Fire occurrence prediction in Mediterranean: Application to South France

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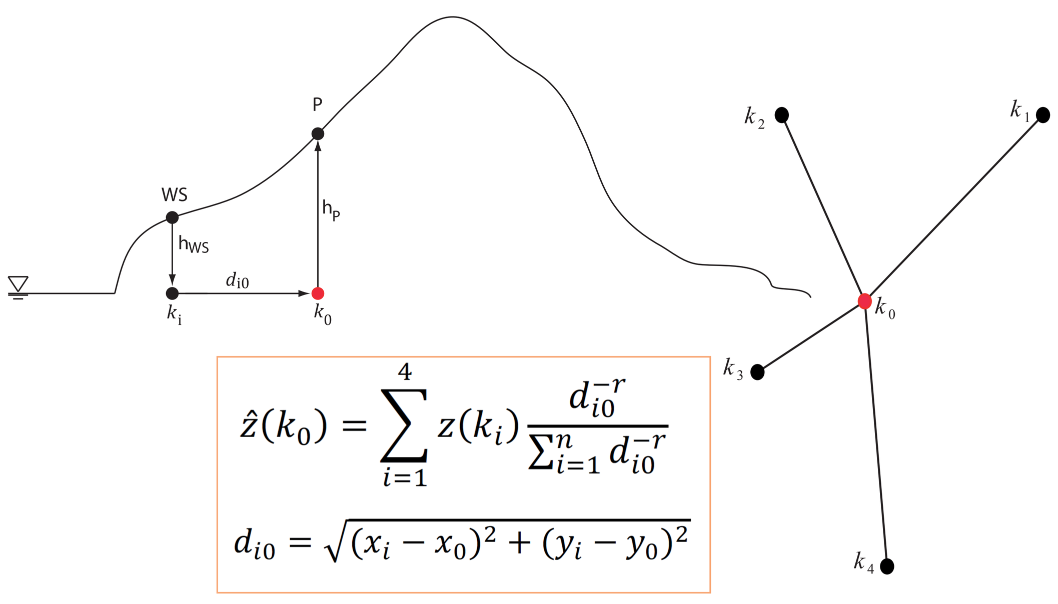
Aim of the Study

Probabilistic prediction of fire occurrence in the mesoscale in the Mediterranean using natural causes (weather conditions) and human involvement (population density, road density, land cover) as influencing factors.

Methods

Weather conditions expressed by **Canadian Fire Weather Index** (CFWI). Six standard components (three fuel moisture codes and three fire behavior indexes) provide numeric ratings of relative potential for wildfire (Lawson et al. 2008). Daily weather parameters (dry-bulb temperature, relative humidity, wind speed, precipitation) observed in weather stations are interpolated (**Inverse Distance Weighting**-Shepard's Method) on a grid with 1 km ² resolution. Temperature is additionally fitted to the altitude based on **normal lapse rate** (0.65°C/100m) (Figure 1). CFWI components calculated daily for each grid cell.

$$Temp_{k_i} = Temp_{WS} + 0.0065 \cdot h_{WS}$$



$$\hat{z}(k_0) = \sum_{i=1}^{4} z(k_i) \frac{d_{i0}^{-r}}{\sum_{i=1}^{n} d_{i0}^{-r}}$$

$$d_{i0} = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2}$$

Figure 1. Inverse Distance Weighting - Shepard's Method. Temperature fitted to altitude based on normal lapse rate.

Probabilistic prediction of fire occurrences based on parameters estimated with **Poisson regression**. Fire occurrences is a random variable (response variable N) that can be modeled by the Poisson distribution for given rate of occurrence, with probability mass function:

$$\Pr(N = k \mid \lambda, \alpha) = \frac{(\lambda\alpha)^k}{k!} \exp(-\lambda\alpha), \quad k = 0,1,2,\ldots$$

wherein α [km²] is the 1 km² spatial reference and λ [Nr. Occurrences/(day · km²)] is the occurrence rate. The rate λ is related to the explanatory variables $\mathbf{x} = [x_1; \ldots; x_k]$ by means of the link function:

$$\log(\lambda) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k = \mathbf{x}^T \boldsymbol{\beta}$$

$\boldsymbol{\beta} = [\beta_0, \ldots, \beta_k]$ is the vector of regression coefficients (parameters) estimated based on data from Cyprus given in Papakosta & Straub 2013.

