Value of Weather Observations for Reduction of Forest Fire Impact on Population

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Subject of research:

- forest fires model based on Nesterov index using
- varying amount of weather information for input
  - "rough" and "fine" weather data grids
  - number of weather stations
  - combining different data sets (System of Systems effect)

Objectives:

Assessment of the *incremental value of information* in terms of

- saved forest
- patrolling costs
- fire impact on population

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Weather Dataset:
JRC-AGRIFISH / MARS-STAT Data Base

- Daily basis
- Interpolated
- Europe, 50 x 50 km grid

for the *year 2000* containing:

- maximum temperature (^{o}C)
- minimum temperature (^{o}C)
- mean daily vapour pressure (hPa)
- mean daily windspeed at 10m (m/s)
- mean daily rainfall (mm)

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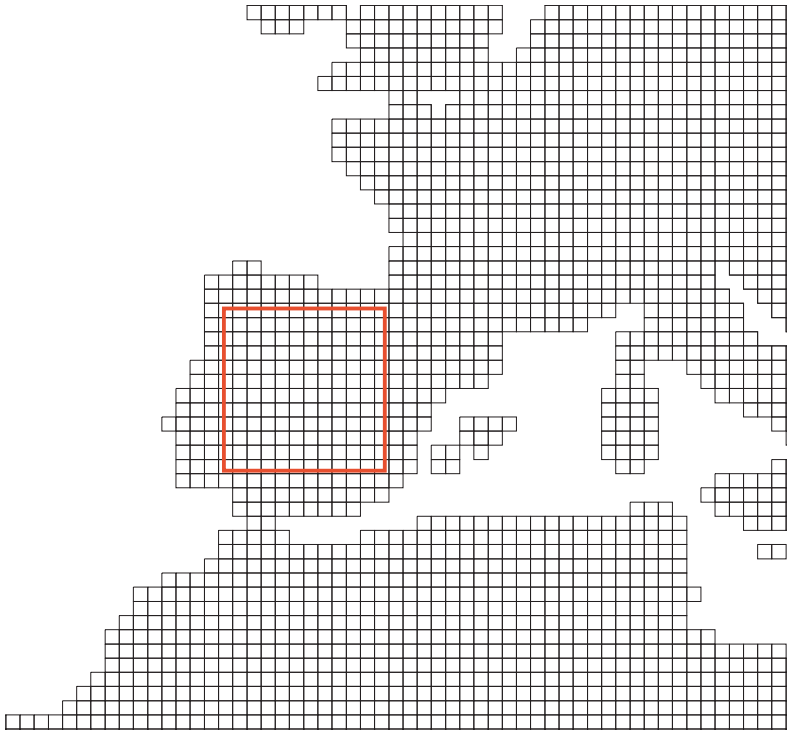
Area and Grids



The area partly covering the territory of Spain and Portugal located approximately between -7.5W, 42.0N & -0.5W, 38.0N.

- "Fine" grid: 12 x 12 cells, 50 x 50 km each: ⊞
- "Rough" grid: 6 x 6 cells, 100 x 100 km each: □

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Nesterov index definition

$$I(t) = \sum_{k=K_0(t)}^{t} (T_k - T_k^d) \cdot T_k,$$

$$K_0(t): \; p(k) < 3, \text{ for all } k = K_0(t), \ldots, t, \text{ and } p\left(K_0(t) - 1\right) \geq 3,$$

$$I\left(K_0(t) - 1\right) = 0,$$

$$I(0) = 0,$$

T_k – temperature measured at 15:00,
T_k^d – dew point temperature,
$p(k)$ – precipitation.

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Fire Danger Classes (FDC) and Air Patrol Frequency*

Nesterov index	Fire danger	FDC	Frequency of air patrol
0 ... 300	—	I	No patrol
301 ... 1000	Low	II	Once in 2–3 days
1001 ... 4000	Medium	III	Once daily
4001 ... 10000	High	IV	Twice a day
more than 10000	Extreme	V	Three times a day

