SPATIAL ASPECTS OF WILDFIRES

Cristina Vega-Garcia & Marc Padilla
D. Agriculture and Forestry Engineering, University of Lleida, Spain

Jesús Martínez
Instituto de Recursos Naturales, CSIC, Madrid, Spain

FIRES3: Forecasting and modelling wildfire risk for UK moorlands and heaths
The University of Manchester, 31st March – 1st April 2009
Humans are the predominant cause for fires all over the world.

In the Mediterranean 95% of all fires are caused by people and they constitute the main threat to forest protection.

Nº of fires and burned areas in Mediterranean EU countries (1981-1997)

<table>
<thead>
<tr>
<th></th>
<th>Nº incendios 1981-1997</th>
<th>Nº medio anual</th>
<th>Sup quemada (ha)</th>
<th>Sup quemada media por incendio</th>
<th>Sup quemada media anual</th>
<th>Índice de riesgo²</th>
<th>Índice de gravedad³</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESPAÑA</td>
<td>227,819</td>
<td>13,401</td>
<td>3,580,286</td>
<td>15,7</td>
<td>210,605</td>
<td>6</td>
<td>0,8</td>
</tr>
<tr>
<td>PORTUGAL</td>
<td>237,894</td>
<td>13,994</td>
<td>1,465,322</td>
<td>6,2</td>
<td>86,195</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>FRANCIA¹</td>
<td>88,148</td>
<td>5,185</td>
<td>542,924</td>
<td>6,2</td>
<td>31,937</td>
<td>15</td>
<td>0,9</td>
</tr>
<tr>
<td>ITALIA</td>
<td>194,737</td>
<td>11,455</td>
<td>2,225,432</td>
<td>11,4</td>
<td>130,908</td>
<td>18</td>
<td>1,8</td>
</tr>
<tr>
<td>GRECIA</td>
<td>27,911</td>
<td>1,642</td>
<td>825,843</td>
<td>29,6</td>
<td>48,579</td>
<td>3</td>
<td>0,6</td>
</tr>
</tbody>
</table>

1. Solo región mediterránea
2. Número de incendios forestales/10000 ha de superficie forestal
3. (Superficie quemada / superficie forestal) por 100

Elaboración propia. FUENTE: Datos obtenidos a partir de Vélez (2000) y datos de la DG-CN
The fire problem in Spain

An increasing trend in number of fires is evident from fire statistics. For burned area there is a cyclic trend with catastrophic years (>400,000 ha) every 4-7 years approximately (1978, 1985, 1989, 1994).

From http://www.mma.es/portal/secciones/biodiversidad/defensa_incendios/estadisticas_incendios/index.htm
The fire problem in Spain

Reasons for this severe situation are often linked to the Mediterranean climate and the flammable vegetation, and a more hazardous forest environment generated by land use and social changes (land abandonment).
The human fire problem in Spain

Causal analysis has always been a difficult task. For 25% of all fires the cause remains unknown, on average (Valencia <2%, Madrid >75%), but since 1989 motivations are included in fire records.

<table>
<thead>
<tr>
<th>CAUSE OR MOTIVATION</th>
<th>Num.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intentional motivation unknown or non specified in fire reports</td>
<td>134333</td>
<td>35.63</td>
</tr>
<tr>
<td>Unknown cause</td>
<td>96052</td>
<td>25.47</td>
</tr>
<tr>
<td>Agricultural burning (both by negligence or deliberated)</td>
<td>39767</td>
<td>10.55</td>
</tr>
<tr>
<td>Burning to create and maintain pastures (both by negligence or deliberated)</td>
<td>32555</td>
<td>8.63</td>
</tr>
<tr>
<td>Lightning</td>
<td>14453</td>
<td>3.83</td>
</tr>
<tr>
<td>Negligence causes unknown or non specified in fire reports</td>
<td>11716</td>
<td>3.11</td>
</tr>
<tr>
<td>Pyromaniacs (mental illness)</td>
<td>8911</td>
<td>2.36</td>
</tr>
<tr>
<td>Smokers</td>
<td>6154</td>
<td>1.63</td>
</tr>
<tr>
<td>Forestry Work</td>
<td>4813</td>
<td>1.28</td>
</tr>
<tr>
<td>Rubbish burning</td>
<td>4217</td>
<td>1.12</td>
</tr>
<tr>
<td>Bonfires</td>
<td>3319</td>
<td>0.88</td>
</tr>
<tr>
<td>Engines and machines (combine harvesters, tractors, vehicles accidents, etc)</td>
<td>2870</td>
<td>0.76</td>
</tr>
<tr>
<td>Reproduced fire</td>
<td>2860</td>
<td>0.76</td>
</tr>
<tr>
<td>To facilitate hunting</td>
<td>2736</td>
<td>0.73</td>
</tr>
<tr>
<td>Power lines</td>
<td>2708</td>
<td>0.72</td>
</tr>
</tbody>
</table>

The fire problem in Spain

In 2007, 58.2 million € were spent in suppression by the Ministry of Environment alone, 29.2 in prevention (including fuel treatments, detection, database management, etc.)

