
Plantation	1600 trees/ ha (3 x 2)
Pre-commercial thinning	15 years
Commercial thinning	30, 40, 58 and 76 years
1st debarking	30 years
2nd debarking	40 years
3rd debarking	each 9 years

FMM8 – Riparian systems



The main reasons

- Is not focused on the supply of wood but in:
  - ✓alluvial ecosystems sustainability
  - ✓nature conservation
  - ✓watershed management
  - ✓provides carbon stock storage
  - ✓assist water resources (filtration and purification in waterlogged soils)
  - ✓root system helps to control floods and stabilize riverbanks



- Mainly a lentic system **located in depressional areas of the Vale Sousa CSA**,

✓ on soils subject to frequent flooding and saturation,

✓ or with markedly impeded drainage with different levels of connectivity with the fluvial network

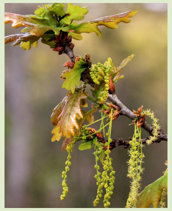
- Number of simulated MUs: 60;
- Area: 100,29 ha;
- dominated by :
  - ✓*Alnus glutinosa*
  - ✓*Salix atrocinera*
  - ✓*Salix alba*
  - ✓*Fraxinus angustifólia*
  - ✓*Populus nigra*

aFMMs – IIASA scenarios

Challenges

FMM5

FMM6



1. **Challenge**
   - It is not feasible to use a process-based model to project the growth of Maritime pine and pedunculate oak

1. **Approach**
   - Our timber projections and pine-related products such as resin ⇨ empirical growth and yield models :

   scenario REF = 10% productivity

   scenario BIO = 6,76%

   scenario GLOB = 4.75%

FMM7

FMM8

2. **Challenge**
   - It is not feasible to use a process-based model to project the growth of cork oak, dominant production is based on cork extraction

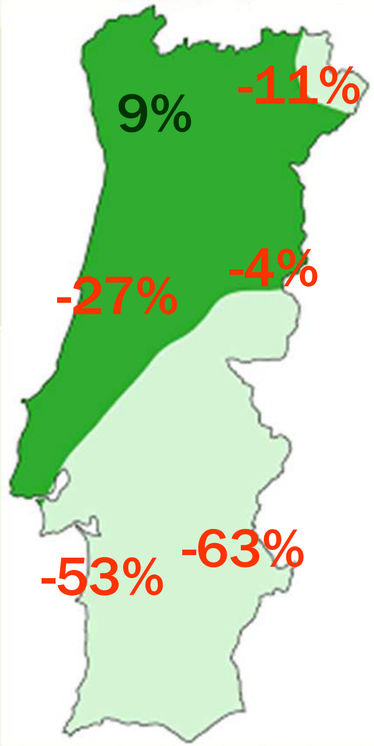
2. **Approach**
   - adjustments on cork projections by empirical growth and yield models. scenario REF = 19% productivity

   scenario BIO = 12,8%

   scenario GLOB = 9%

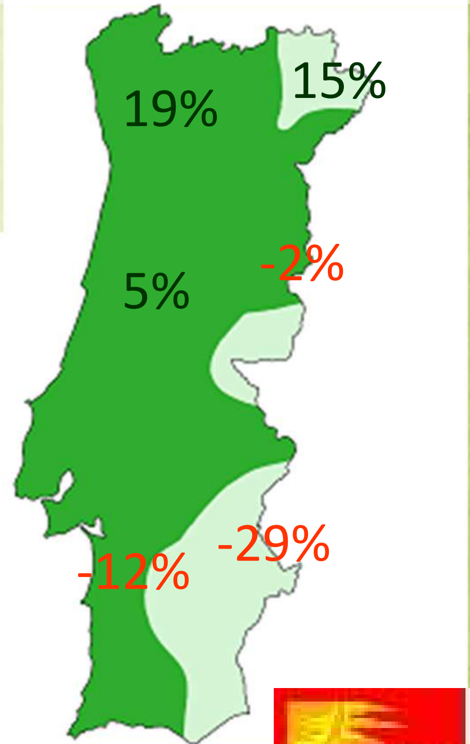
Maritime pine

Productivity – AMA (m^3 ha^{-1} ano^{-1})



Cork oak

Produtivity– NPP (gC m^{-2} ano^{-1})



Multiple use of the forests and Ecosystem services

How to quantify them?

- Growth and Yield models

    (eg. 3PG, Globulus,…)

