IMPROVING MANAGEMENT DECISIONS IN PORTUGUESE FORESTS THROUGH FIRE BEHAVIOUR MODELING: GUIDELINES TO SUPPORT A SUSTAINABLE LANDSCAPE

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I. BACKGROUND

Research purposes

- Understanding wildfire behavior at the landscape-level is critical to address wildfire impacts in Portuguese forest management planning.
- Thus, **fire spread** was simulated in three forested landscape to assist forest managers in identifying high-risk areas for actively integrating stand-level fuel treatments with explicit landscape-level management planning and develop fire prevention priorities.
- Specifically, several **modeling applications** to detect significant fire-landscape interactions between stand-level features and fire behavior were fitted to classify Portuguese forests to fire risk levels and create guidelines to support hazard-reduction silvicultural practice.

II. STUDY AREA

Three Portuguese forested landscapes

- **Vale de sousa (V. Sousa):** 12 308 ha

  A mixed Forest with multiple non-industrial private forest owners
- **Mata Nacional de Leiria (MNL):** 10 881 ha

  An even-aged maritime pine (*P. pinaster* Ait.) public forest
- **"Globland Area" (Glob):** 11882 ha

  An industrial property where eucalypt (*E. globulus* Labill) is predominant

III. MATERIAL & METHODS

Three steps approach

I. COMPUTE FIRE BEHAVIOUR

- Fire simulation was carried out with **FlamMap 3.0.0** (Finney *et al.* 2003) for three typical fire weather scenarios (moderate, average and critical) crossed with wind speeds of 10, 20 and 40 km/h to produce specific elements of each fire.

Meteorological scenarios

Meteorological Scenarios *1	T (ºC)	H (%)	Dead Fuels (%) 1h	10h	100h	FFMC	Fuel moisture content *2 (FFMC)	Fuel moisture content (applied)
Moderate (P75)	35,8	22,5	10	11	13	91.9	8.8	10
Average (P90)	37,8	20,0	7	8	10	94.2	6.5	7
Critical (P97)	40,1	17,2	4	5	7	95.9	4.8	4

Geographical

Case study	V.Sousa	MNL	Glob.
DTM (resolution)	90x90	25x25	25x25
	Min/Max	Min/Max	Min/Max
Altitude(m)	37-541	4-142	0-192
Slope (º)	0-37.4	0-35	0-35.9
Aspect (more freq.)	Sw	Nw	Sw

*1 *Moderate: 75th percentiles, i.e. higher values occur in 25% of the day from May to October 1998 -2008. The Live Fuels were 75%, 120% for Shrub and Foliar, respectivelly.*

*2 *The fuel moistures were calculated using "Fine Fuel Moisture Code" FFMC (Van Wagner and Pickket, 1985) "Canadian Forest Fire Weather Index System" (FWI).*

Surface fuel model

Case Study	Fuel Model	Description	Kg/ m²	References
MNL	PPIN-05	Mature *Pinus pinaster* plantation	0,8	Cruz, 2007
	F-PIN	*P. pinaster* litter	0,8	Fernandes *et al.*, 2009
	M-PIN	*P. pinaster* litter and understorey	1,71	
	V-MAb	Small shrubs (< 1 m) *Erica, Ulex* or *Pteropartum tridentatum* shrubland	1,4	
Glob.	M-EUCd	*E. globulus* with discontinuous surface fuel model	0,448	Fernandes *et al.*, 2009
	M-EUC	*E. globulus* litter and understorey	1,669	
	V-MAb	Small shrubs (< 1 m) *Erica, Ulex* or *Pteropartum tridentatum* shrubland	1,4	
V. Sousa	M-CAD	Broadleave evergreen	1,61	Fernandes *et al.*, 2009; Cruz, 2007
	M-EUC	*E. globulus* litter and understorey	1,669	
	M-PIN	*P. pinaster* litter and understorey	1,71	
	V-Hb	Herbaceous understorey (< 0,5 m)	0,15	
	V-MAb	Small shrubs (< 1 m) *Erica, Ulex* or *Pteropartum tridentatum* shrubland	0,9	
	V-MH	Young shrubs and grassland	1,4	
	V-MMa	Tall (> 1 m) *Q. coccifera, Cistus ladanifer , Cytisus triatus* and others mediterranean shrubs	2,3	

