20th CONFERENCE OF THE INTERNATIONAL FEDERATION OF OPERATIONAL RESEARCH SOCIETIES

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The Art of Modeling BARCELONA 2014
13th-18th July

U LISBOA UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
Hinc Patriam Sustinet

ForChange
Forest Ecosystem Management Under Global Change

"A three-step approach to forest optimization modelling for assessing trade-offs in spatial fuel management strategies"

July, 15th

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FIRE-ENGINE PROJECT

"FLEXIBLE DESIGN OF FOREST FIRE MANAGEMENT SYSETMS" (MIT/FSE/0064/2009)

U LISBOA UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
MIT ESD Massachusetts Institute of Technology Engineering Systems Division
INESCPORTO INSTITUTO DE ENGENHARIA DE SISTEMAS E COMPUTADORES DO PORTO
utad
grupo Portucel Soporcel
MIT Portugal
FCT Fundação para a Ciência e a Tecnologia MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR Portugal
COMPETE PROGRAMA OPERACIONAL FACTORES DE COMPETITIVIDADE
QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL PORTUGAL 2007.2013
UNIÃO EUROPEIA Fundo Europeu de Desenvolvimento Regional

SUMMARY:

Relevance of the problem

- Background

Problems, challenges and ideas

- Purpose of the research

Research design alternatives

- |A three-step approach for enhanced decision-making in eucalyptus forest

Points of view

- |Addressing trade-offs in spatial fuel management strategies

Ongoing work

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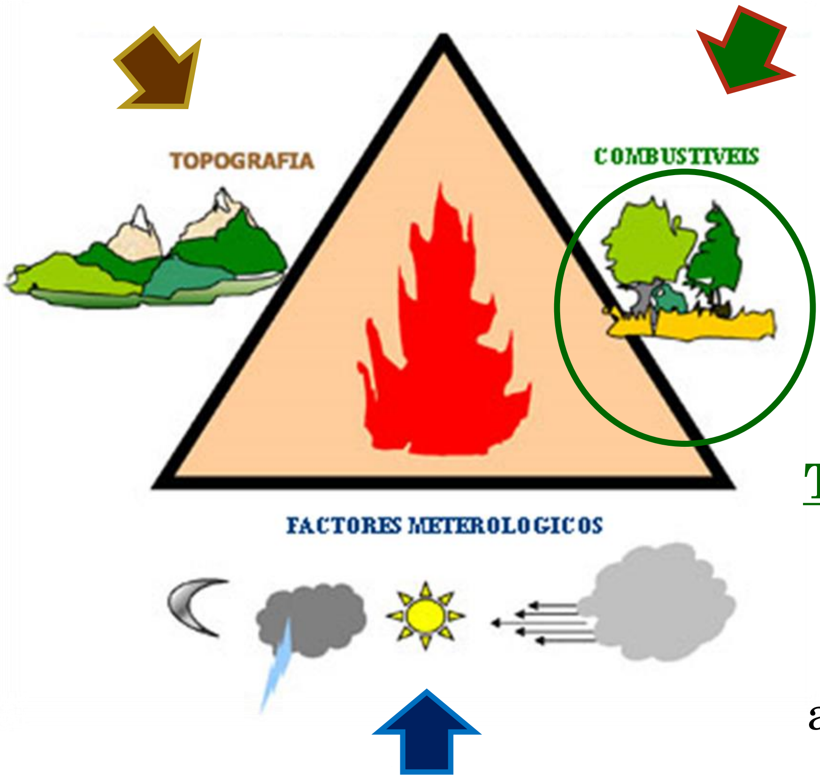
University of Lisbon
The Institute of Agronomy of Lisbon

| Background

- We have little or no control over most factors in the fire behavior triangles



- the area's topography
- weather conditions
- the amount of fuel

<u>The common denominator is fuel</u>

Fire Behavior : influence the intensity and severity of a wildfire reducing the amount and changing the arrangement of fuel before a wildfire erupts

| Quantifying risk for wildfire management

|Several definition of Risk?!...

Risk assessment

Let... $p(f_i) =$ Probability of burning intensity level i — "Exposure"

$R(f_i) =$ Response for intensity i — "Susceptibility"

$E(L) =$ Expected loss — "Risk"

$$E(L) = \sum_i p(f_i) * R(f_i)$$

Finney 2013

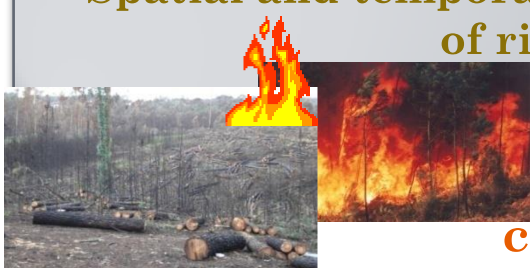
Spatial and temporal quantification of risk

Risk management

Impact of changes in "controllable" biometric variables

- stand density, fuel availability at surface level and vertical structure of the stand

Guidelines for fuel and stand structure modification, which are critical for integrating forestry and fire management activities



Using risk assessment to change perceived or actual risk

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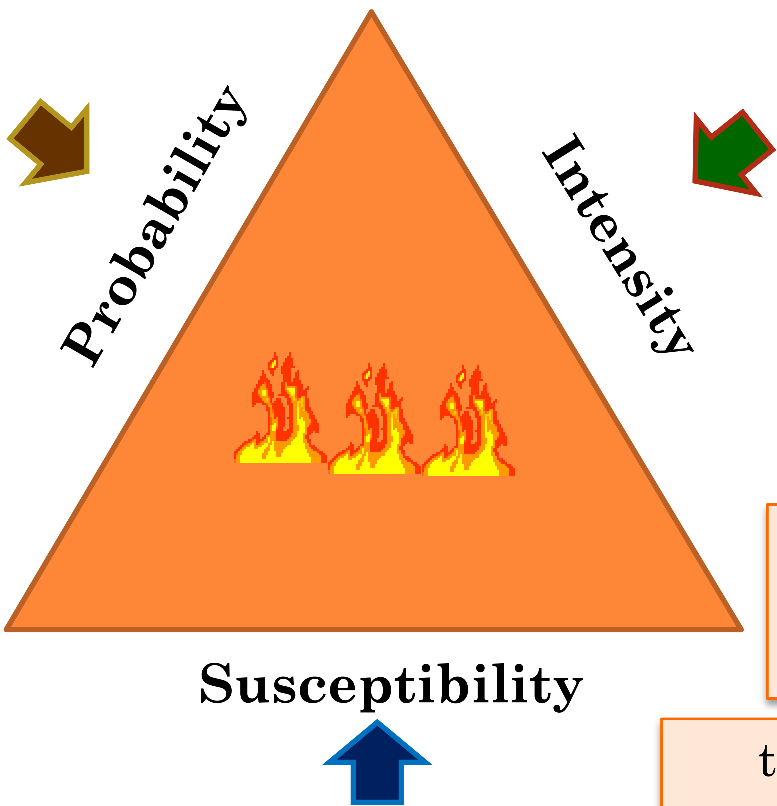
| Background

