FOREST FIRE RISK IN PORTUGAL

Mário G. Pereira¹,², Marj Tonini³, Joana Parente¹, Carmen Veja Orozco³

¹ CITAB, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal.
² Instituto Dom Luiz, University of Lisbon, Lisbon, Portugal
³ Center for Research on Terrestrial Environment, University of Lausanne, Switzerland

This work is supported by national funds by FCT - Portuguese Foundation for Science and Technology, under the project UID/AGR/04033.
Outline

1. Motivation
2. Objectives
3. Materials and Methods
4. Results
5. Conclusions
6. Future work
1. Motivation: Why forest fires in Portugal?

Portugal is the European country most affected by wildfires.

According to EFFIS, the Southern European countries accounts for 78% of total Burnt Area (BA) and 83% of total Number of Fires (NF) in Europe.

- **France**: 02% BA & 03% NF
- **Greece**: 12% BA & 05% NF
- **Italy**: 11% BA & 17% NF
- **Portugal**: 32% BA & 37% NF
- **Spain**: 21% BA & 24% NF
- **Sum**: 78% BA & 83% NF

**Fig.1** - Perimeters of area burnt by fires in the five most affect Mediterranean countries of Europe in the 2000-2013 period. Adapted from Pereira et al., 2014.
1. Motivation: Why forest fires in Portugal?

High variability

Summary Statistics

<table>
<thead>
<tr>
<th>Area_\text{ha}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Kurtosis</td>
</tr>
<tr>
<td>Skewness</td>
</tr>
<tr>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
</tr>
<tr>
<td>Sum</td>
</tr>
<tr>
<td>Count</td>
</tr>
</tbody>
</table>

Fig.2 – Total annual number of fires and área burnt by fires in Portugal during the 2000 – 2013 period. Adapted from Tonini et al., 2015
1. Motivation: Why fire risk?

Verde and Zezere (2010) Assessment and validation of wildfire susceptibility and hazard in Portugal

Assessment of Forest Fire Hazard is also provided in the Institute for the Conservation of Nature and Forests (ICNF) web site.

The IPMA provide a daily forest fire risk index which is a combination of two indices: the meteorological index of forest fire danger, FWI and a structural risk index.

Antunes et al. (2011) Forest Fire Risk Assessment in the municipality of Arganil.

But, there is no HIGH RESOLUTION DYNAMICAL FIRE RISK map for entire Portugal
2. Objectives

- Develop a dynamical fire risk map
- Assess the structural forest fire risk in Portugal
  - higher spatial resolution (80 m to 25 m)
  - updated vegetation cover (CLC2006)
  - longer fire history (from 1975-2004 to 1975-2013)
  - focused on the potential economic damage.
3. Materials and Methods: Data

- Digital elevation model derived from the Shuttle Radar Topographic Mission in a resolution of 1 arc-seconds (DEM-SRTM 25 m) provided by J. Gonçalves (Gonçalves and Fernandes 2005; Gonçalves and Morgado 2008 (http://www.fc.up.pt/pessoas/jagoncal/srtm/)):
  - altitude, slope
  - > 140 million pixels!
3. Materials and Methods: Data

- Corine land cover 2006 inventory provided by the European Environment Agency (http://www.eea.europa.eu/pt);
- Level 1 (Artificial surfaces), 4 (Wetlands) and 5 Water bodies classes were excluded
- 134 million records!

**Corine Land Cover 2006**

- 2.1. Arable Land
- 2.2. Permanent Crops
- 2.3. Pastures
- 2.4. Heterogeneous agricultural areas
- 3.1. Forests
- 3.2. Scrub and/or herbaceous vegetation associations
- 3.3. Open spaces with little or no vegetation
3. Materials and Methods: Data

- National Mapping Burnt Areas (NMBA) provided by the Institute for the Conservation of Nature and Forests (ICNF) ([http://www.icnf.pt/portal](http://www.icnf.pt/portal)).
3. Materials and Methods: the framework

- Susceptibility
- Probability
- Vulnerability
- Economical value

Hazard

Potential damage

Risk
3. Materials and Methods: the framework

Susceptibility
Probability
Vulnerability
Economical value

Hazard
Potential damage
Risk


Antunes et al. (2011) Avaliação do Risco de Incêndio Florestal no Concelho de Arganil.
3. Materials and Methods: the framework

The susceptibility,

\[ \text{UCF} = F(p_a). F(Sf1). F(Sf2) \ldots F(Sf_n), \]

where, \( p_a = \frac{f}{N} \times 100\% \) is the simple (not conditioned) probability, \( f \) the number of times the pixel burns within the \( N \) years of study.

\[ Sfx = \frac{umAx}{\Omega x} \times 100\%, \]
\[ umAx \] is the number of burnt pixels in class \( x \) and \( \Omega x \) is the total number of pixels of class \( x \).

Assuming the Corine-Slope-Probability (CSP) model (Verde and Zêzere, 2010).
3. Materials and Methods: the framework

The probability (associated with each susceptibility class $x$),

$$P = 1 - \left(1 - \frac{aaf}{at_x} \cdot vprev_x\right),$$

where,

- $aaf$ is the total area to be burnt in the considered scenario,
- $at_x$ is the total area within the susceptibility class $x$,
- $vprev_x$ is the predictive value for the susceptibility class $x$. 
The vulnerability of the elements are defined according to the level or degree of destruction of the elements caused by fire.