* Officially in force in Russian Federation

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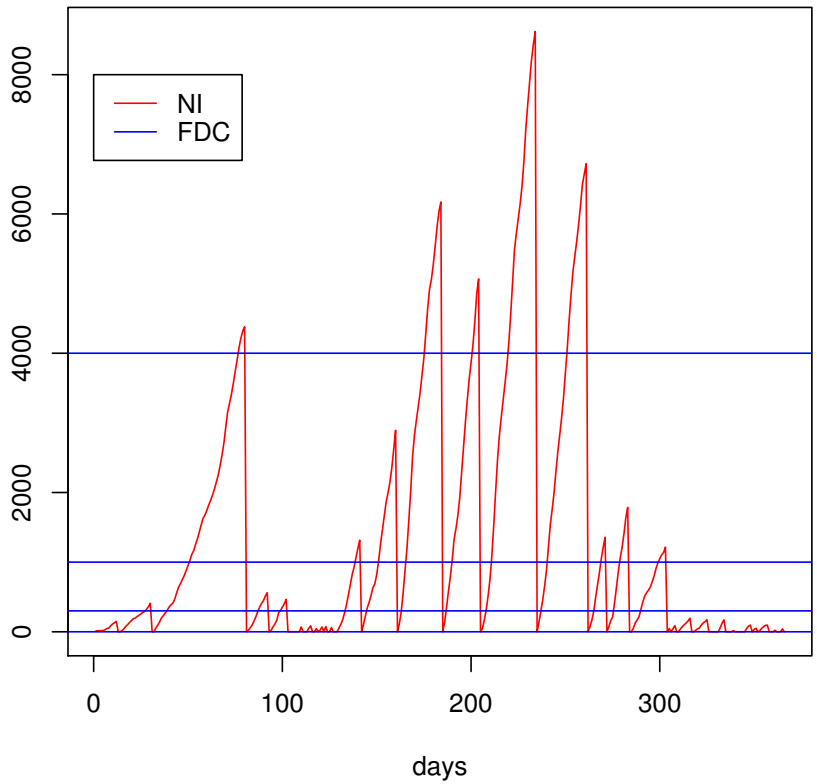
Nesterov index example graph



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Probabilities assessment

Probability of a fire in case of ignition:

$$\tilde{P}(I) = 1 - e^{-\alpha I}, \quad \alpha = 0.000337.$$

The average number of ignitions during a day:

$$N(\rho) = (\kappa(\rho)\rho a + z)S,$$

$$a = 0.1, \quad \kappa(\rho) = 6.8\rho^{-0.57}, \quad z = 0.02,$$

ρ – population density, habitants/km^2, S – area, km^2.

The probability of at least one fire in the area:

$$P(I, \rho) = 1 - (1 - \tilde{P}(I))^{N(\rho)}.$$

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Simplifying assumptions

- Homogeneous forest
- No extreme winds
- Fire spread velocity $v = 0.3$ m/min
- Area burnt in Δt is $\pi(v\Delta t)^2$
- Maximum fire duration is 24 h

Fire duration, area patrolled per day, and burnt area

FDC ν	Frequency of air patrol	FDO[1] $\Delta t(\nu)$	BA[2] $d(\nu)$	APD[3] $c(\nu)$
I	no patrol	24	0.85	0
II	once in 2 days	15	0.36	1250
III	once daily	6	0.08	2500
IV	twice a day	3	0.03	5000
V	three times a day	2	0.02	7500

[1] Fire duration until observed (hours). We assume it to be constant depending on the fire danger class only.

[2] Burned area (km^2). We allow 2 hours to extinguish the fire.

[3] Area patrolled per day (km^2).

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Benefits calculation

Patrolled area: $S(\nu) = \sum_{t=1}^{365} \sum_{i,j=1}^{12} c(\nu_{ij}^t)$. Expected burned area:

$$D(\nu) = \sum_{t=1}^{365} \sum_{i,j=1}^{12} P(I_{ij}^t, \rho_{ij}) \cdot d(\nu_{ij}^t).$$

Fire impact on population index:

$$\mathrm{FIPI}(\nu) = \frac{1}{S_{total}} \sum_{i,j=1}^{12} \rho_{ij} \sum_{t=1}^{365} P(I_{ij}^t, \rho_{ij}) \cdot d(\nu_{ij}^t), \quad S_{total}\text{– total area.}$$

Benefits ('r' and 'f' – rough and fine grids respectively):

$$S(\nu_r) - S(\nu_f), \quad D(\nu_r) - D(\nu_f), \quad \text{and} \quad \mathrm{FIPI}(\nu_r) - \mathrm{FIPI}(\nu_f).$$