- **Changing the expect output:**



- reducing wildfire probability P(f_i)
- Reducing wildfire intensity (f_i)
- Reducing the landscape response or susceptibility

The emphasis today in forest management is on **forest restoration** and **fuels reduction**.

there is an urgent need for decision support tools to enable **effective fire management**

| Purpose of the research

Address the problem of **spatially optimize treatments** to prioritize fuel management activities, aimed at **disrupt fire spread** and **protect eucalyptus areas** from burning without encroaching budget constraints, have loss of important ecological and commercial timber values.

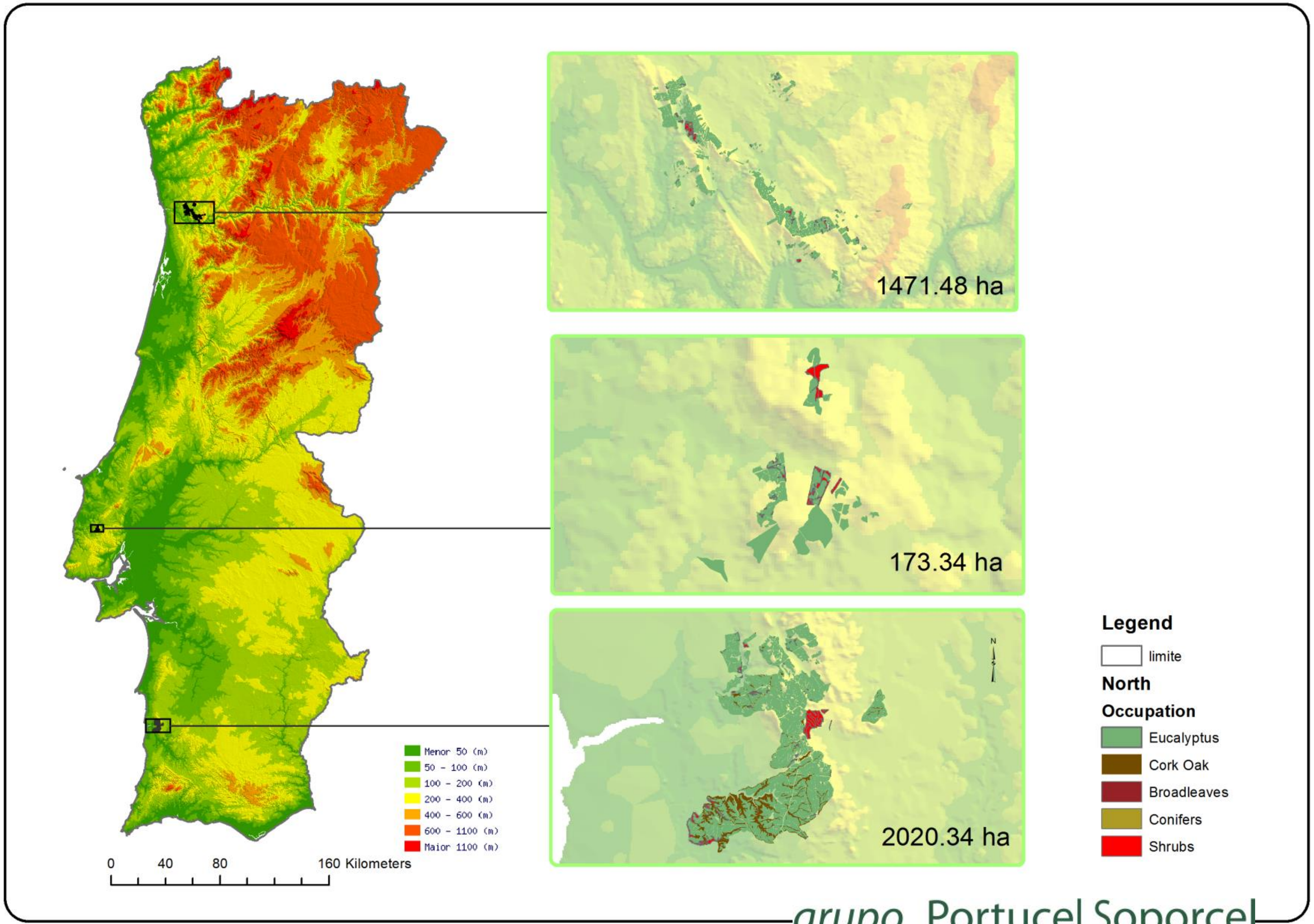
- Developing a Forest System Dynamic Model in order to identify temporal stand-scale and fuel dynamics;

- Characterizing for each fuel arrangements the spread rate curve trends, thereby allowing the calculation of changes in the annual expected wood;

- Simulating in the Landscape Treatment Designer tool the optimal levels of fuel landscape treatment configurations.

| gPS FOREST AREAS ("FARMS")

Three properties of pulp mill's from the Grupo Portucel Soporcel (gPS)