The vulnerability scores for the adopted CLC classes were adapted from Antunes et al. (2011).
3. Materials and Methods: the framework

The economical value was assessed from the *Estratégia Nacional para as Florestas*, which is a resolution of the Council of Ministers (Resolução do Conselho de Ministros n.º 114/2006, de 15 de setembro)
4. Results: Annual probability of occurrence
4. Results: Slope & Slope favorability score
4. Results: CLC favorability scores

**Corine Land Cover 2006**

2.1. Arable Land
2.2. Permanent Crops
2.3. Pastures
2.4. Heterogeneous agricultural areas
3.1. Forests
3.2. Scrub and/or herbaceous vegetation associated with forest
3.3. Open spaces with little or no vegetation

**CLC 2006 Favourability Score**

- [0-10]
- [10-20]
- [20-30]
- [30-40]
- [40-50]
- [50-60]
- [60-70]
- [70-80]
- [80-90]
4. Results: Susceptibility

Five classes (DL 156/2004)

Interpretation

Susceptibility
(Predictive Value)

- Very Low (0.3%)
- Low (1.3%)
- Medium (4.5%)
- High (15.7%)
- Very High (78.2%)

Verde and Zezere (2010)
4. Results: Hazard

\[ P = 1 - \left(1 - \frac{aaf}{at_x} \cdot v_{prev_x}\right) \]

<table>
<thead>
<tr>
<th>Susceptibility class</th>
<th>Area (nr. of 80m pixels)</th>
<th>Probability scenario 1 (500 000 ha)</th>
<th>Probability scenario 2 (112 000 ha)</th>
<th>Probability scenario 3 (12 000 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>33443751</td>
<td>0,00</td>
<td>0,06%</td>
<td>0,01%</td>
</tr>
<tr>
<td>Low</td>
<td>19013965</td>
<td>0,01</td>
<td>0,55%</td>
<td>0,12%</td>
</tr>
<tr>
<td>Medium</td>
<td>28911293</td>
<td>0,05</td>
<td>1,25%</td>
<td>0,28%</td>
</tr>
<tr>
<td>High</td>
<td>27427301</td>
<td>0,16</td>
<td>4,59%</td>
<td>1,03%</td>
</tr>
<tr>
<td>Very high</td>
<td>26020791</td>
<td>0,78</td>
<td>24,04%</td>
<td>5,37%</td>
</tr>
<tr>
<td>Soma</td>
<td>134817101</td>
<td>1,00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Susceptibility class</th>
<th>Area (nr. of 80m pixels)</th>
<th>Predictive value</th>
<th>Probability scenario 1 (500 000 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>2783096</td>
<td>0,03</td>
<td>0,84%</td>
</tr>
<tr>
<td>Low</td>
<td>2780358</td>
<td>0,05</td>
<td>1,40%</td>
</tr>
<tr>
<td>Medium</td>
<td>2758308</td>
<td>0,12</td>
<td>3,40%</td>
</tr>
<tr>
<td>High</td>
<td>2634032</td>
<td>0,28</td>
<td>8,30%</td>
</tr>
<tr>
<td>Very high</td>
<td>2401267</td>
<td>0,52</td>
<td>16,92%</td>
</tr>
<tr>
<td>Sum</td>
<td>13357061</td>
<td>1,00</td>
<td></td>
</tr>
</tbody>
</table>
4. Results: Hazard

Case 1
- Very Low (0.06%)
- Low (0.55%)
- Medium (1.25%)
- High (4.59%)
- Very High (24.04%)

Case 2
- Very Low (0.014%)
- Low (0.122%)
- Medium (0.279%)
- High (1.026%)
- Very High (5.367%)

Case 3
- Very Low (0.002%)
- Low (0.013%)
- Medium (0.030%)
- High (0.111%)
- Very High (0.581%)
4. Results: The fire risk

- **Case 1**: Very Low (0.062% and 20.0€/ha), Low (0.547% and 17.1€/ha), Medium (1.249% and 47.0€/ha), High (4.593% and 32.3€/ha), Very High (24.036% and 12.2€/ha)

- **Case 2**: Very Low (0.014% and 20.0€/ha), Low (0.122% and 17.1€/ha), Medium (0.279% and 47.0€/ha), High (1.026% and 32.3€/ha), Very High (5.367% and 12.2€/ha)

- **Case 3**: Very Low (0.001% and 20.0€/ha), Low (0.013% and 17.1€/ha), Medium (0.030% and 47.0€/ha), High (0.111% and 32.3€/ha), Very High (0.581% and 12.2€/ha)
5. Conclusions

- Structural forest fire risk map was produced;
- Importance of risk assessment update with greater quantity and quality data;
6. Future work

- To assess the usefulness of other variables (e.g., meteorological, socioeconomic) i.e. to refit the susceptibility map;

- Update the vulnerability map;

- To include the dynamical risk factors (e.g., weather conditions);

- To consider human, landscape and ecological potential damage;
Thank you for your attention
Forest fire risk in Portugal
Global Pyrogeography
(Krawchuk et al. 2009)

Köppen-Geiger climate classification
(Peel et al. 2007)

Climate defines the existence, type and life cycle of the vegetation in each site.
Burnt area perimeters in Southern Europe (Pereira et al. 2014)

Köppen-Geiger climate classification (Peel et al. 2007)
1. Motivation: How to model?

Extreme fire events are associated to also extreme atmospheric conditions.

Meteorological conditions are able to tell us when fires are more likely to occur.

Pereira et al. 2005
1. Motivation: **How to model?**

In some cases, atmospheric conditions are also able to tell us where fires are more likely to occur.

**Fig. 4 a-f** - Daily sequence of **850 hPa air temperature anomalies** (°C). Days are identified on the top of each panel. Regions with temperature above the historical maximum are delimited by **solid contours** (°C). (Trigo et al. 2006)