Case Study

The regions Languedoc-Roussillon and Provence-Alpes-Côte d'Azur in South France is chosen to serve as study areas, due to the Mediterranean climate (in altitudes < 1000m) and the typical Mediterranean mosaic formed landscapes with relevant land cover and vegetation types. Explicit spatial and temporal data are incorporated. Daily weather data from 28 weather stations for the period 2005-2011 are used for interpolation and CFWI calculation (Figure 2).

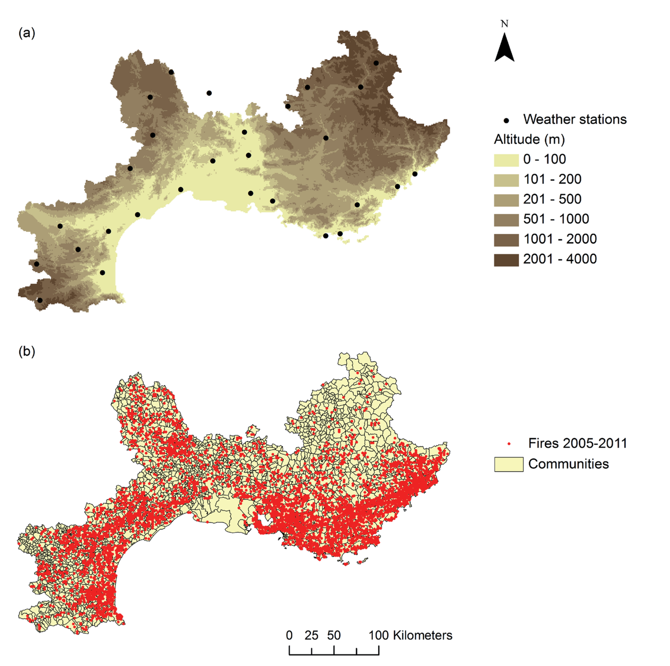


Figure 2. (a) DEM for study areas Languedoc-Roussillon and Provence-Alpes-Côte d'Azur (Source: ASTER-GDEM), and locations of 28 weather stations (Source: Deutscher Wetterdienst and Météo-France), (b) Fire events 2005-2011 (Prométhée forest fire database).

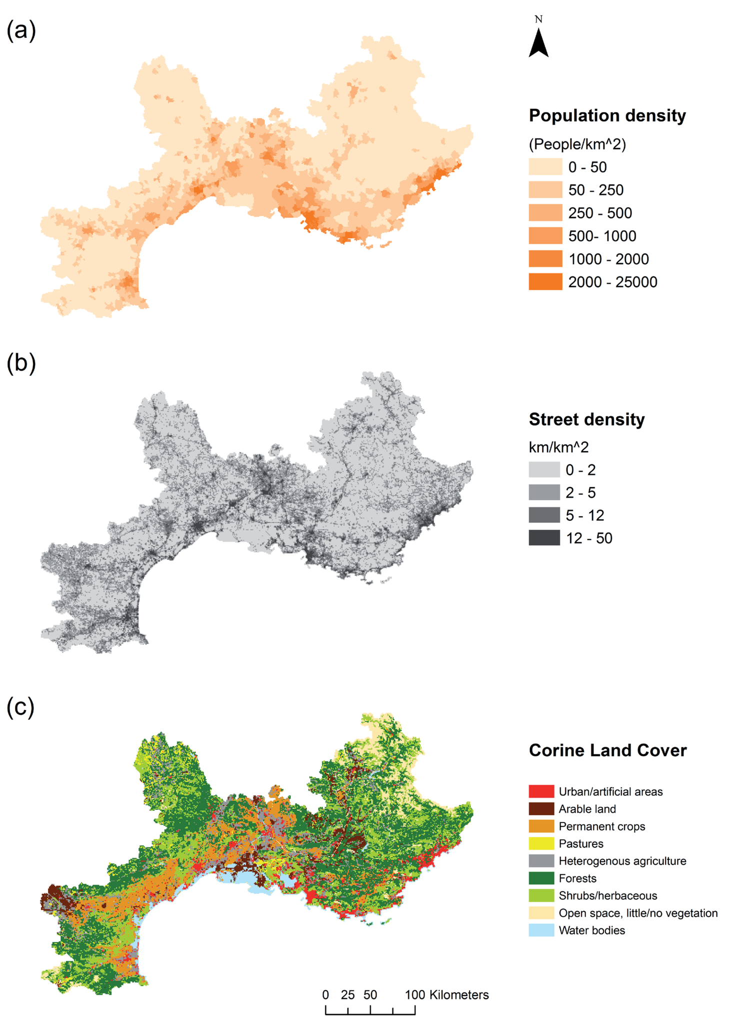


Figure 3. (a) Population density (People/km²) (Source: Insee 2009), (b) Street density (km/km²) (Source: OpenStreetMap), (c) Land cover types (Source: CORINE Land Cover, EEA)

Results

Figure 4 shows the occurrence rate λ [Nr. Occurrences/(day · km²)] for the period (2005-2011) for different spatial information. The occurrence rate increases with increasing population and street density. Olivegroves (Ol) showed the highest fire occurrence rate among land cover types.

