Probabilistic Risk Modelling at the Wildland Urban Interface: the 2003 Cedar Fire,

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Data preparation, data preparation, data preparation

Booker’s Law

An ounce of application is worth a ton of abstraction.
Overview.

A story of wildfires at the urban-wildland interface

“… where humans and their development meet or intermix with wildland fuel.” Federal Register (2004)

Getting/preparing data – yiiihih

Focus on the San Diego County Cedar Fire of 2003

Looking for: associations with explanatories, understanding of movement, …

Trying to understand costs - losses of life, property, animals, social cost (veg), private cost (home), fire suppression, …

Insurance premium?
The Cedar Fire.


15 deaths, 6000 firefighters, 2232 homes, 273246 acres, many evacuations, … (All ±)

Santa Anna conditions

A disaster

Large amounts of data, but …
Some formalism.

Spatial marked point process

Data \((x_i, y_i, M_i)\)

\((x_i, y_i)\): location, \(M_i\): mark

How to describe a point process \(X\)?

\[
dX(x,y)/dxdy = \sum \delta(x-x_i,y-y_i)
\]

Dirac delta

Rate/intensity

\[
\mu_X(x,y) = \mathbb{E}\{\sum \delta(x-x_i,y-y_i)\}
\]
Perhaps Y a subset of X (e.g. destroyed)

Ratio of rates

\[ p(X, Y) = \frac{\mu_Y(x, y)}{\mu_X(x, y)} \]

Useful for comparison, …
How to describe a m.p.p.

\[ dU(x,y)/dxdy = \sum M_i \delta(x-x_i, y-y_i) \]

Average

\[ v_U(x,y) = E\{\sum M_i \delta(x-x_i, y-y_i)\} \]

Thinning with \( M_i = 0 \) or 1 randomly yields p.p.

Y subset of X

Ratio of averages

\[ v_V(x,y)/v_U(x,y) \]
Logit-gam model

\[
\text{Logit\{Prob[destroyed|explanatories]\}} = \alpha_j \text{ with } j \text{ vegetation class}
\]
\[
= \beta(x,y) \text{ with } (x,y) \text{ location}
\]
\[
= \gamma(s) \text{ with } s \text{ slope}
\]
\[
= \delta(a) \text{ with } a \text{ assessed improvement value}
\]
\[
= \alpha + \beta + \gamma + \delta + (\alpha\beta) + \ldots
\]

After first case, function is assumed smooth
Developing “the” data set.

Many people, organizations, file formats, coordinate-systems, decisions, definitions, authorities, issues, skills, tricks, uncertainties, Nas, errors, checks,…

Publically available data

Tax records, assessors, satellites

GIS files – didn’t need package

Difficulty merging – APN, (X,Y), address,…

Response: 0-1 (destroyed) or continuous (sq ft)

Explanatories: topography, vegetation, roofing, brush,…
<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AREA</td>
<td>Area of parcel</td>
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<tr>
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<td>Parcel identification number</td>
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<tr>
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<td>Post identification number</td>
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<td>Legal description</td>
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<td>ASR imprint</td>
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<td>ADDRFRAC</td>
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<tr>
<td>YEAR_EFFEC</td>
<td>Year of effect</td>
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<tr>
<td>TOTAL_LVG</td>
<td>Total living area</td>
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<tr>
<td>BEDROOMS</td>
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<td>BATHS</td>
<td>Bathrooms</td>
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<td>ADDITION_A</td>
<td>Addition A</td>
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<td>GARAGE_CON</td>
<td>Garage construction</td>
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<td>GARAGE_STA</td>
<td>Garage status</td>
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<td>Carport status</td>
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<td>CommUNITY</td>
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<td>-----------</td>
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<tr>
<td>5012</td>
<td>Alpine</td>
</tr>
<tr>
<td>5015</td>
<td>Alpine</td>
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**AL & COMMERCIAL STRUCTURES**

<table>
<thead>
<tr>
<th>Replacement Cost Per Sq Ft</th>
<th>Structure Damage</th>
<th>Out Building Damage, Other Improvements</th>
<th>Vehicles, Travel Trailer Tractors</th>
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<tr>
<td>$150</td>
<td>DS</td>
<td>DM</td>
<td>Pct.</td>
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<tr>
<td>$ 240,000</td>
<td>1</td>
<td>1</td>
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<tr>
<td>$ 237,600</td>
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**OTHER LOSS**