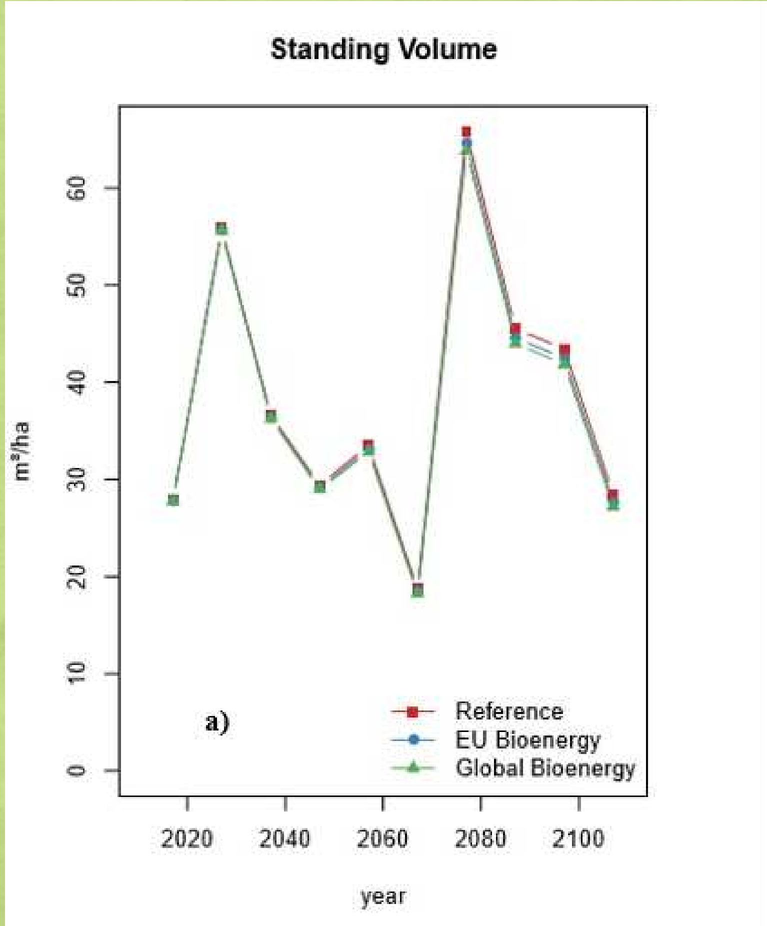
- Indicators

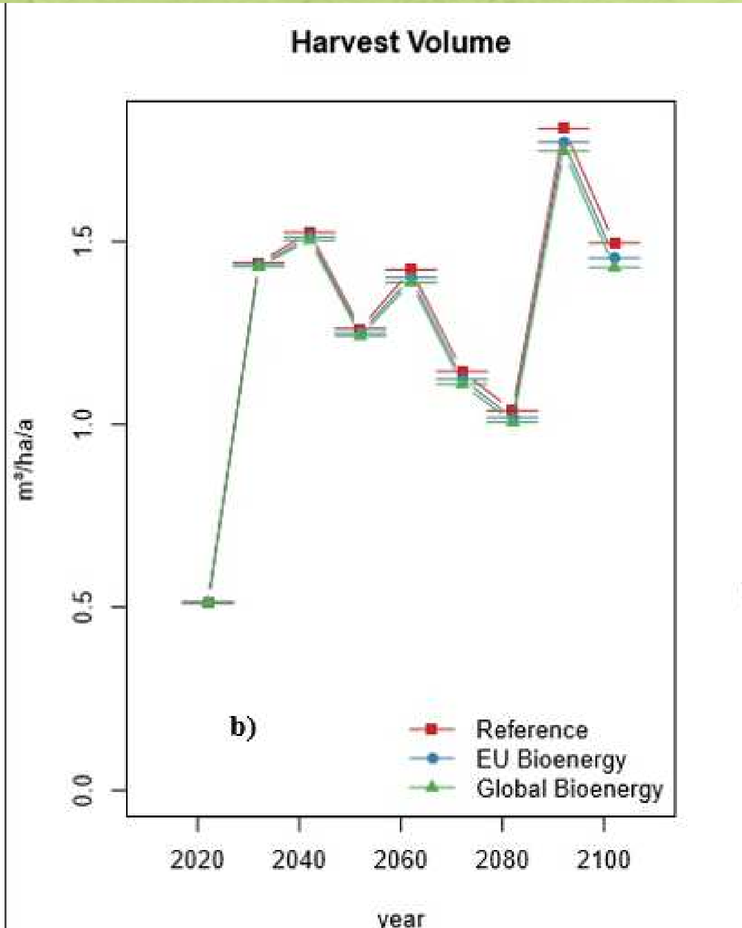
    (eg. Wildfire resistance, biodiversity)

- Indexes (eg. RALF index)

Wood production – Landscape level

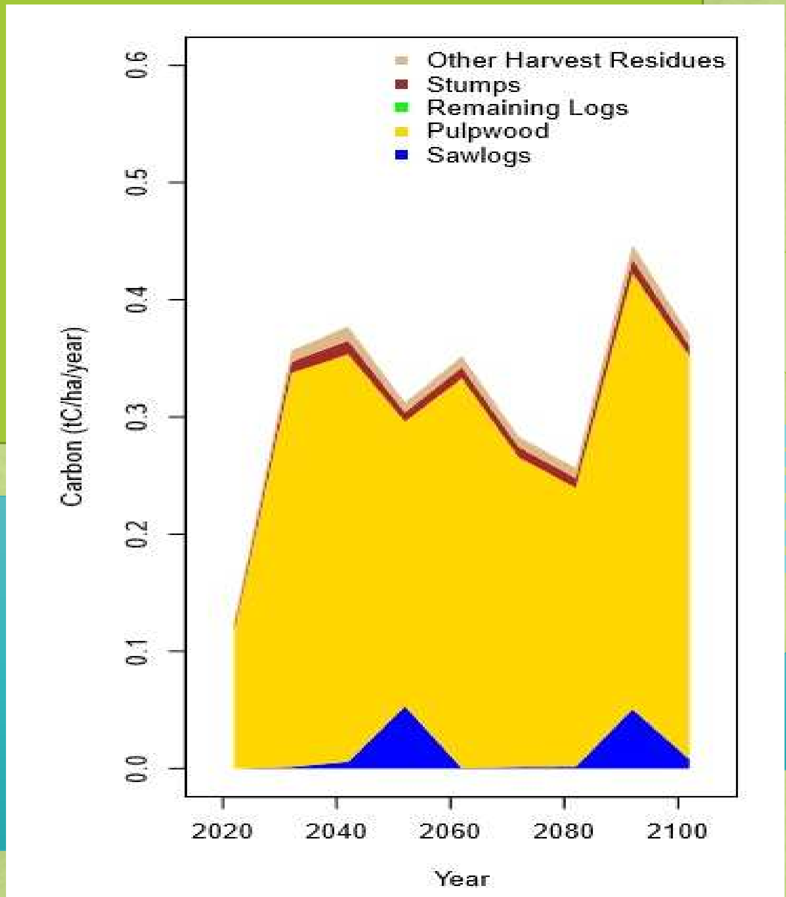
Evolution of the standing volume (m^3ha^{-1}) and the harvest volume (m^2ha^{-1})





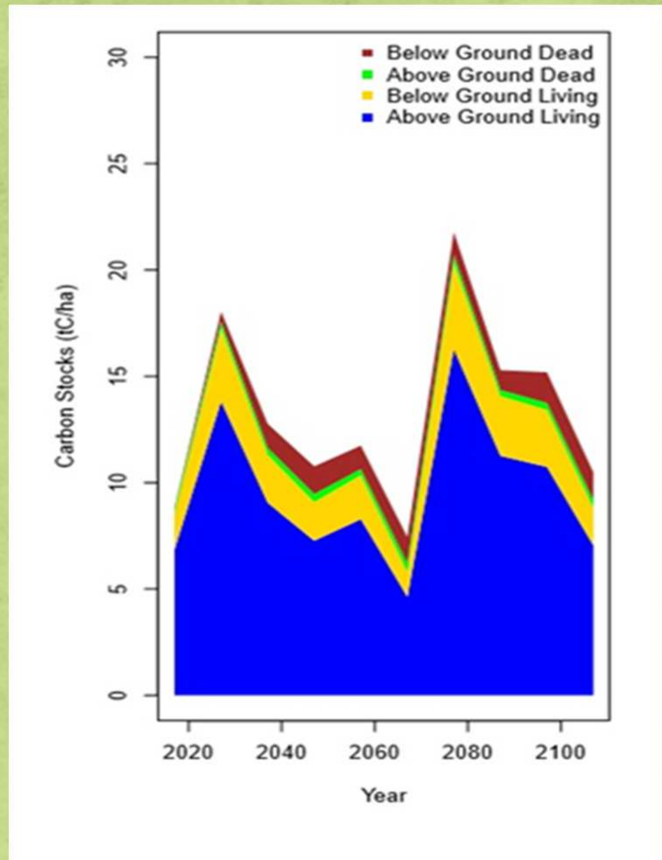
Carbon assessment

C-Components of the harvested wood



Coarse wood-based forest carbon stocks

Forest carbon stocks in the living trees



Biodiversity values

- Biodiversity score increasing with shrub cover and changing according to tree composition and forest management

#1. Tree species composition

$$= \left[Minimum\ score + \frac{Maximum\ score\ - minimum\ score}{Maximum\ score} * age \right]$$

#2. amount of forest fuel loading <u>shrub cover</u>

$$= \left(\frac{1}{Biomass\ Maxima} * Biomass\ t\right)$$

Eucalyptus	[min 1 - max 2]
Maritime pine	[min 2 – max 3]
Chestnuts	[min 3 – max 4]
Pedunculate oak	[min 4 – max 5]
Cork oak	[min 4- max 5]
Ripiarian species	[min 5 – max 6]

- **Fuel load |** values range [0-1]
- Asessment of biomass accumulation (Mg. ha-1) under canopy cover by Botequim et al. 2015

Water-related - Erosion

RUSLE: REVISED UNIVERSAL SOIL LOSS EQUATION

$$A = R * K * LS * P * C$$

<u>**C-Factor** refers to cover management factor by different species</u>

A dynamic C -factor according to the % of coverage over time that shows the silvicultural practices defined for the several prescriptions of each FMM.