We need a better knowledge of the processes that result in unwanted, destructive fire. Protection from wildfire requires forecasting. There are opportunities for research:

What is out there?
Previous work on human risk assessment

Hypothesis:

Fires are rare events, but they are not completely random: they tend to cluster in certain areas and time periods. Human risk is not completely unpredictable.
Previous work on human risk assessment

Early attempts at estimating human risk relied on experience (EMC, knowledge-based systems) ....

Matrix for a Saaty’s Analytical Hierarchy Process in Catalonia
Previous work on human risk assessment

Early attempts at estimating human risk relied on experience (EMC, knowledge-based systems) ……or historical data.

Previous work on human risk assessment

The spatial statistics field has contributed valuable spatial pattern analyses of fire starts in historical records, through secondary statistics and aggregation, point pattern analysis (distribution, quadrat-variance and distance models), spatial autocorrelation measures or kernel density estimation.

*Previous work on human risk assessment & FOP*

The next logical step would be to try to develop explanatory or predictive models of fire occurrence from available variables expected to have a significant relationship to the event.

**Hypothesis:** human activities responsible for ignitions were determined by the conditions in the forest environment.

Considerable work has been done in terms of identification of the conditions that determine the probability of ignition (or density/number of ignitions), based on weather or fire danger data, fuels, and presence/activity of human sources of ignition indirectly estimated through geographic/territorial and environmental factors.
Previous work on human risk assessment & FOP

With the generalized use of GIS systems, variables under consideration grew to encompass all types of cartographic and statistical data, including afterwards remote sensing data.
Previous work on human risk assessment & FOP

The most popular models have been the Poisson and Binomial distributions, logit and probit models, and neural network models, but Weights Of Evidence, MARS and CART models have been tested recently, and interestingly, also Geographically Weighted Regression, in an attempt to tackle the difficult problem of spatial stationarity.
Previous work on human risk assessment & FOP

The models have been applied from the Pan-European scale to the forest stand level.

Resolution can vary widely, from small cells (m$^2$), or pixels (i.e. Landsat TM 30x30 m$^2$ pixels) to UTM grid units (1km$^2$, 100 km$^2$) to forest districts, municipalities, provinces or large regions.

Source: Chou (1990)
Previous work on human risk assessment & FOP

First, large prediction units predominated. Models were based primarily on weather data. In a very general way, spatial resolution has improved over time, but temporarily, risk models have diversify towards short-term and long-term time frames, with the variables entering these models selected differently, and accordingly to their temporal variability.

Two cases are presented
Daily models for 10x10 km² cells stratified in 53 ecological regions based in geographic and temporal variables for Peninsular Spain.

Variables
Physiographic
Fuels
Legal Ownership & Designation
Location:
density power lines
density roads
density railways
distance to roads
distance to towns
distance recreational areas
population density

Low temporal variability
Daily models for 10x10 km² cells stratified in 53 ecological regions based in geographic and temporal variables for Peninsular Spain.

Variables
Meteorological Fuel Moisture:
DFMC: dead fuel moisture content
AFMC: live fuel moisture content
Danger Indices

High temporal variability
Fire Danger Indices Computation

MFDIP - Meteorological Fire Danger Index Processor

- EMC
  - Anderson
  - Simard
  - Van-Wagner
  - BEHAVE

Index
- Carrega
- Keetch-Byram
- FWI
- Rieue
- Portuguese
- SOL
- ICONA
- Irepi
- Italian
- McArthur FDI
- McArthur FMM
- NFDRS
  - 1h-10h
  - 100h
  - 1000h

Compute  Quit  Readme  About...
Daily models for 10x10 km² cells stratified in ecological regions based in geographic and temporal variables for Peninsular Spain.

Three-layered non-linear feedforward neural network models were simulated for daily wildfire prediction using the Cascade Correlation learning algorithm by Falhman and Lebiere (1990). Input selection was based on a genetic algorithm (Koza 1993).

Logit models were also computed after removing highly correlated variables.

Predictions ranking from 70% - 85% Fire Yes/No
Daily models for 10x10 km² cells stratified in ecological regions based in geographic and temporal variables for Peninsular Spain.

Significant Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>AFMC</th>
<th>FW</th>
<th>MOD_02</th>
<th>MOD_05</th>
<th>MOD_09</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COMB_VAR</td>
<td>HRmin_MIN</td>
<td>SLOPE_30</td>
<td>SLOPE_MEAN</td>
<td>T_max_MAX</td>
</tr>
<tr>
<td></td>
<td>DENS_ELEC</td>
<td>MCA TH67</td>
<td>MONTES_PB</td>
<td>SLOPE_30</td>
<td>SLOPE_MEAN</td>
</tr>
<tr>
<td></td>
<td>DENS_VIAS</td>
<td>MDT_MIN</td>
<td>MONTES_PV</td>
<td>SLOPE_30</td>
<td>SLOPE_MEAN</td>
</tr>
<tr>
<td></td>
<td>DMC</td>
<td>MDT_RANGE</td>
<td>NUCL EOS_D</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re regiones de ocurrencia de incendios de la Dirección General de la Biodiversidad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A long-term (12-year) structural study focused in socioeconomic and demographic characteristics at the municipality level
ERROR: stackunderflow

OFFENDING COMMAND: ~

ERROR: stackunderflow