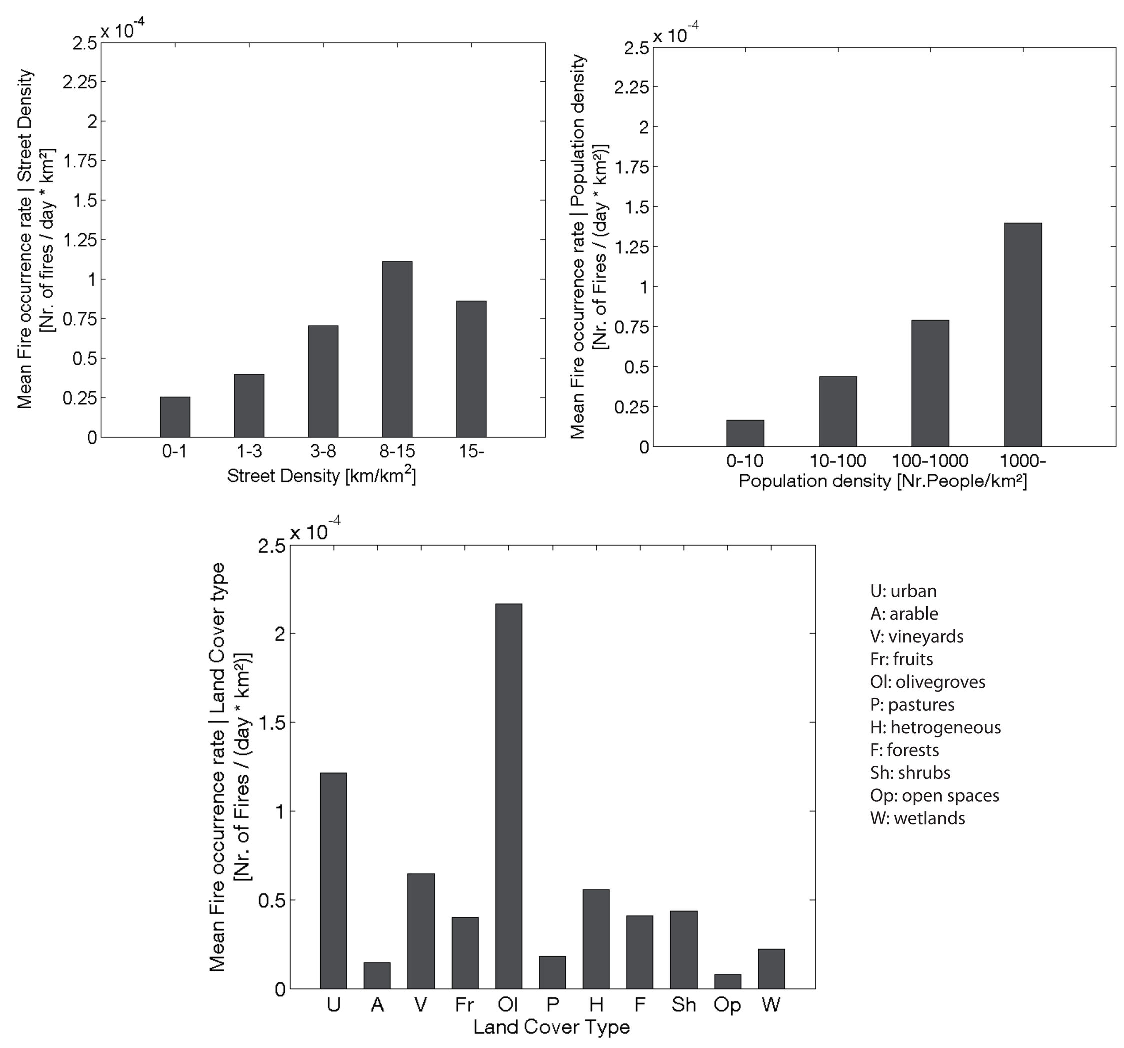


Figure 4. Mean fire occurrence rate [Nr. Occurrences/(day · km²)] vs street density, population density, land cover types.