A set of explanatory variables was colected

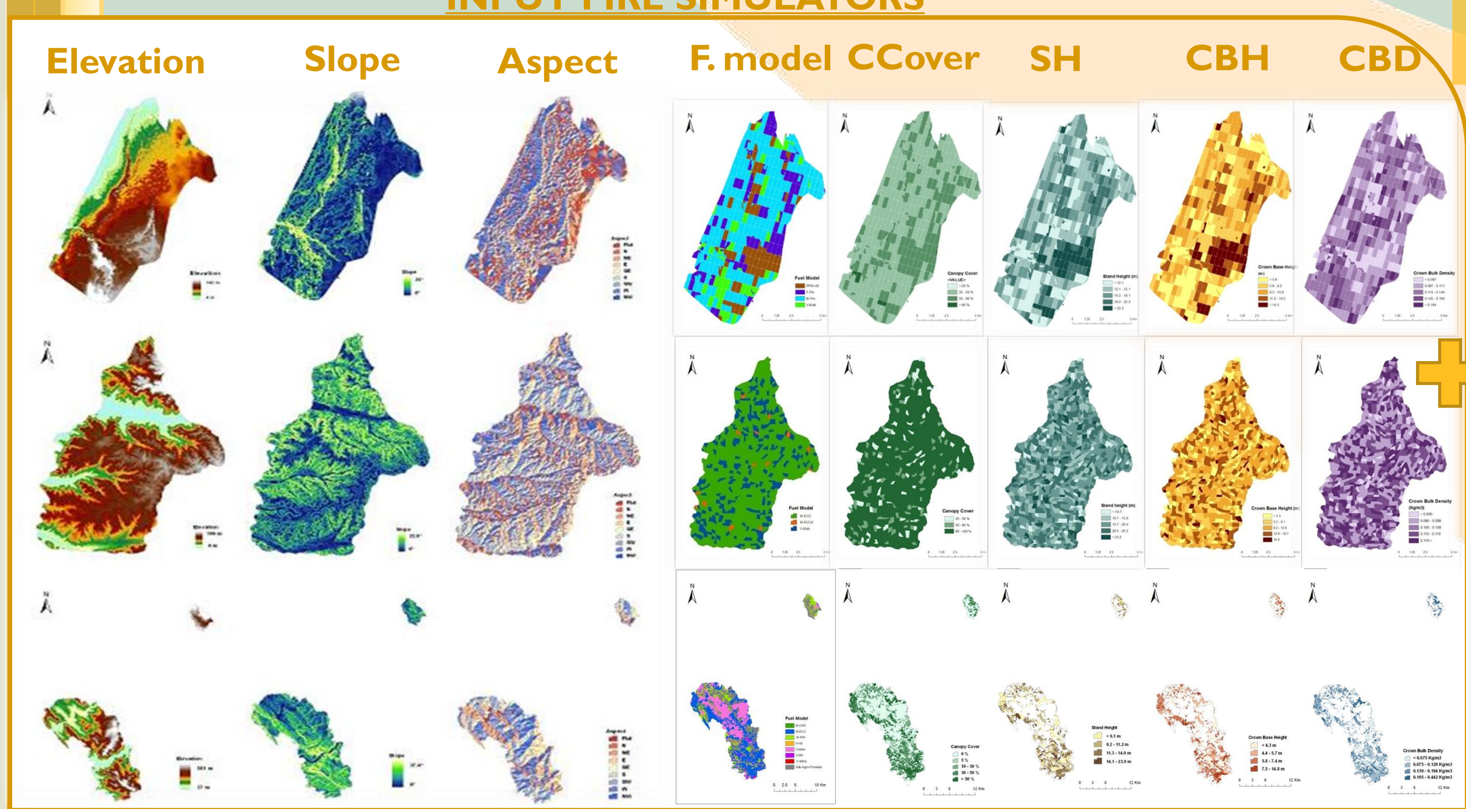
Forest canopy characteristics

Canopy characteristics	V. Sousa (1029 plots) Min/max	V. Sousa Ref.	MNL (539 plots) Min/max	MNL Ref.	Glob. (1000 plots) Min/max	Glob. Ref.
Stand Height (SH, m)	3-23	Inventory Data	7-29	Inventory Data	5-30	Soares & Tomé, 2002
Crown Base Height (CBH, m)	1-14	Inventory Data	2-23	Torres ,2004	1-20	Soares & Tomé, 2002
Crown Bulk Density (CBD, Kg/m³)	0.004-0.441	Zianis et al. 2005 (*F. sylvatica / A. Unedo*) Faias et al. 2009 (*P.pinaster*) Montero et al. 2005 (*Q. róbur/Q.faginea*) Correia et al. 2008 (*P.pinea*) Paulo & Tomé, 2006 (*Q. suber*)	0.037-0.315	Faias ,2009	0.050-0.160	Cruz & Viegas, 1998
Canopy Cover (CC, %)	5-50	Inventory Data	19-97	Torres, 2004	35-90	Cruz & Viegas, 1998