grupo Portucel Soporcel

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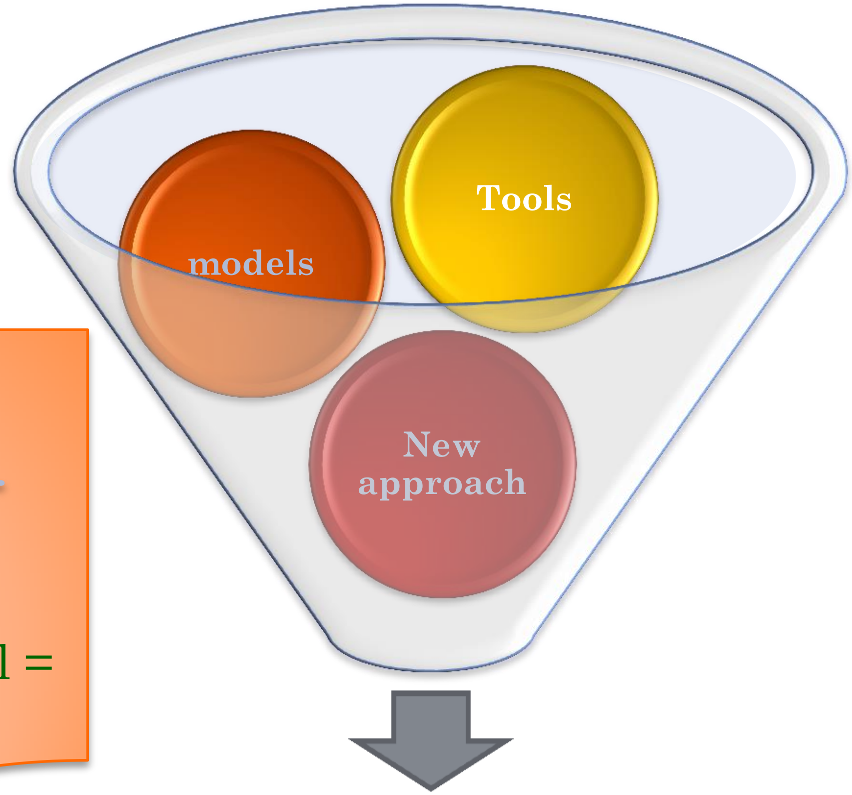
| How to reach the gPS goals?

National level

Fire risk
Fire damage
Fire behaviour
Fire suppression

System dynamic model = Forest model

Regional level



Insight Maker
Ex-RATE
FlamMap
LTD

Fuel management strategies

- ✓ Prioritization of investments
- ✓ Landscape treatment strategies

| Methodology framework

(Tool)

I. **Forest System Dynamic Model**
(Insight Maker)

II. **Calculate Expected spread rate & flame Lenght**
(FlamMap & Ex-rate)

III. **Explore optimal levels for fuel treatments & supression deployment program**
(LTD)

Fuel management strategies need to be informed by fire risk assessment + fire risk analysis

FIRE-ENGINE

| FOREST SYSTEM DYNAMIC MODEL

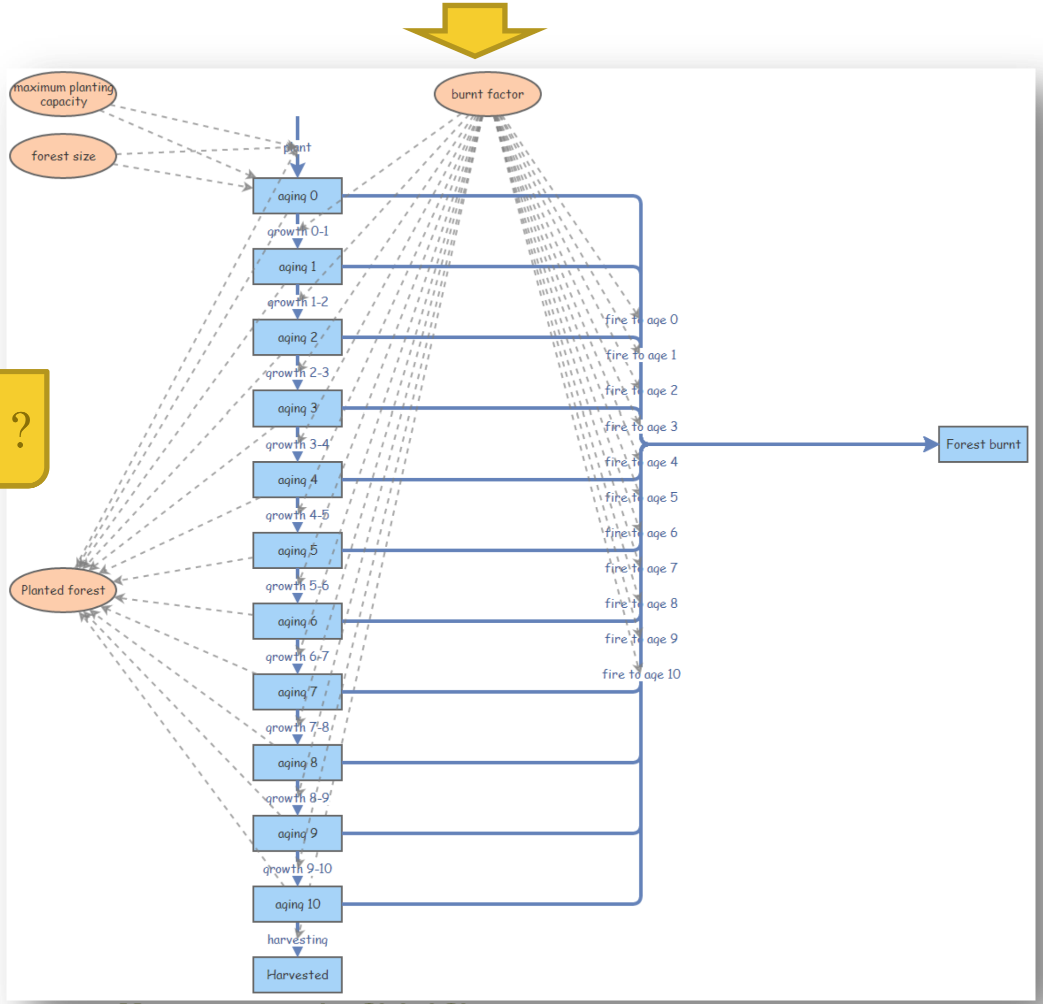
- STEP I

STEP #1

1.1 | How to solve the timing problem ?

- % planting ?
- % harvesting ?
- **% burnt probability ?**
- % dead trees ?
- % fuel model ?

each year/ per 10 years



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STEP #1

1.2| Burnt Factor adjusted ?