A = the soil loss (t ha^{-1} yr^{-1})
R = the rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1})
K = the soil erodibility factor (t ha-1 MJ mm-1), LS = the slope length factor and slope steepness (adimensional)
C = cover management factor **C-Factor,** ranges from 0,001 to 1,0 (adimensional)
P = support practice factor ranges from 0,3 to 1,0) (adimensional)

<u>**Dynamic C-Factor** :quantifies the effect of management</u>
practices (harves
C = Min (Cf) + Ra
Cf = Min and Max
(Condés & Sterb

<u>**Fcover calculation (% C. cover) :**</u>

- C factor reaches its maximum value when the CC is equal to **"0" (no vegetation protection, and high risk of erosion)**
- its minimum value when the CC is equal **to "1" (soil is fully covered by vegetation)**

Cultural services

RAFL-index - recreational and aesthetic value of the forested landscape

Concepts	Dimensions	Attribute (following template)	Nr	Indicator (units)	Direction of attribute	Value-function
Stewardship	Sense of care / upkeep	Harvest residues	1.1.1	m^3/ha	-	0.67 m^3= 0 , 0.34 = 1. linear
Naturalness / disturbances	Alteration/impact	% of area harvested (final felling area)	2.1.1	%, between 0 and 1	-	0% =1, 10% = 0, linear
	Wildernis	Mortality volume	2.2.1	m^3/ha	+	0 m^3/ha = 0, 2 m^3/ha = 1, linear
	Intrusion	Naturalness	2.3.1	0 = natural, non-disturbed forest, 0.33 = close to natural, 0.66 = semi-natural, 1 = far from natural (monocultures, plantation)	-	linear
Complexity	Diversity	One (0), two (0.33), three (0.66), more than three (1)	3.1.1	(re)scale 0 - 1	+	linear
	Variety	even-aged (0), two-aged (0,5), uneven-aged (1)	3.2.1	(re)scale 0 - 1	+	linear
	Spatial pattern	Stand size variation	3.3.1	%, between 0 and 1	-	0.001%=0, 0%=1, linear
Visual scale	Openness	Mean tree number	4.1.1	stems/ha	-	500 = 1, 1000 = 0, linear
	Visibility	Understory	4.2.1	%, between 0 and 1	-	linear
Historicity / imageability	Historical richness	Mean stand age	5.1.1	years	+	0yr = 0, 10 yr = 1, linear
	Historical continuity / place identity	Change in forest location (afforestation, deforestation)	5.2.1	%, 0 - 1	-	25% = 0, 0% =1, linear
Ephemera	Seasonal change	Share broadleaves	6.1.1	%, between 0 and 1	+	20% = 0, 90%=1, linear

- Cul… DEX on…
- …6)

Regulatory services - Fire

- Stand specific wildfire resistance indicator (Rit)

$$Rit = (1 - Pburn * Psd * Pdead)$$

Ferreira et al. 2015

Pburn *= Probability of wildfire occurence in stand i managed with prescription k in year t*

Psd *=Probability of mortality to occur if there is a wildfire in stand i managed with prescription k in year t*

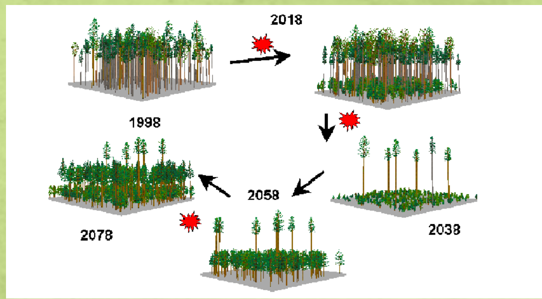
Pdead *=Proportion of dead trees in stand i managed with presciption k in year t if mortality occurs*

- **Landscape Fire Vulnerability Indicator classes**

Class		
1	Most vulnerable	[0.394140452; 0.958784542]
2	High to medium vulnerability	[0. 958784542; 0.977027132]
3	Medium vulnerability	[0. 977027133; 0.989945805]
4	Medium to low vulnerability	[0. 989945806; 0.998424741]
5	Least vulnerable	[0. 998424741; 1]
Min		0.394140452
Max		1.000000000

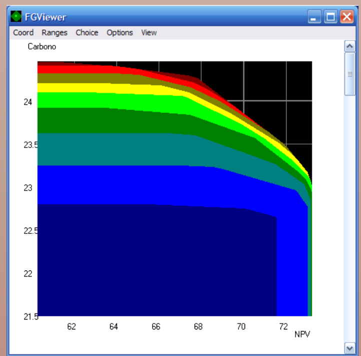
After stand design and simulation of decision spaces

1.cFMM and aFMM (**FMM5, 6, 7 and 8**) simulation for all stands



2. Forest evolution scenarios, ES provision

3. Mathematical model building



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

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

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

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

4. Ecosystem services tradeoffs analysis

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

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

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

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

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

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

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

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

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

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

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

$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} corkA_{ijt} x_{ij} = CORKA_t, \ t = 1, \ldots, T$$

$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} cones_{ijt} x_{ij} = Cones_t, \ t = 1, \ldots, T$$