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Results

Total expected FIPI, burned area (% of total area) and cumulative patrolled area (times of the total area) for rough and fine grids and respective improvement ratios

	Rough* grid	Fine grid	Improvement
FIPI	0.4496	0.3807	15%
Burned area	0.5261%	0.3910%	26%
Patrolled area	295.2	300.8	-2%

*The upper left sub-cell represents the weather data for aggregated cell:

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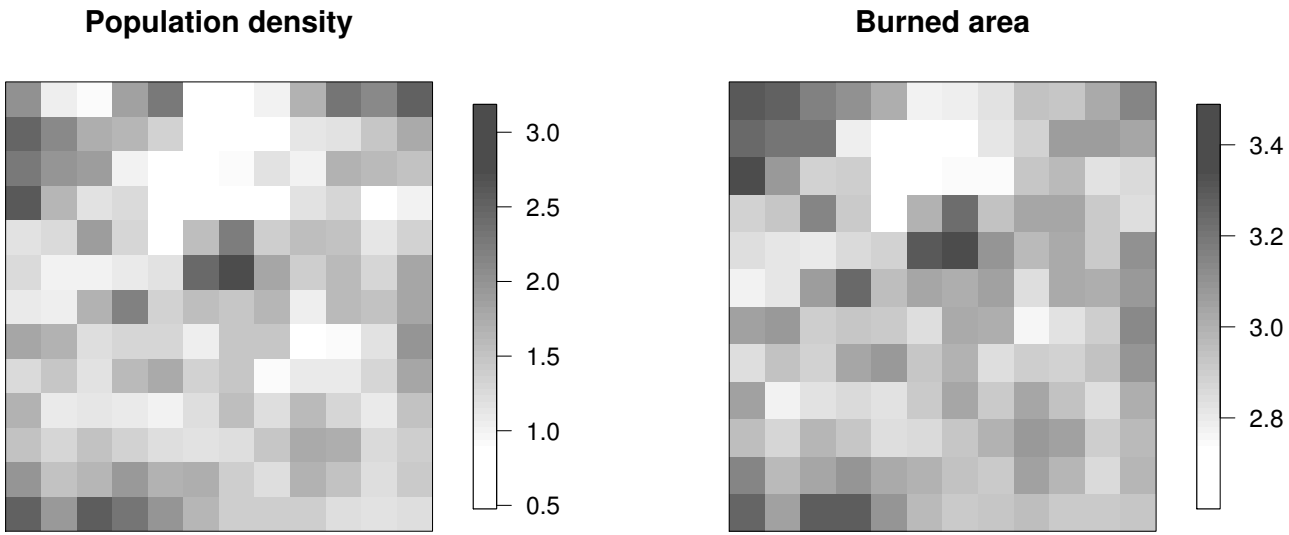
Patterns of population density (inhabitants/km2) and expected yearly burned areas (hectares) – both on $\log_{10}$-scale.

The population density alone or even integrated into FIPI cannot be used as the only fire impact measure, since it becomes quite insensitive to burned areas.



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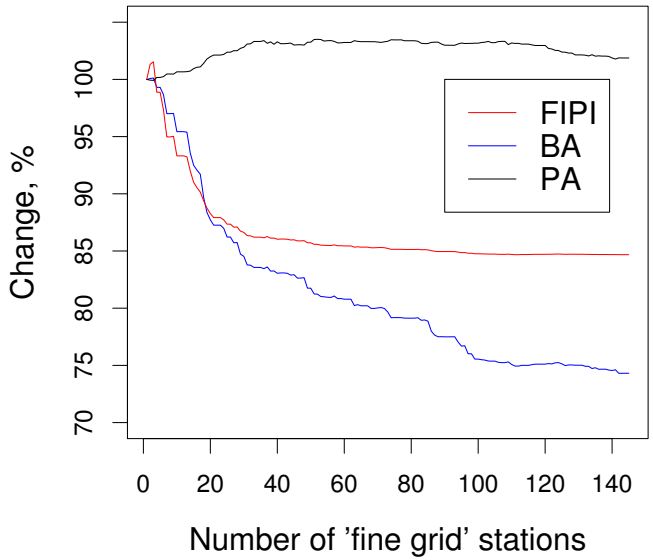
Minimization of the impact on population



Dependence of the FIPI, burned (BA) and patrolled (PA) areas on the number of 'added' weather stations.

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Thank you!

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