Calculating a Burnt probability adjusted:

|Regional-scale level

- 1| Fire frequency by Weibull equation from Oliveira *et al*. 2012
- 2| Multiple correspondence analysis / Cluster analysis from ISA team 1: José M. C. Pereira/Inês Melo (in preparation)

|Stand-scale level

- A Management-oriented model to predict annual wildfire in eucalyptus stands from Botequim *et al*. 2013

STEP #1

1.3| calculating BP : Regional-scale level information

RO PUBLISHING
rnational Journal of Wildland Fire 2012, 21, 48–60
://dx.doi.org/10.1071/WF10131

Fire frequency analysis in Portugal (1975–2005), using Landsat-based burnt area maps

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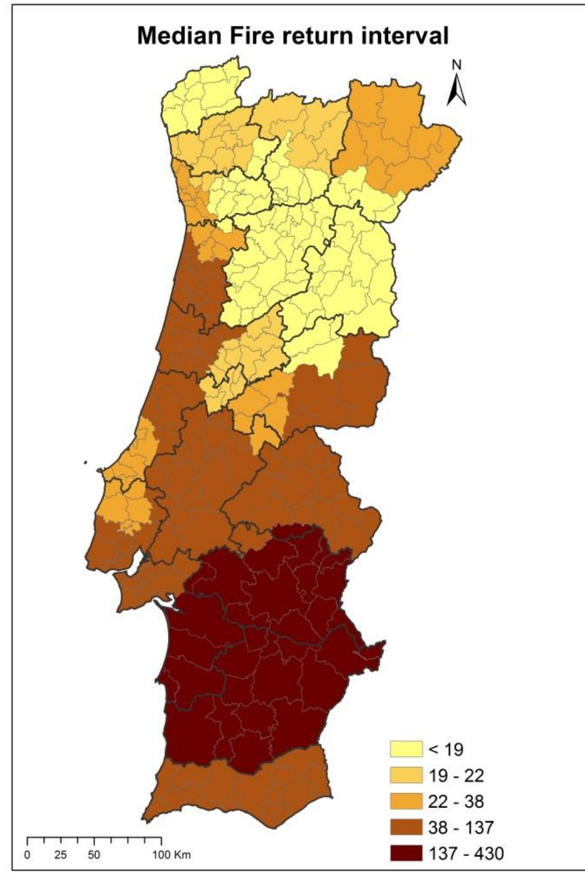
Abstract. Fire frequency in 21 forest planning regions of Portugal during the period 1975–2005 was estimated from historical burnt area maps generated with semi-automatic classification of Landsat Thematic Mapper (TM) satellite imagery. Fire return interval distributions were modelled with the Weibull function and the estimated parameters were used to calculate regional mean, median and modal fire return intervals, as well as regional hazard functions. Arrangement of the available data into three different time series allowed for assessment of the effects of minimum mapping unit, time series length and use of censored data on the Weibull function parameter estimates. Varying the minimum mapping unit between 5 and 35 ha had a negligible effect on parameter estimates, whereas changing the time series length from 22 to 31 years substantially affected the estimates. However, the strongest effect was caused by censored data. Its exclusion led to substantial overestimation of fire frequency and of burning probability dependence on fuel age. We estimated a country-wide mean fire interval of 36 years and an annual burnt area of 1.2%. Regional variations in fire frequency descriptors were interpreted in terms of land cover and land use practices that affect the contemporary fire regime in Portugal.

Additional keywords: censored data, Weibull model.

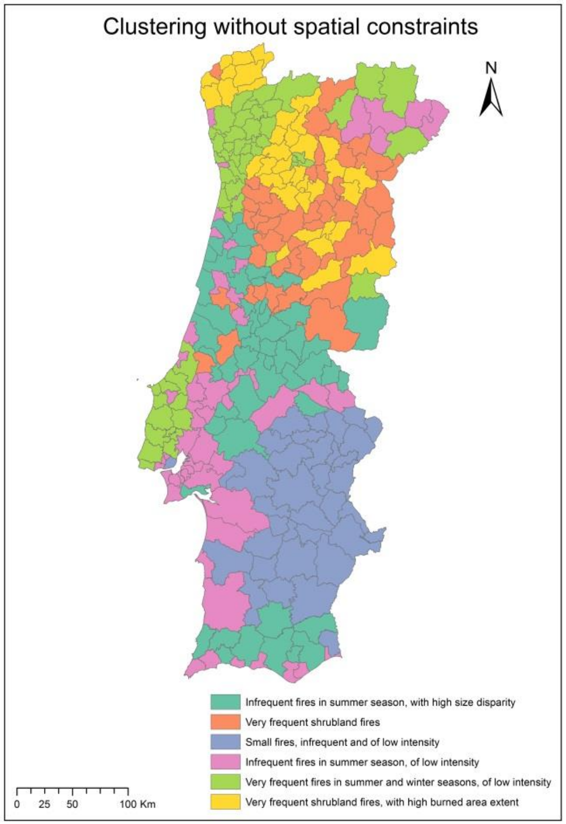
Received 23 October 2010, accepted 24 April 2011, published online 24 October 2011

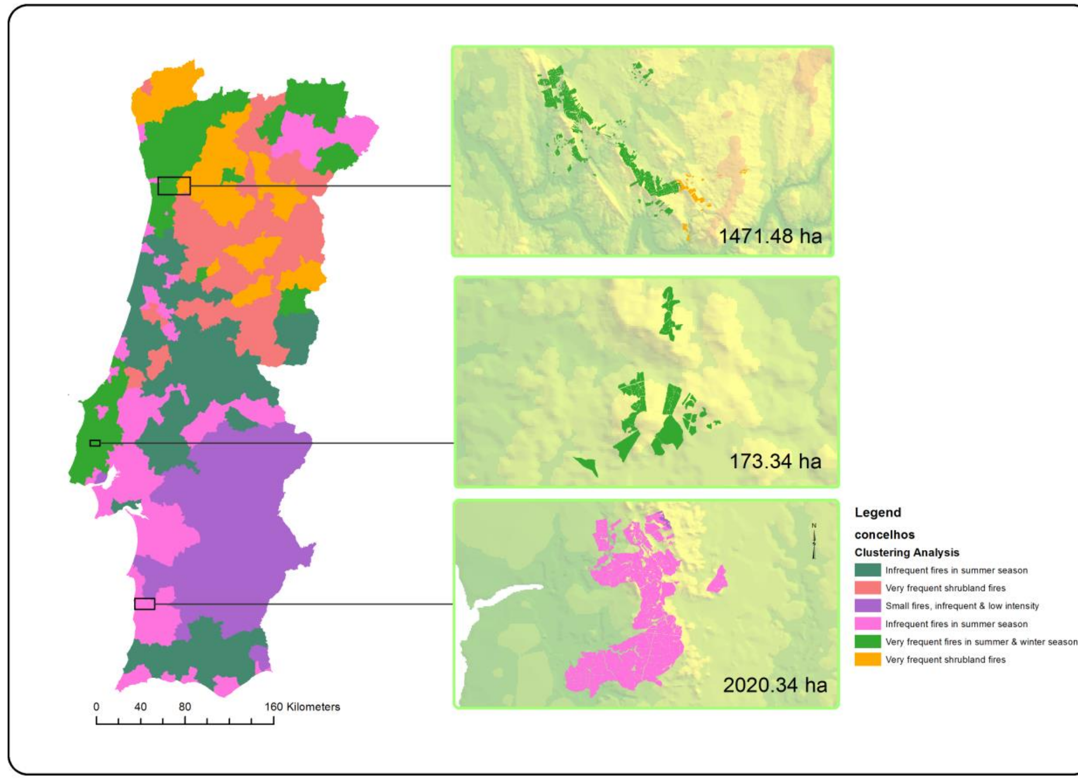


Oliveira *et al*. 2012

STEP #1

1.5| calculating BP: Regional-scale level information





From ISA team 1: *José M. C. Pereira/Inês Melo*

STEP #1

1.7| calculating BP: stand-scale level information

- **Management-oriented model to predict annual wildfire risk**

Botequim *et al. 2013*

$$PburnEc = \frac{1}{1+e^{-(-5.4005-0.0540Hdom+0.3166G/dg+0.3959Biomass+0.5372RoadDist)}}$$