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

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

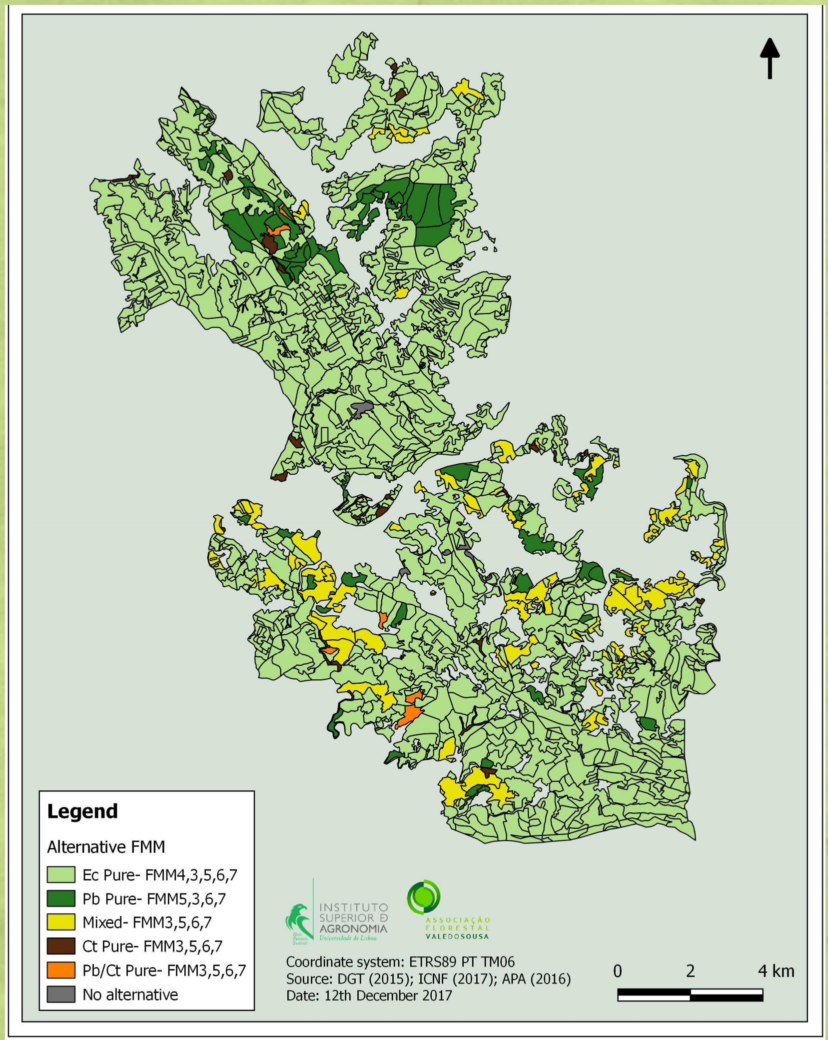
$$\sum_{t=1}^{T} \frac{WF_T}{T} = WF$$

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

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

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

After stand design and simulation of decision spaces



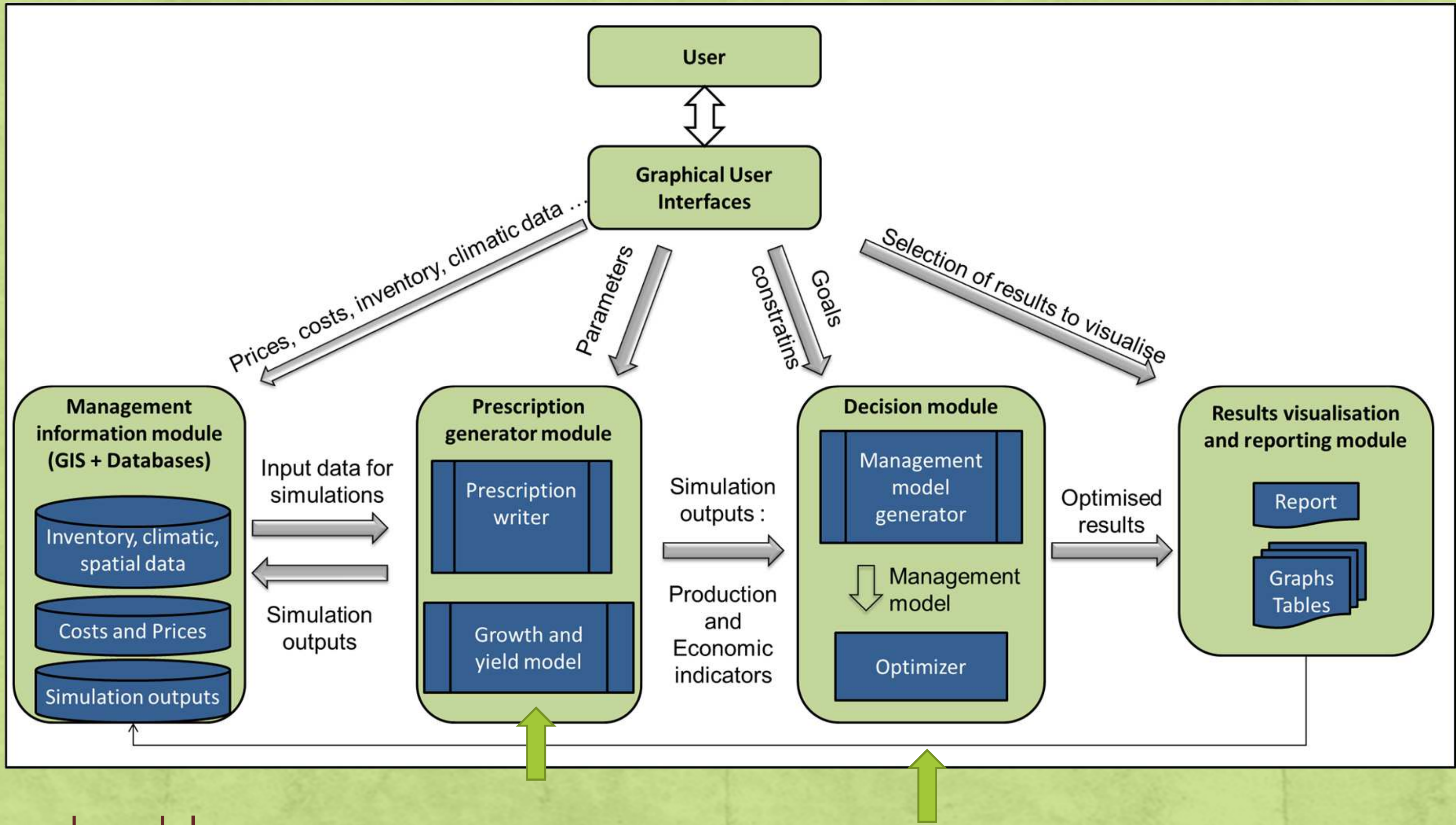
?

- *What can we do to meet demand, safeguard biodiversity, and reduce risks by modified FMM?*

