Forest Fire Risk Assessment: An Illustrative Example from Muskoka, Ontario

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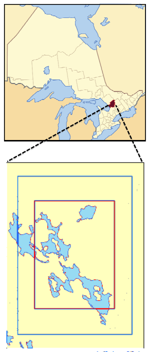
Introduction

- Forest fires are a naturally occurring disturbance on the forested landscape and plays an important ecological role.
- It also poses threats to human safety and can cause a lot of damage to timber resources and other economic assets.
- The District of Muskoka, a popular recreational area in Ontario, is a wildland-urban interface at risk of forest fire.
- It spans 6,475 square kilometers and contains over 100,000 seasonal properties or cottages.
- This concentration of values is of particular interest to the Canadian insurance industry due to the risk of claims from damage caused by wildfire.



Study Area

- A 25 x 35 km study area in the Muskoka District was chosen encompassing three major lakes on which much of the expensive properties are located.
- A further 5-km wide "buffer" zone around the study area was considered as well to reduce boundary effects.

A Simple Burn Probability Model

- A Generalized Additive Model (GAM) was used to create a simple burn probability map based on historic fires, with burn points grown in a circle from ignition points based on the size of the resulting fire.
- Each pixel is assigned a 1 or 0 depending on whether the pixel was burned.
- To account for the large proportion of 0-sites, only a simple random sample of 0-sites are taken. Adding a deterministic offset term of $\log(1/\pi_s)$ corrects for this in our stochastic model. Here π_s represents the inclusion probability of site $s=(s_1,s_2)$.

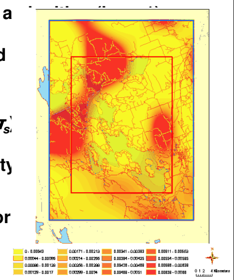
$\pi_s =$ { 0.01 if sites do not contain an ignition (i.e. a 0)

1 if sites contain a

- A GAM model was selected of the following form:

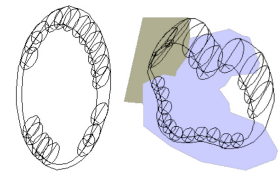
$$\text{logit}(p_s) = f(s_1,s_2) + \log(1/\pi_s$$

- ✓ p_s represents the probability of ignition at site $s=(s_1,s_2)$
- ✓ $f(s_1,s_2)$ is a penalized tensor product spline smoother.



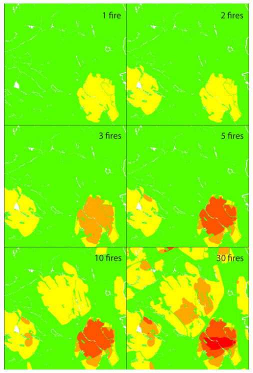
The Prometheus Fire Growth Model

- The Prometheus fire growth model is a deterministic model based on computer simulation of fires, taking account of fuel and local weather patterns.
- The evolution of a fire front simulated by Prometheus relies on the theory developed by Huygens for wave propagation: each point of a fire front at a given time acts as an ignition point for a small fire which grows in the shape of an ellipse based at that point. The size and shape of each ellipse depend on fuel composition information, weather and various fire growth parameters as well as the time duration. The envelope containing all of the ellipses is taken to be the fire perimeter at the next time step.



Burn-P3 Simulation Model

- A burn risk probability map can be generated using the Burn-P3 simulation model software developed by Marc Parisien of the Canadian Forest Service. P3 stands for Probability, Prediction, and Planning.
- Burn-P3 runs repeated simulations of the Prometheus Fire Growth Model, under different weather scenarios, to give estimates of the probability distribution of locations being burned during a single fire season (see figure on right).

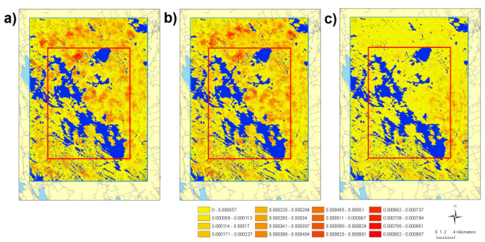


Burn-P3 Inputs

- Fuel map: From OMNR, verified and corrected through fieldwork. Our multi-stage sample survey revealed that approximately 22% of the sampled fuels were classified incorrectly.
- Ignition Grid: Using same GAM technique as the initial burn probability modelling, an ignition grid was generated for human fires based on historic human caused ignition points. A uniform ignition grid was used for lightning caused fires.
- Weather: Daily weather taken from nearby weather station and was block-randomized for use in simulation.

Simulation Results

- Running 20,000 fire year simulations of various scenarios, we generate multiple burn probability maps.



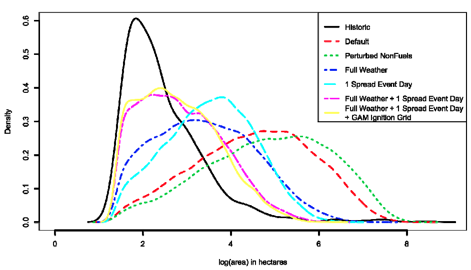
a) Full weather stream with default inputs

b) One spread event day with default inputs

c) Full weather stream with one spread event day using GAM ignition grid

Matching Fire Size Distribution

- We experimented with weather and spread event day values to try to identify which combination of settings and inputs produced a simulated fire size distribution that was similar to the historic fire size distribution.



- Comparing the resulting distributions, the closest model selected was the one with 1 spread event day and full weather stream using the GAM ignition grid.

Large Fires

- From the 20,000 simulations, we can get an estimate of the "1 in X year" fire size.
- Comparing this with the historic data, the fire sizes match up considerably well.

	Simulated	Historic
1 in 5 year	28.7 ha	15 ha
1 in 10 year	47.4 ha	50 ha
1 in 20 year	72.1 ha	75 ha
1 in 100 year	142.9 ha	No data
1 in 200 year	179.1 ha	No data
1 in 500 year	224.8 ha	No data

- Further research is being conducted to generate burn probability maps with these fire sizes set as minimums in order to estimate potential property-insurance claims from an "1 in X year" fire.

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