$$\begin{cases} RoadDist = 0 & If \quad \text{RoadDistance} < 1km \\ RoadDist = 1 & If \quad \text{RoadDistance} > 1km \end{cases}$$

Research Article - doi: 10.3832/ifor0821-006 ©iForest

Developing wildfire risk probability models for *Eucalyptus globulus* stands in Portugal

Brigite Botequim [(1)], Jordi Garcia-Gonzalo [(1)], Susete Marques [(1)], Alexandra Ricardo [(1)], José Guilherme Borges [(1)], Margarida Tomé [(1)], Maria Manuela Oliveira [(2)]

This paper presents a model to predict annual wildfire risk in pure and even-aged eucalypt stands in Portugal. Emphasis was in developing a management-oriented model, *i.e.*, a model that might both: (a) help assess wildfire occurrence probability as a function of readily available forest inventory data; and (b) help predict the effects of management options (*e.g.*, silvicultural treatments) on the risk of fire in eucalypt stands. Data from both the 1995/1998 and the 2005/2006 Portuguese National Forest Inventories as well as wildfire perimeters' data were used for modeling purposes. Specifically, this research considered 1122 inventory plots with approximately 1.2 million trees and 85 wildfire perimeters. The model to predict the probability of wildfire occurrence is a logistic function of measurable and controllable biometric and environmental variables. Results showed that wildfire occurrence probability in a stand increases with the ratio basal area/quadratic mean diameter and with the shrubs biomass load, while it decreases with stand dominant height. They further showed that the probability of wildfire occurrence is higher in stands that are over 1 Km distant from roads. These results are instrumental for assessing the impact of forest management options on wildfire risk levels thus helping forest managers develop plans that may mitigate wildfire impacts.

Keywords: Forest Fires, Forest Management, *Eucalyptus globulus* Labill, Annual Wildfire Risk Model

- ***Hdom*** : Dominant stand height (m)
- ***Biom*** : the total biomass of shrubs load (Mg ha^{-1}),
- The predictor ***G/dg*** is non-linearly related to the number of trees per hectare ***G:*** basal area (m^2 ha^{-1});***dg*** : quadratic mean diameter of trees (cm)
  - ***RoadDist:*** dummy variable, distance to road: < a 1Km - RoadDist take value "0", otherwise value "1"

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STEP #1

1.8| calculating the impact of wildfires

- Management oriented post-fire mortality stand level models

#1. Predict whether mortality will occur in a **stand** after wildfire

$$Psd = \frac{1}{1 + e^{-(-0{,}7882 + 1{,}1079.PBr + 2{,}1698.PC - 0{,}5553.G + 4{,}328.\frac{G}{dg} + 3{,}2549.\frac{Sd}{dg})}}$$

#2. Proportion of trees that died in **stands** where mortality did occur **($0 \leq Pr \geq 1$)**

$$PMort = \frac{1}{1 + e^{-(0{,}3579 - 0{,}1361.PEc - 1{,}3872.PBr + 0{,}0525.Slope + 0{,}0017.Alt + 0{,}0393.AVGdbh)}}$$

#3. Probability of a **tree** to die if fire occurs

$$PdTree2 = \frac{1}{1 + e^{-(1{,}5896 + 1{,}1315.Con + 0{,}6714.Ec - 0{,}9362.Oak + 0{,}0128.Slope - 0{,}0679.h - 0{,}0846.G + 0{,}000697.N)}}$$

Botequim, B., Garcia-Gonzalo, J., Silva, A., Marques S, Borges J. G., Oliveira M. M., Tomé, J., Tomé, M. ***Modeling post-fire damage and tree mortality in forest stands in Portugal***. A forest planning oriented model (being edited to be submitted to International forest Review)

STEP #1

1.8| calculating the impact of wildfires

- Variables descriptions of post-fire mortality models

  - **0 ≤ *Pcover type* ≤1**, proportion of cover type in the stand

PBr : proportion of broadleaves ("0" indicating no presence and "1" indicating that stand is purely occupied by broadleaves

PEc : proportion of eucalypt

PC : proportion of conifers

The predictor *G/dg* is non-linearly related to the number of trees per hectare

G: basal area (m^2 ha^{-1}); ***dg*** : quadratic mean diameter of trees (cm)

N: number of trees per hectare

The predictor *Sd/dg* expresses the relative variability of tree diameters

- ***sd*** : the standard deviation of trees' diameters at breast height (cm)
- ***AVGdbh*** the mean tree diameter at breast height of the stand (cm)
- ***Alt***: altitude (m); ***Slope*** : declive (º)

[tree level]

Broad, Con, Ec, Oak **: dummy variable to identify presence of cover type**
(Take value "1" when the tree is from one of the cover types)