Our DSS - WebSADfLOR

https://sadflor.isa.ulisboa.pt/ISA3/PHP/inicio.php

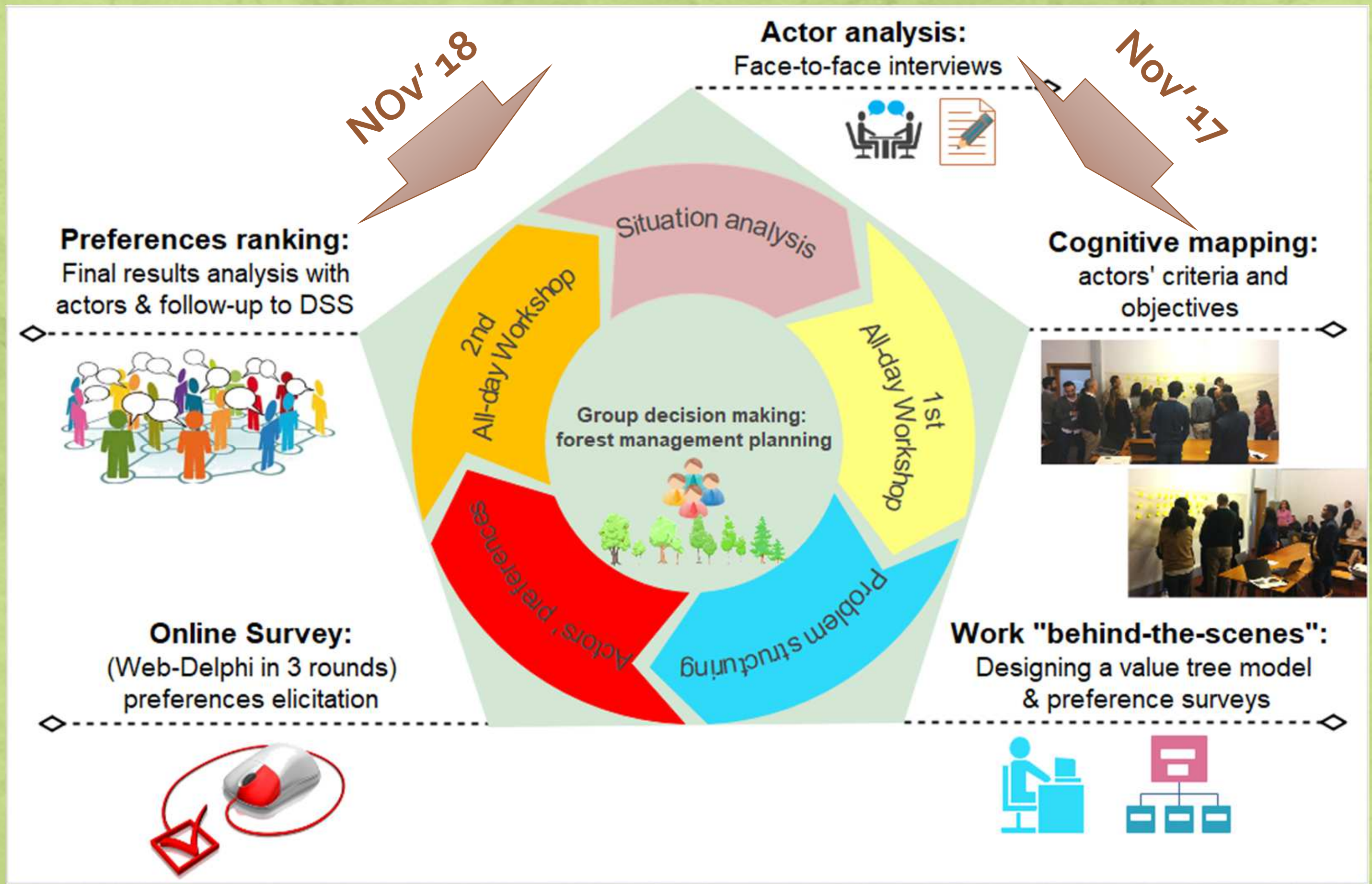
The DSS architecture



- Process-based models
- Wood Quality models
- Risk and damage models...

- Different mathematical techniques are implemented

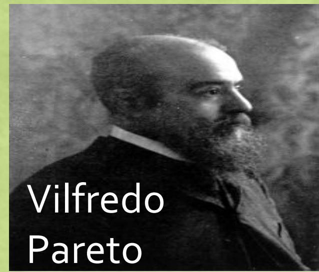
Group decision making process

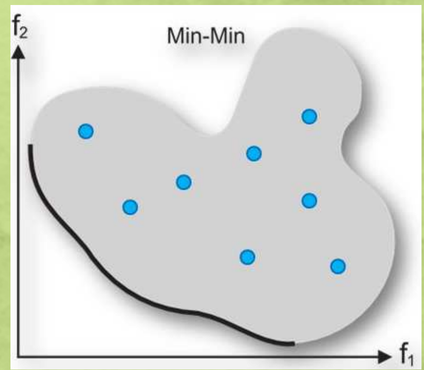


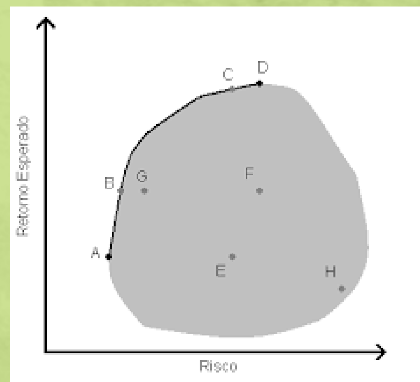
Group decision making process

Pareto Frontier – Tradeoff analysis

- Multicriteria Decision Analysis
  - Decision makers intervention level
    - A *priori*
    - Progressive articulation of preferences
    - A *posteriori*
      - Pareto Frontier
  - Number of decisions
  - Preferences Modeling
  - Uncertainty in criteria definition
  - N. of entries and/or results obtianed