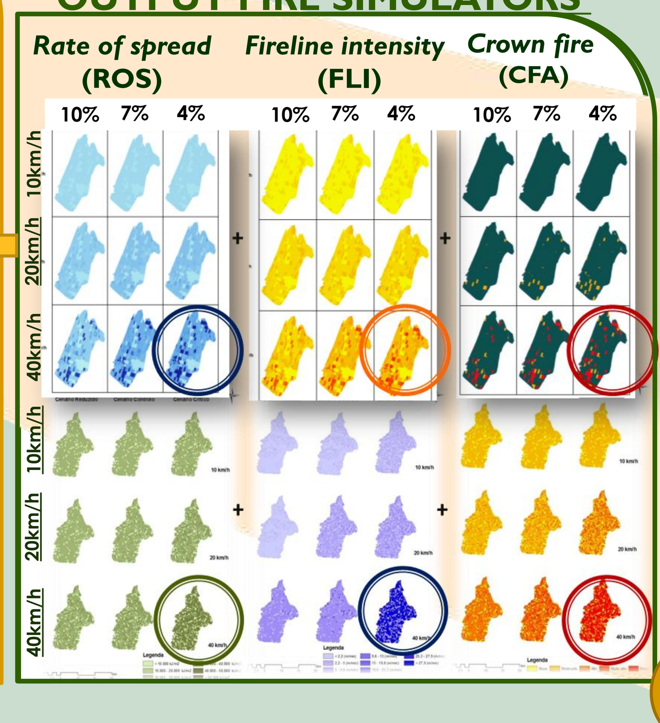
II. COMBINE LANDSCAPE LAYERS

- A total of twenty Landscape map layers (e.g. Initial landscape data, modeled fire behaviour characteristics and **biometric stand variables**) from each forested area were overlaid in **ArcGIS 9.3** for each scenario combination.

INPUT FIRE SIMULATORS



OUTPUT FIRE SIMULATORS



BIOMETRIC STAND LAYERS

- Tree density (N, Nº trees per ha)
- Basal area (G, m²/ha
- Quadratic mean diameter in the stand (Dg, m)
- Dominant height (Hdom, m)

- A **database** that stores landscape pixels that are homogeneous according to those attributes was established for each area/scenario to identify stand characteristics and spatial pattern metrics of fire prone areas.