Weather interpolation and CFWI components calculation for the period 2005-2011 results to daily maps (Figure 5).

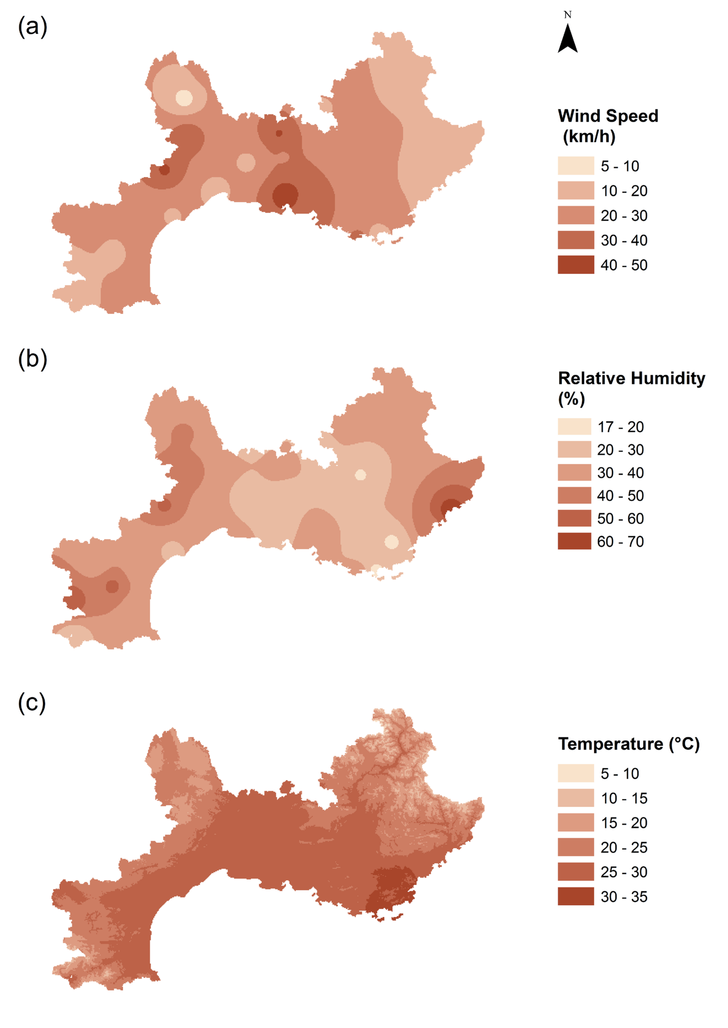


Figure 5A. Interpolated weather conditions on 25.07.2009 (day with max number of fire occurrences - 27 fires)
(a) Wind speed(km/h), (b) Relative humidity(%), (c) Temperature(°C)