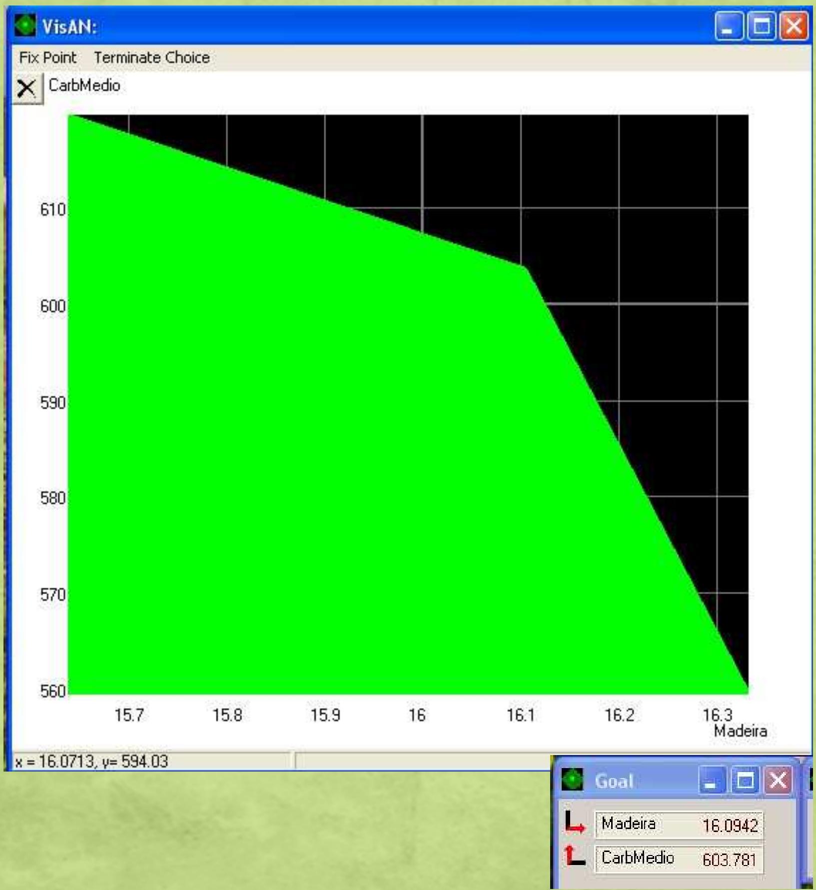




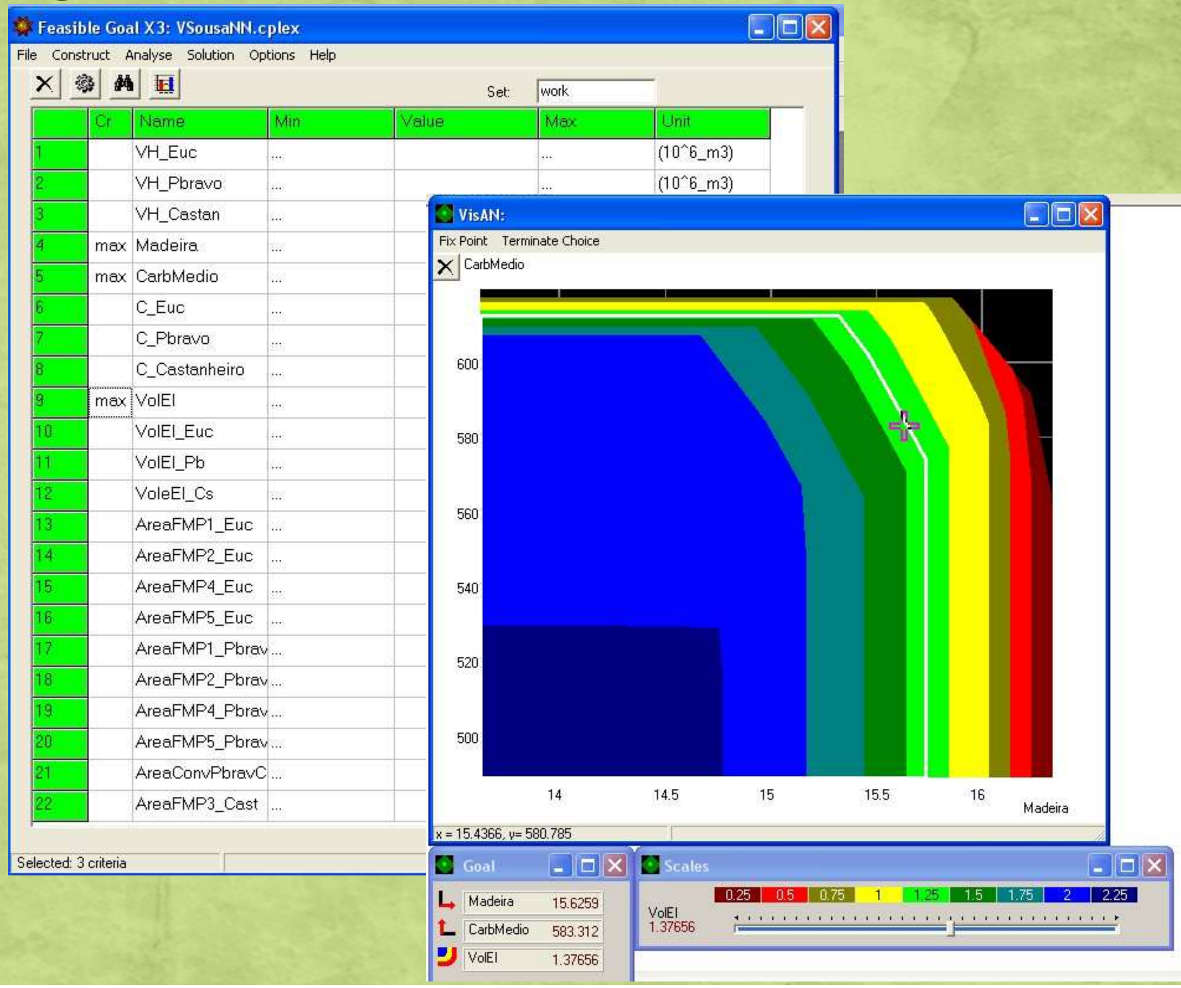


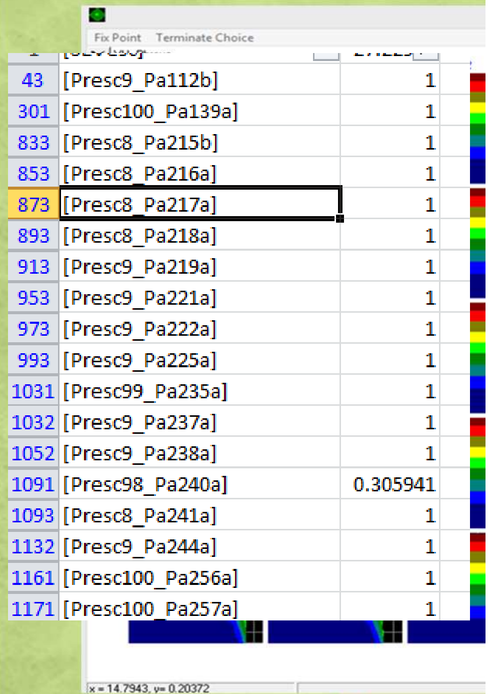
Pareto Frontier – Tradeoff analysis

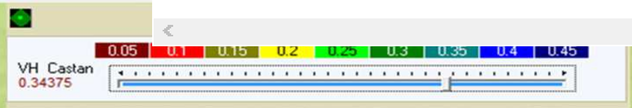
- *2 criteria*

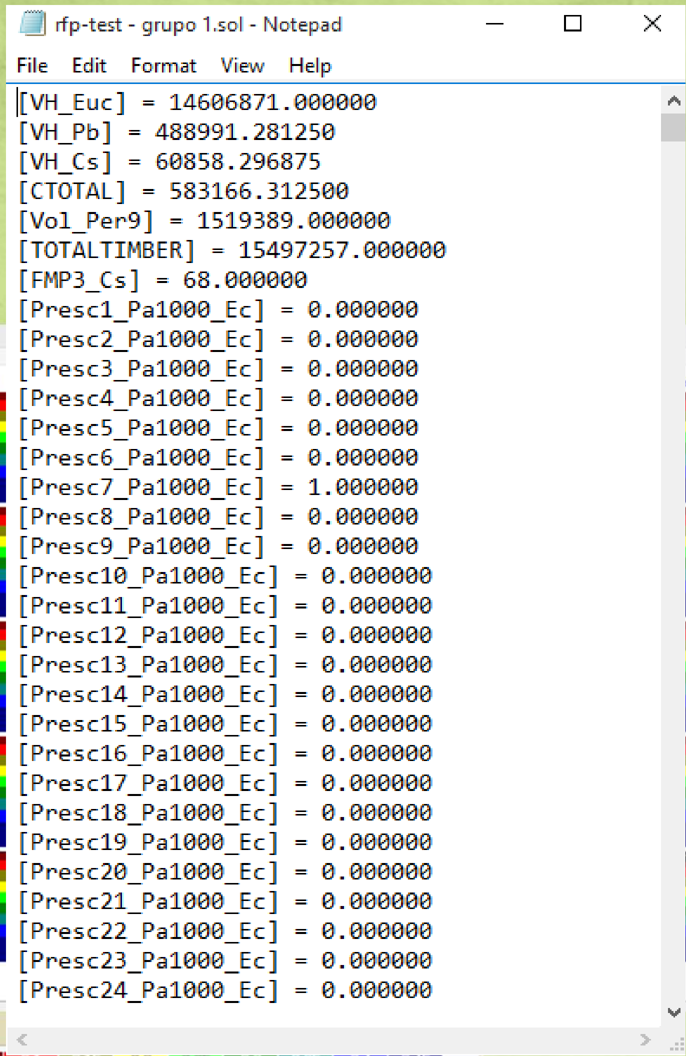


- *3 criteria*








rfp-test - grupo 1.sol - Notepad

File Edit Format View Help

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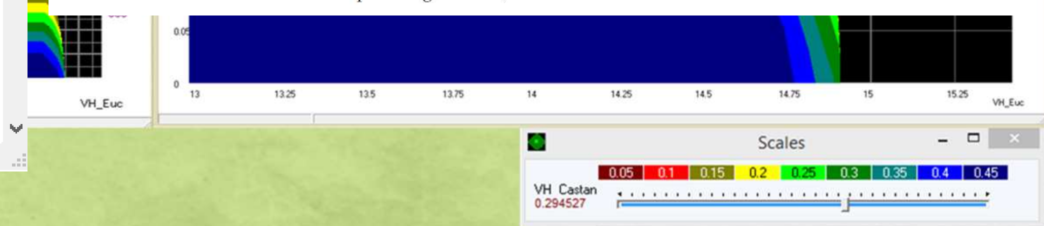
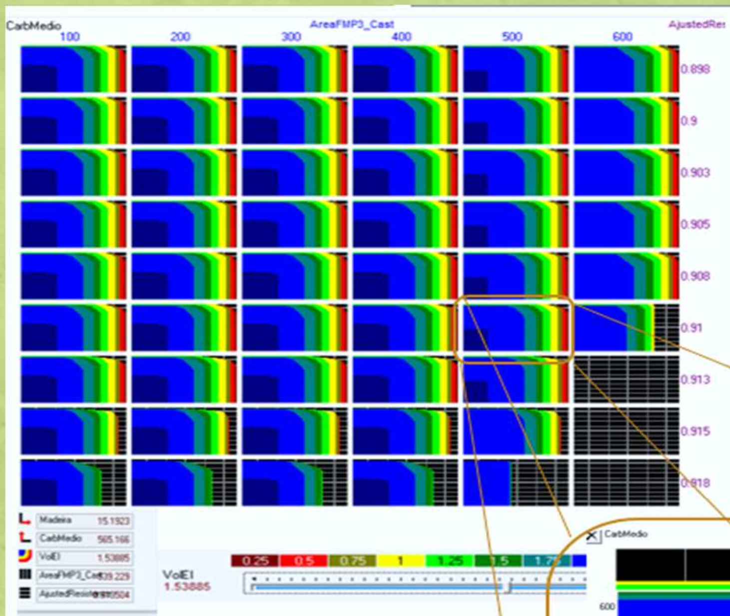
```

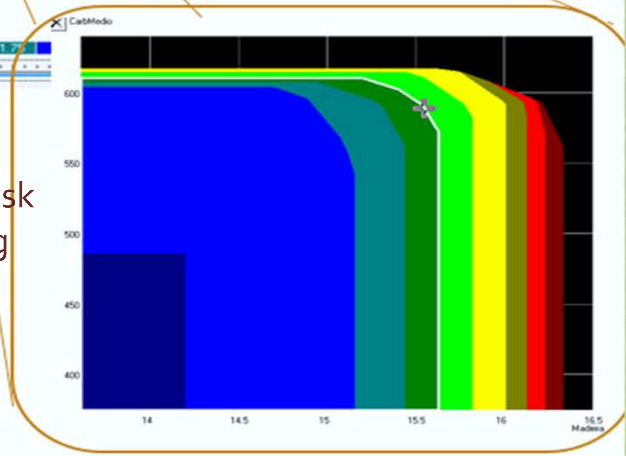
Ecosystem Service List	Value	Units
HV_Euc	14.72	10^6 m^3
HV_Mp	0.23	10^6 m^3
HV_Chest	0.14	10^6 m^3