FIRE-ENGINE

CALCULATE FIRE BEHAVIOUR CHARACTERISTICS

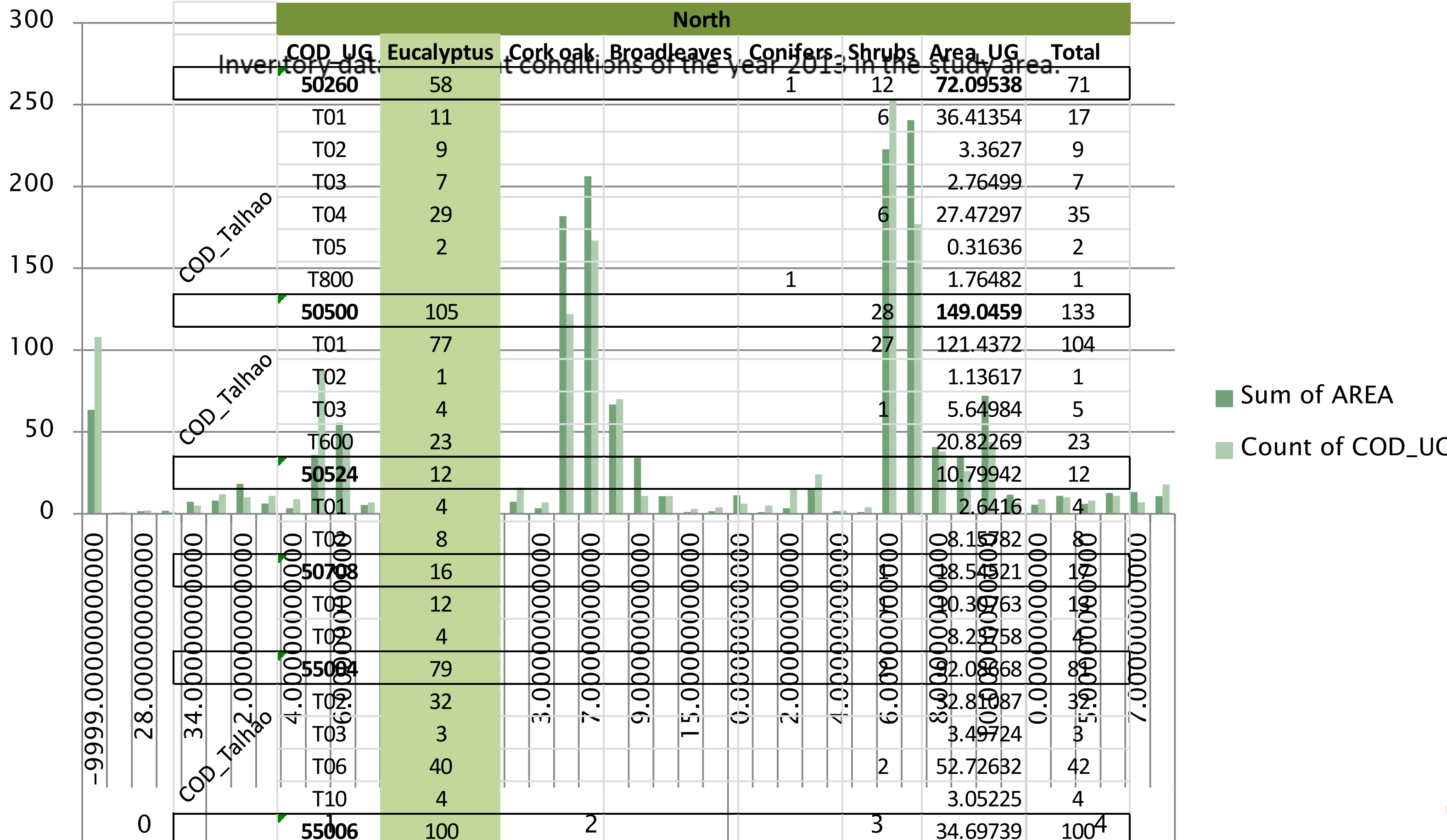
STEP II

STEP #2

2.1|Characterizing each gPS "farm"

Inventory data ... t conditions of the year 2013 in the study area.

	North							
	COD_UG	Eucalyptus	Cork oak	Broadleaves	Conifers	Shrubs	Area_UG	Total
	50260	58			1	12	**72.09538**	71
COD_Talhao	T01	11				6	36.41354	17
	T02	9					3.3627	9
	T03	7					2.76499	7
	T04	29				6	27.47297	35
	T05	2					0.31636	2
	T800				1		1.76482	1
	50500	105				28	**149.0459**	133
COD_Talhao	T01	77				27	121.4372	104
	T02	1					1.13617	1
	T03	4				1	5.64984	5
	T600	23					20.82269	23
	50524	12					10.79942	12
	T01	4					2.6416	4
	T02	8					8.15782	8
	50708	16				1	18.54521	17
	T01	12				1	10.30763	13
	T02	4					8.23758	4
	55004	79				2	92.08868	81
COD_Talhao	T02	32					32.81087	32
	T03	3					3.49724	3
	T06	40				2	52.72632	42
	T10	4					3.05225	4
	55006	100					34.69739	100
COD_Talhao	T01	66					15.52005	66
	T05	15					7.55571	15
	T08	3					1.48177	3
	T09	16					10.13986	16



STEP #2

2.2|Characterizing fuel arrangements

- Standard fire behaviour fuel models
  - (GR. Grass fuel type models ;
  - GS Grass shrub type model;
  - TU Timber understory fuel type);
  - SB Slash blowdown fuel type)

- Scott & Burgan (2005)
- Tool: comparemodels4

- **Finney, M**. 2003. *Calculation of fire spread rates across random landscapes.*

  IJWF.12:167-174

STEP #2

2.3|Characterizing fuel arrangements & wildfire parameters

- customize fuel model – Portugal to assign fuel distribution

  - specific fuel models collected "in loco" for each gPS' farm and calibrated to Portugal conditions (Fernandes *et al.* 2009)

Wilfire behaviour characteristics :

|Fireline intensity (FLI, Kw/m)

|Rate of spread (ROS , min/m)

Estimate the change in the annual expected wood loss (WL) due to fire from treatments

$$E\,(WL) = \Delta SR * \Delta FL$$

STEP #2

2.4|Calculating spread rate & flame lenght across landscapes

- 1|Calculate Spread Rate (SR)

Run in **Ex-RATE program** for each weather condition

0.1	1.0	1.0
1.0	1.0	0.1
1.0	0.1	1.0

- 2|Calculate Flame length (FL)

- <u>For each fuel arrangement/weather scenario</u>:
  - Calculate ΔFL
  - Calculate ΔSR
- Analyze the corresponding sigmoid curve trends

Finney, M. 2003. *Calculation of fire spread rates across random landscapes. IJWF*.12:167-174

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STEP #2

UG Sul: Odemira

2.5| Outputs FlamMap

- 8 combinations of wind speed * direction
- 3 fire behaviour parameters
- 24 layers