III. FIRE BEHAVIOUR MODELLING

- The database with the **most critical combination** (4% fuel moisture content x 40 km/h wind speed) was selected as input in **JMP Statistical Software v. 8.**
- **Logistic regression** was applied to develop models to predict crown fire activity (*Pfcrown)* suited to end users ranging from typical forest practitioners to researchers.
- **A classification tree** approach was used to model the type of fire (surface, passive or active crown fire) and the difficulty of fire suppression (Alexander & Lanoville, 1989).

IV. RESULTS & DISCUSSION

MNL landscape for demonstration purposes

- **1. A consistent set of models to "build" forest landscapes more resistant to fire, that replaces the need to use fire simulators was provided.**

MODEL I

$$PfCrownI = \frac{1}{1+e^{-(-53.705+\beta_1 \times Fmodel1+\beta_2 \times Fmodel2 + 0.347 \times ccover + 6.502 \times CBH - 0.352 \times Slope)}}$$

$$\begin{cases}\beta_1 = 22.378 & \text{If } Fmodel1 = 0 \\ \beta_1 = -22.378 & \text{If } Fmodel1 = 1\end{cases} \qquad \begin{cases}\beta_2 = -22.584 & \text{If } Fmodel2 = 0 \\ \beta_2 = 22.584 & \text{If } Fmodel2 = 1\end{cases}$$

Dummy Variable		
Fmodel	*Fmodel 1*	*Fmodel 2*
MPin	0	0
Ppin_Fpin	0	1
Vmab	1	1

- based on simulator input data and can be used when fuel model, slope, crown base height and canopy cover are known

MODEL II

$$PfCrownII = \frac{1}{1+e^{-(-53.884+\beta_1 \times Fmodel + 3.881 \times Hdom + 1.206 \times G)}}$$

$$\begin{cases}\beta_1 = 19.891 & \text{If } Fmodel = 0 (Litter) \\ \beta_1 = -19.891 & \text{If } Fmodel = 1 (Shrub)\end{cases}$$

Dummy Variable	
Fmodel	*Fmodel*
Mpin_Vmab	1 (Shrub)
Ppin_Fpin	0 (Litter)

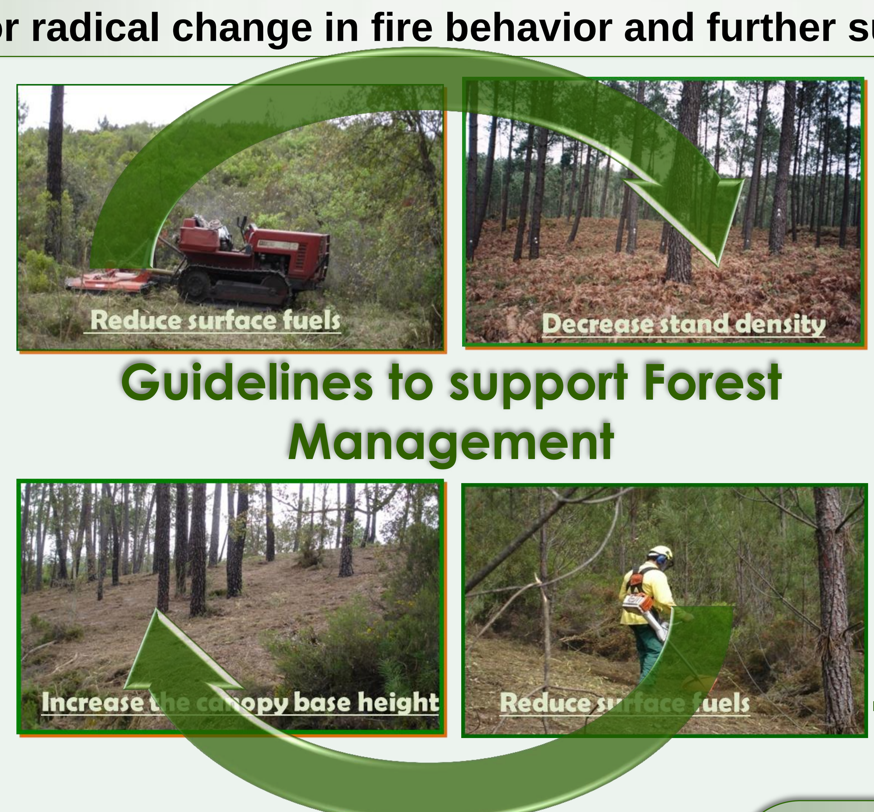
- just needs easily available inventory data, e.g. fuel model (litter or shrub dominated), dominant height and basal area