Thwood	0.39	10^6 m^3
TWood	15.48	10^6 m^3
AvgCarb	593.47	10^3 $Mg{\cdot}year^{-1}$
VolEI	1.5	10^6 m^3
Euc area	12729.9	Ha
MP area	1174.5	Ha
Chestnut area	256.9	Ha
AreaConvMPChest	355.39	Ha
WF	0.760	-
WF_T	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.



Ecosystem Services tradeoffs analysis





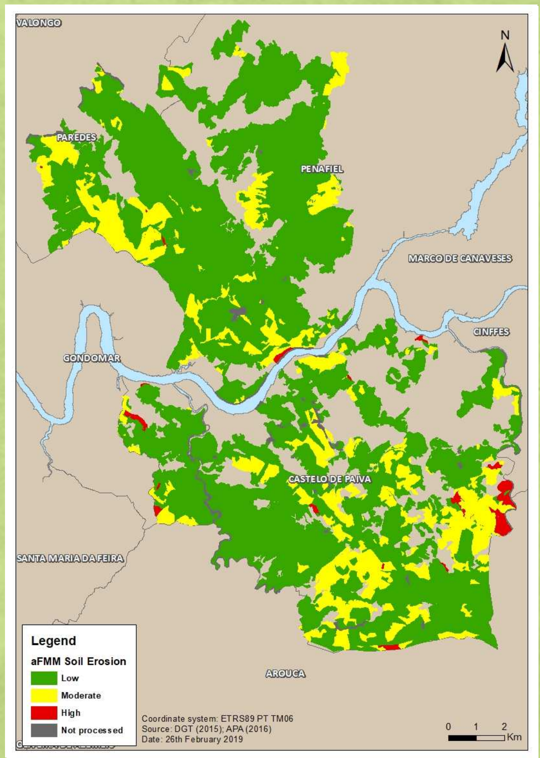
- Trade-offs between wildfire risk and the supply of provisioning (timber) as well as regulatory (carbon) ES

Marques, S.; Marto, M., Bushenkov. V., McDill , M. Borges . J.G. (2017) Addressing Wildfire Risk in Forest Management Planning with Multiple Criteria Decision Making Method. Sustainability, 9, 298; doi:10.3390/su9020298