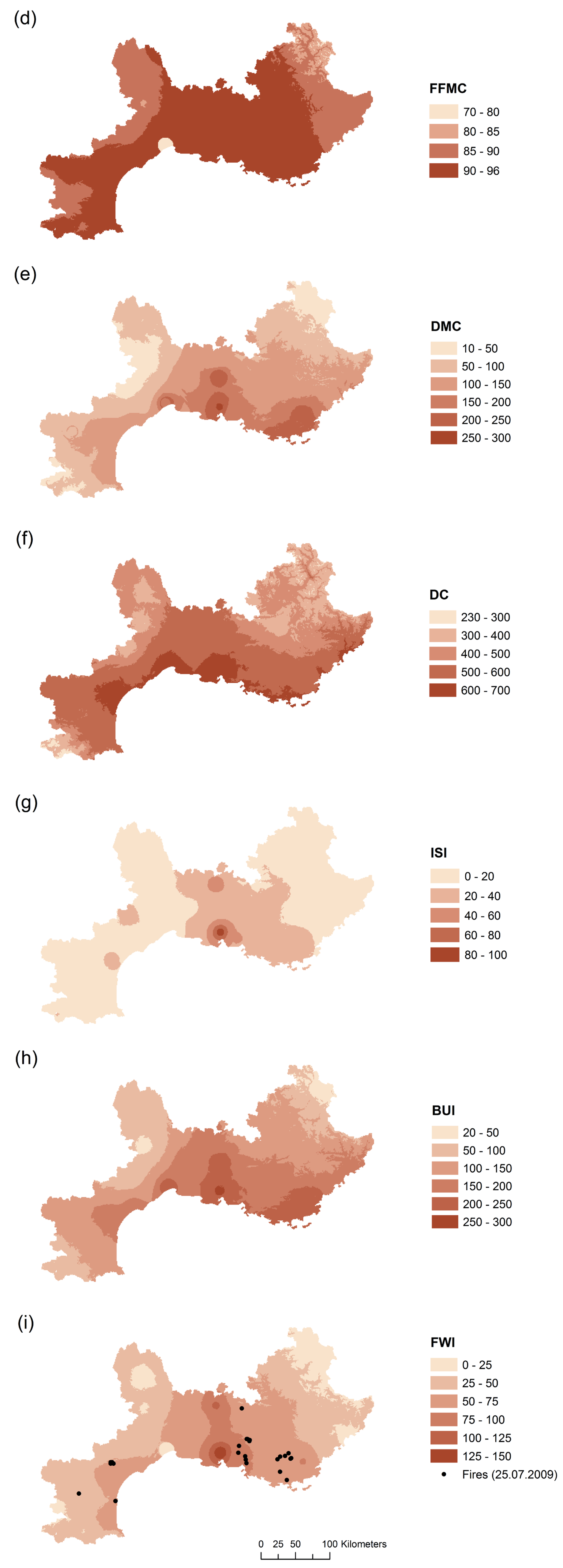


Figure 5B. Calculated CFWI components and observed fire occurrences on 25.07.2009. (d) Fine Fuel Moisture Code (FFMC), (e) Duff Moisture Code (DMC) , (f) Drought Code (DC), (g) Initial Spread Index (ISI), (h) BuildUp Index (BUI), (i) Fire Weather Index (FWI)

Based on Poisson regression results (regression coefficients given in Papakosta & Straub 2013) the predicted occurrence rate for 25.07.2009 from two models is illustrated in Figure 6. Explanatory variables are FWI (Figure 6a) and FWI, street density, population density and land cover types (Figure 6b).

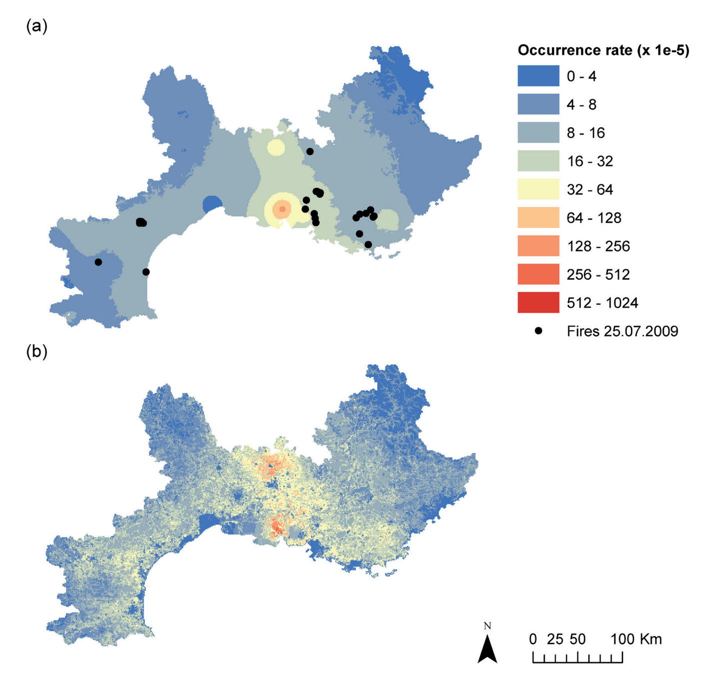


Figure 6. Predicted fire occurrence rate (Nr.Ocurrences/(day*km²) with explanatory variables (a) FWI, (b) FWI, street density, population density, land cover types.

Conclusions

Occurrence rate increased with increasing street density and population density. Urban areas showed high occurrence rate, evidence on high occurrence rate in wildland urban interface areas. Areas covered with olive groves proved to have the highest mean fire occurrence rate among the other Corine Land Cover classes. FWI on fire days reached values considered extreme for Canadian standards.

References

Lawson, B. D.; Armitage, O. B. (2008): Weather Guide for the Canadian Forest Fire Danger Rating System. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre. Alberta, Canada

Papakosta, P.; Straub, D. (2013): Probabilistic prediction of fire occurrence in the Mediterranean, manuscript in process

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