- **2. A set of numerical patterns derived from biometric variables was estimated to facilitate the identification of thresholds for radical change in fire behavior and further support preventive silvicultural.**

FIRE ACTIVITY

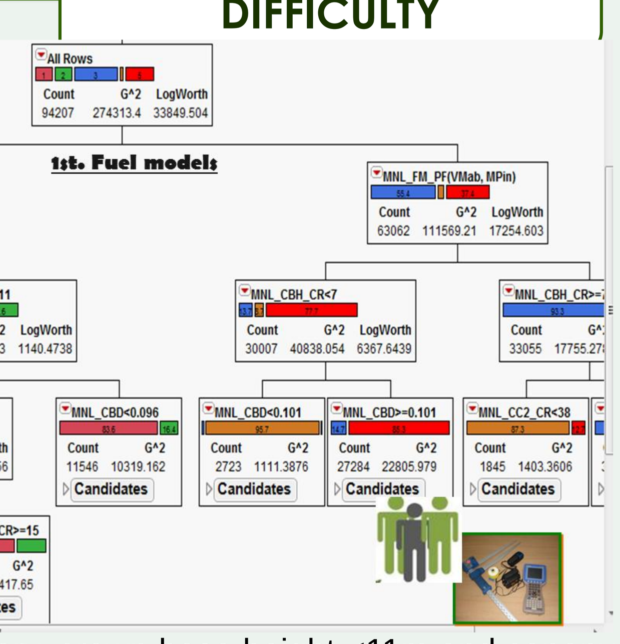
BIOMETRIC VARIABLES CBH (m)	CBD (kg/m³)	FModel	Ccover (%)	FIRE ACTIVITY
< 7	< 0,101	Litter		Surface fire
< 7	< 0,101	Shrub		Passive Crown fire
< 6	≥ 0,101	Shrub		Active Crown fire
≥ 7			< 33	Active Crown fire
≥ 7			≥ 33	Surface fire

- Illustration of fire behavior according the effect of changes in fuel characteristics with different stand structures.



FIRE SUPPRESSION DIFFICULTY

1. Low (pink)
2. Moderate (Green)
3. Hight (Blue)
4. Very hight (Brown)
5. Extreme (Red)



- Stands with litter in the understory, crown base height <11m and canopy cover <66% are more likely to moderate fire suppression (88,6%).

V. Acknowlegments

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use under changing humidity/outside climate conditions is limited due to relatively high swelling/shrinking coefficients and limited natural resistance to fungal decay. Thermal treatment may improve these features,but also may have negative effects on physical and mechanical properties.

Extensive studies have been carried out on beech, ash and oak (Quercus petreae)samples both as small test specimen and real size boards. A hygrothermal pressure treatment method (WTT) was applied with 2 temperature levels (160°, 180°C) and moisture equilibrium, density, dimensional stability, static bending strength (MOR), Modulus of elasticity (MOE)and dynamic impact bending strength were tested. and compared with non-treated samples.

Results show statistically significant improvements in moisture equilibrium and dimensional stability in most cases already at the 160 °C level. whereas technological parameters, especially impact bending strength is affected already at the 160°C level and is substantially reduced at 180°C.