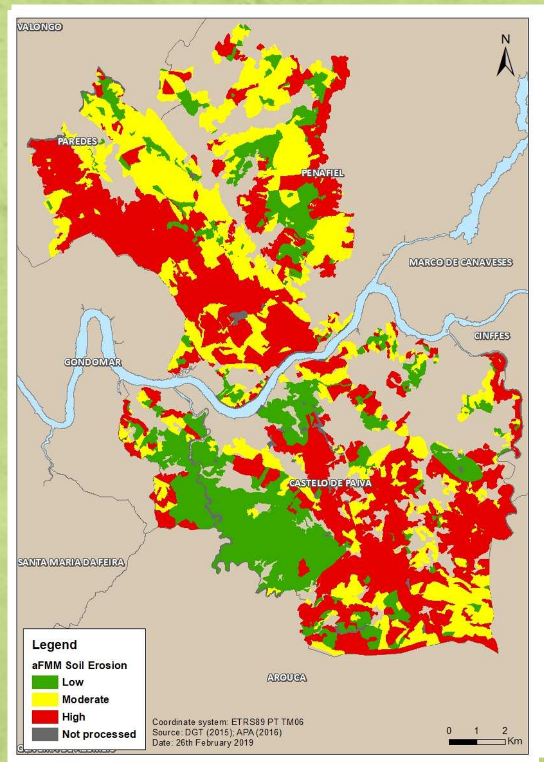
Assessment of ES – After selecting a management plan

EROSION CONTROL

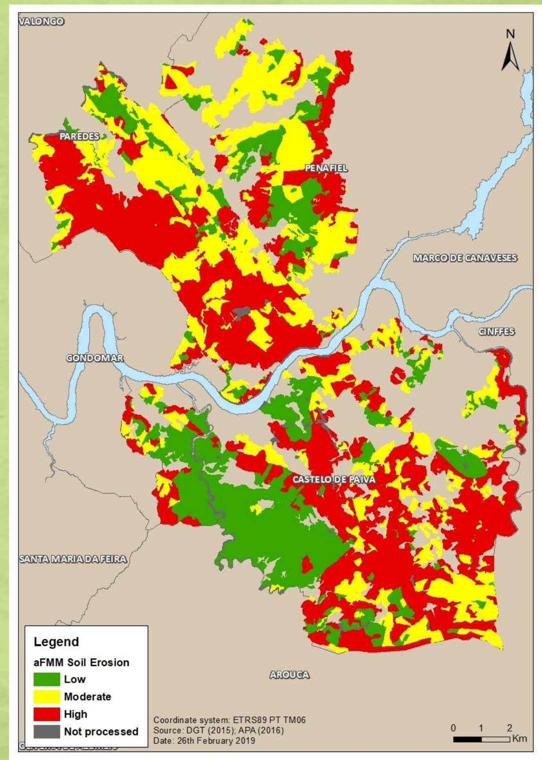
BAU _aFMM



REF _aFMM



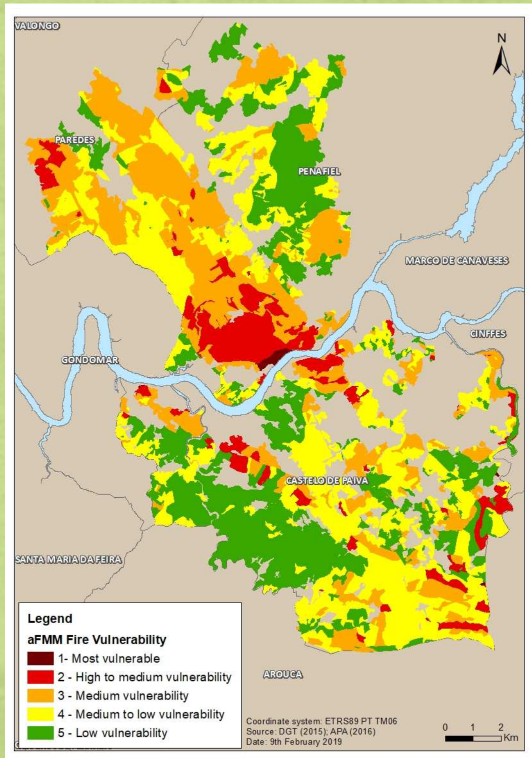
BIO _aFMM



Assessment of ES – After selecting a management plan

FIRE VULNERABILITY

BAU _aFMM



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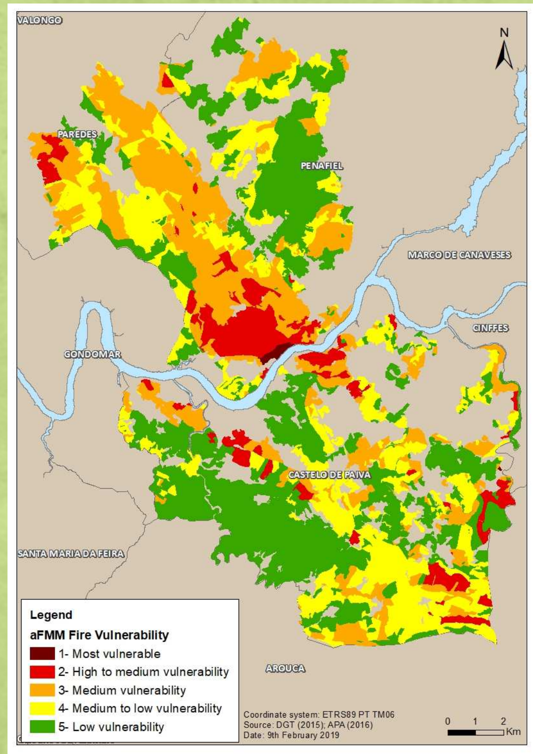
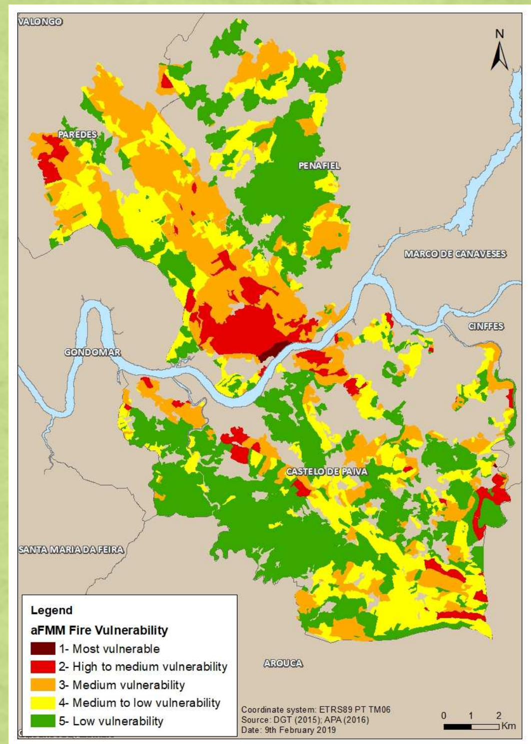


BIO _aFMM



landscape-level

Methods and tools to support forest management planning in Portugal

Susete Marques (smarques@isa.ulisboa.pt)