Scenario : 12km/h - 180

FLI		ROS		CFA
Min	Max	Min	Max	Tipo
738.05	14761	1.381	27.618	Passive crown fire

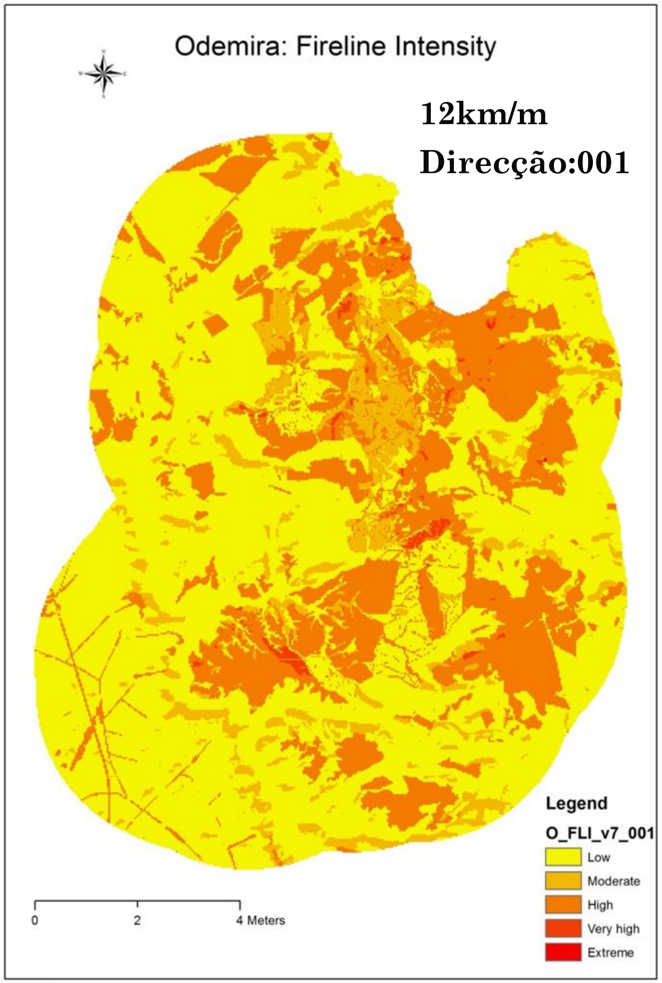
Scenario: 40km/h - 304

FLI		ROS		CFA
Min	Max	Min	Max	Tipo
1268.55	25371	2.374	47.470	Active crown fire

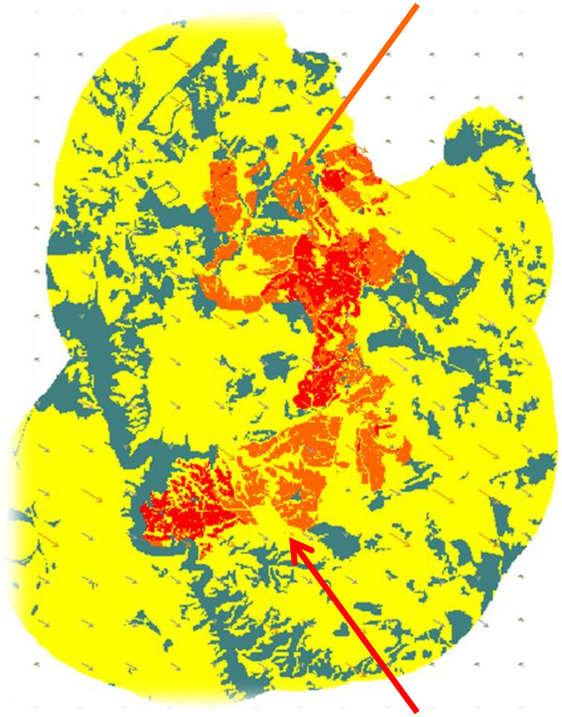
STEP #2

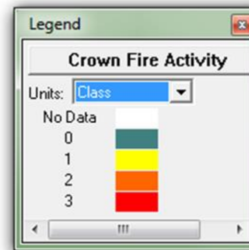
2.5| Outputs FlamMap

UG Sul: Odemira



Passive crown fire





40km/m

Direcção:338

Active crown fire

FIRE-ENGINE

| Explore optimal level for fuel treatment

- STEP III

STEP #3

3.1 Landscape treatment designer ?

- Where to treat?
- How much?
- Shape and size?
- Examine change in risk

Ager, A.A.; Vaillant, N.M.; McMahan, A. 2013. *Restoration of fire in managed forests: a model to prioritize landscapes and analyze tradeoffs.* Ecosphere 4:art29.