Keywords: Thermal treatment, European hardwoods, Oak, Ash, Beech

PP244

Improving Management Decisions In Portuguese Forests Through Fire Behaviour Modeling: Guidelines To Support A Sustainable Landscape

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The purpose of the research was to simulate fire spread in three forested landscapes to assist forest managers in identifying high-risk areas for actively integrating stand-level fuel treatments with explicit landscape-level management planning and develop fire prevention priorities. Specifically, several modeling applications to detect significant fire-landscape interactions between stand-level features and fire behavior were fitted through logistic regression and classification tree analysis to classify Portuguese forests to fire risk levels.

This research considered a data set encompassing 2504 inventories plots located in the three forested areas. This allowed us to make comparisons between different topographic and fuel structure patterns on different landscapes: Leiria National Forest, an even-aged maritime pine (Pinus pinaster Ait.) public forest in the Centre (≈10 881 ha), Vale de Sousa a mixed forest with multiple non-industrial private forest owners in the North (≈ 12 308 ha) and Globand area an industrial property where eucalypt (Eucaliptus globulus Labill) is predominant (≈ 11882 ha). The estimation of further non-spatial data was based on an exhaustive research of methodological issues, such as surface fuel models, fuel moisture (fine fuel moisture content) and stand characteristics (stand height, crown base height, crown bulk density) modeling in the Mediterranean.

Fire simulation was carried out with FlamMap 3.0.0 for three typical meteorological scenarios derived from historical weather records gathered from May to October over 1998–2008 to represent moderate, average and critical fire weather conditions. For each scenario, modeled fire behavior characteristics, landscape data and stand variables (tree density, basal area, quadratic mean diameter, dominant height) were overlaid in ArcGIS 9.3 and a database that stores landscape pixels that are homogeneous according to those attributes was established for each scenario to identify stand characteristics and spatial pattern metrics of fire prone areas. The database with the most critical combination values (4% fuel moisture content, 40 km/h wind speed) was selected as input for modeling analyses.

Logistic regression modeling was applied to develop models suited to end users ranging from typical forest practitioners to researchers, providing: (1) two compatible modeling fire behavior equations to predict crown fire activity (Pfcrown) depending on the available variables, i.e. Model I, based on simulator input data (slope, crown base height, fuel model and canopy cover), and Model II, using easily measurable stand characteristics suiting forest managers (dominant height, basal area and fuel model). Consequently, a guideline matrix to support the definition of appropriate management options in each forest area was developed according crown fire occurrence probability thresholds. Furthermore, a classification tree approach was employed to assess the type of fire (surface, passive or active crown fire) and the difficulty of fire suppression according to biometric patterns to support forest management.

The results demonstrate the potential of the strategies pursued to understand the influence of both biometric and environmental variables to support hazard-reduction silvicultural practices, through the development of management guidelines for fuel and stand structure modification in these fire-prone forest stands.

Keywords: Fire behaviour modeling; Fire-landscape interactions; Silvicultural practices; Sustainable forest management

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Carbon Sequestration Of Stem Wood In Forest Regenerated Through Enrichment Planting And Strict Nature Reserve

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Carbon dioxide (CO2) is one of the most abundant greenhouse gases and a primary agent of global warming. Dramatic rise of CO2 concentration is attributed largely to human activities. The only practical way of removing large volumes of the major greenhouse gas from the atmosphere is through the absorption by plant into their biological system. The contribution of a natural forest regenerated through enrichment planting to carbon absorption was carried out in this present study. The amount of carbon in the tree biomass from this forest was also compared with the carbon value in the adjacent degraded forest. Tree growth data were collected from eight 25m X 25m plots located in each of the two forest types using the systematic line transect. Volume of the trees was estimated with analytical formula and biomass of every species was computed by multiplying the volume of the tree with its respective wood density. Tree biomass was converted to carbon stocks using 0.5 carbon fractions as default values. Our findings indicate that the potential of degraded rainforests to recover from degradation can therefore be enhanced through enrichment planting as the number of individual (446),