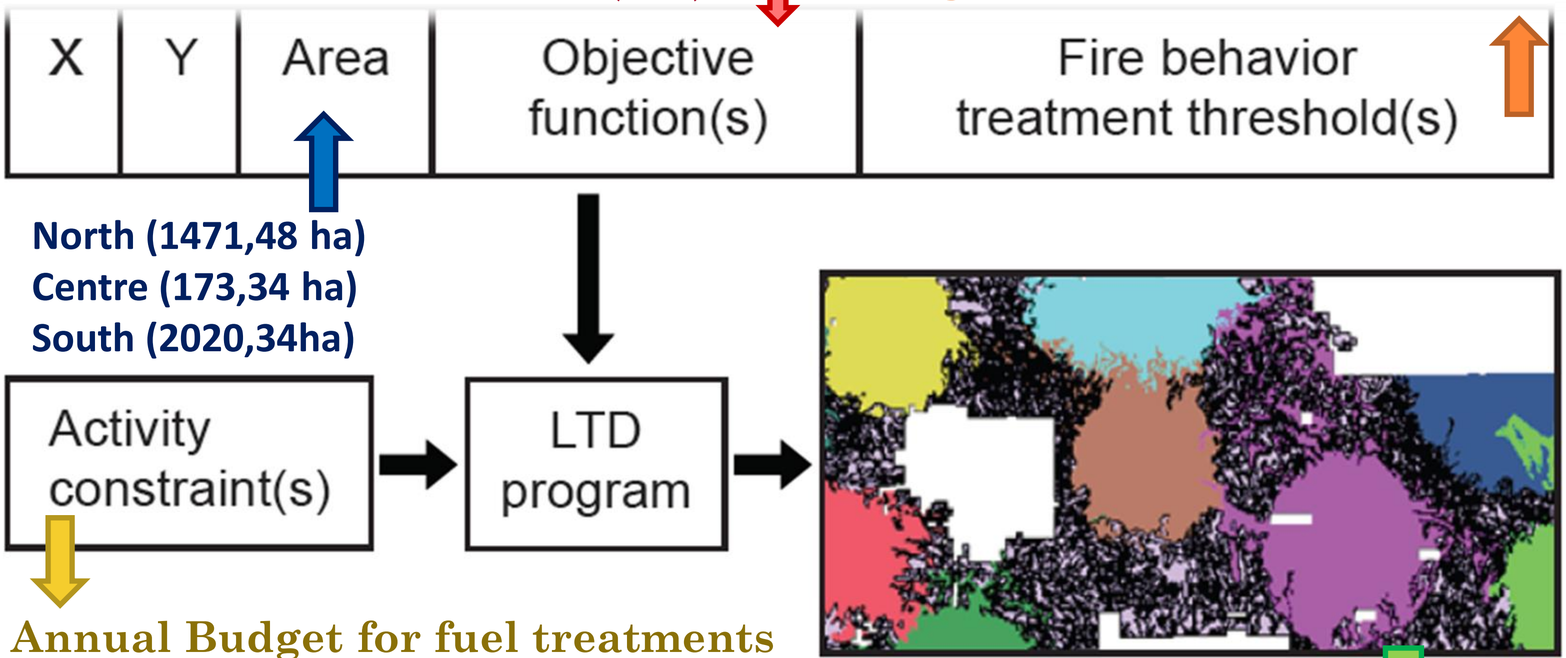
STEP #3

3.2| Explore optimal levels for fuel treatments

3 gPS farms :

***e.g.* Max SR**
Min E(WL)

e.g. fire characteristics (FL), biometric targets from fire behaviour models*



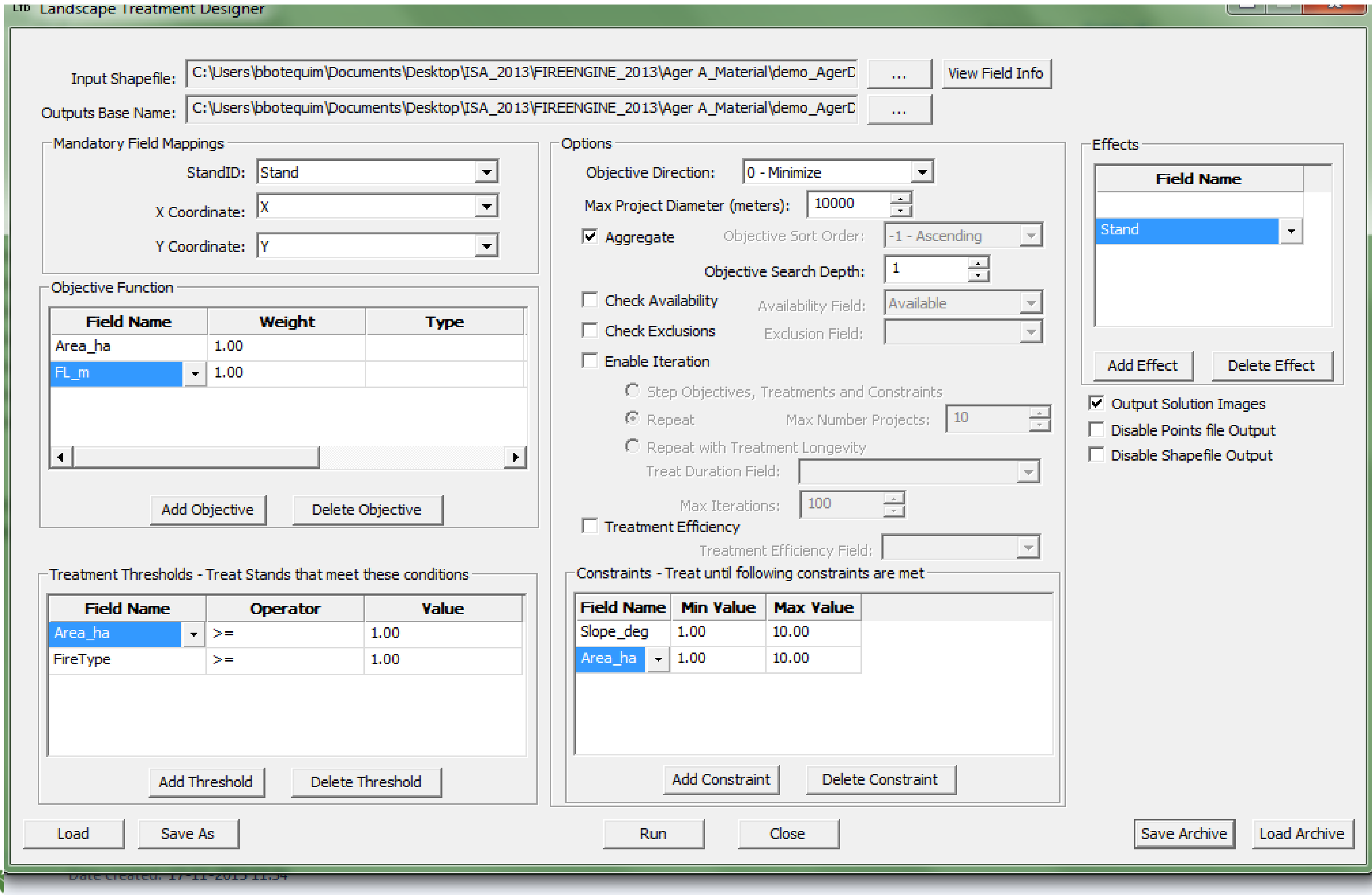
North (1471,48 ha)
Centre (173,34 ha)
South (2020,34ha)

***e.g.* Annual Budget for fuel treatments**
Total area treated
Policy constraints

***e.g.* spatial prioritization of fuel treatments**

STEP #3

3.3| Explore optimal levels for fuel treatments



FIRE-ENGINE

| **Points of view**

| Remarks

The research contains spatial and temporal dimensions to integrate landscape-scale properties required to meet fire management goals in **eucalyptus farms** distributed over Portugal.

- The framework was driven taking into account several decision support tools of the United States Wildfire Modeling System for wildfire risk management, focuses on a three-tiered approach strategy calibrated and applied in Portugal.

- The approach provided an overview of management guidelines for fuel modifications to make the gPS eucalyptus farms, in Portuguese conditions, more resistant to fire, selecting priority intervention areas and designing effective strategies, without encroaching budget constraints.

| AKNOWLEGMENTS

- Project " ***Flexible design of forest fire management systems* - FIRE-ENGINE”** (MIT/FSE/0064/2009), financiado por fundos nacionais através da FCT/MCTES (PIDDAC) e co-financiado pelo Fundo Europeu de Desenvolvimento Regional (FEDER)

- Ph.D. Grant of Brigite Botequim, “***Tools to support the design of fire-resistant landscapes in Portuguese ecosystems***” SFRH/BD/44830/2008, Financiado pela Fundação para a Ciência e Tecnologia

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Muito Obrigada!

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PREVENTIVE SILVICULTURAL PRACTICES!