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<thead>
<tr>
<th>Structures, Boats, Contents</th>
<th>Structure Costs</th>
<th>% of Rep. Cost</th>
<th>Comments</th>
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<tr>
<td>$ 120,000</td>
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<td>50%</td>
<td>utility shed</td>
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<td>$ 118,800</td>
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<td>patio cover 2</td>
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<td>Field</td>
<td>Description</td>
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<tr>
<td>-----------------------------</td>
<td>--------------------------------------------------</td>
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<tr>
<td>CN</td>
<td>Fire Name</td>
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<td>Add'l Location Info</td>
<td>Photo Log</td>
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<td>Owner Name</td>
<td>Foundation Number</td>
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<td>Insurance Carrier</td>
<td>Address Number</td>
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<td>Rated?</td>
<td>Street Name</td>
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<td>Occupancy Type</td>
<td>Property Use</td>
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<tr>
<td>#Dwellings Destroyed</td>
<td>#Dwellings Damaged</td>
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<tr>
<td>Destroyed</td>
<td>#Dwellings damaged</td>
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</tr>
<tr>
<td>#Outbuildings Saved</td>
<td>#Outbuildings damaged</td>
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<td>Structure Condition</td>
<td>#Outbuildings</td>
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<td>Actions Taken?</td>
<td>#Defensive Space</td>
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<tr>
<td>By Whom?</td>
<td>Ground Floor</td>
<td></td>
<td></td>
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<tr>
<td>Roof Covering</td>
<td>Ground Floor Length</td>
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<tr>
<td>SFI</td>
<td>Ground Floor</td>
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<tr>
<td>Number of Stories</td>
<td>FF Injuries</td>
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<td>Purpose of Structure</td>
<td>FF Deaths</td>
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<tr>
<td>Management Civilian Injuries</td>
<td>Area of Fire</td>
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<td>Civilian Deaths</td>
<td>Form of Heat of Ignition</td>
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<tr>
<td>Area: Level of Certainty</td>
<td>Form: Level of</td>
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<tr>
<td>Area: INFO SOURCE</td>
<td>Vegetation Factors</td>
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<td>Certainty Form: INFO SOURCE</td>
<td>Logistical Factors</td>
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<td>Structural Factors</td>
<td>Property Line Setback</td>
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<tr>
<td>Property Line Setback</td>
<td>Veg Distance</td>
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<td>Specific Access One Way?</td>
<td>Veg Condition</td>
<td></td>
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<tr>
<td>Access Dead End?</td>
<td>Access Grade</td>
<td></td>
<td></td>
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<tr>
<td>Driveway Width</td>
<td>Access Width</td>
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<td>Turnaround?</td>
<td>Driveway Grade</td>
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<tr>
<td>Wall Const.</td>
<td>Driveway Passing Lane?</td>
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<td>Deck/Porch</td>
<td>Driveway Vertical</td>
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<td>Vents</td>
<td>Window Frame Type</td>
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<td>Skylight Present?</td>
<td>Skylight TypeDoor: Sliding Glass Type</td>
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<td>Eave Const. Overhang Width</td>
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<td>Rain Gutter Construction</td>
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<td>Address Present?</td>
<td>Contrasting?</td>
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<td>Letter Height Letter Width</td>
<td>Fuelbreak Width</td>
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<td>Fire Sprinklers</td>
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<td>Fuelbreak Length</td>
<td>Fuelbreak Width</td>
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<td></td>
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<tr>
<td>Present?</td>
<td>Observations with GPS and Damage info</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Map 2: Effects/Income Map
Analyses.

spatial, spatial-temporal, binary, continuous

R functions: str(), read.shapefile(), inout(), match(), read.xls(), read.dbf(), image(), as.numeric(as.character()), library(),…
Example of shapefile contents
Looking at the point process data.

Unincorporated SD County + Scripps Ranch

Fire boundary
Locations (destroyed and not)

Rates/intensities and ratio
Looking at the continuous data.

m.p.p. : area of house (square feet)
  a cost proxy ($150/sqft)

Smoothed sqrt(squared feet)
  \[ \sum Z_i K(x-x_i, y-y_i) \]

Some descriptive statistics
Inference results. *Point process case.*

Intensity of houses at \((x,y)\) initially \(\mu_X(x,y)\)

Intensity of destroyed \(\mu_Y(x,y)\)

\[ p(x,y) = \frac{\mu_Y(x,y)}{\mu_X(x,y)} \]

“probability” of a house’s destruction
**Inference results.** *Continuous case.*

Square feet (from tax records)

Is there a difference wrt squared feet between destroyed and rest?

Estimate $v_V(x,y)/v_U(x,y)$
Does size depend on location?

\[ dN(x,y,z)/dx\,dy\,dz = \sum \delta(x-x_i, y-y_i, z-z_i) \]

\[ \sum z_i \delta(x-x_i, y-y_i, z-z_i) \]

If \( Z \) independent of p.p. \( \{X(x,y)\} \), average satisfies

\[ \gamma(x,y,z) = \gamma_1(x,y) \gamma_2(z) \]

Consider \( \gamma(x,y,z)/\gamma_1(x,y) \)
Explanatories.
Vegetation type (15 categories)
Slope
Assessed improvement value
Destroyed
Structure location
Square feet
...
Proportions destroyed by class

- 14. Forest (2637)
- 13. Woodland (732)
- 12. Riparian (1421)
- 11. Grassland/Meadows/Vernal pools (456)
- 10. Coastal sage/Chaparral scrub (90)
- 9. Chaparral (2554)
- 8. Scrub (2)
- 7. Coastal sage scrub (959)
- 6. Agriculture (226)
- 5. Unvegetated (1)
- 4. Open water (13)
- 3. Developed (13353)
- 2. Disturbed (171)
- 1. Eucalyptus woodland (6)
Logit-gam model results.

\[ \text{Logit}\{\text{Prob[destroyed|explanatories]}\} \]

\[ = \gamma(s) \text{ with } s \text{ slope} \]

\( \gamma \text{ smooth} \)
Estimated re-expression of slope
Estimated re-expression of assessed improvement value
Spatial-temporal results.

polygons

wavefront

How quantities in polygons depend on time

Time defined as interval from midnight 25 October to last fire boundary
Observed fire boundaries

Advancing front for the Cedar Fire
Economic Valuation: $$$

- Key distinction:
  - Social Cost (public goods)
    (e.g., vegetation lost or air pollution)
  - Private Cost (private goods)
    (e.g., properties or assets destroyed)
- Short-run vs. Long-run Effects
Example of non-market valuation:

- Stormwater runoff increased by 12 million cubic feet.
- Cost of retaining is estimated at $25 million dollars.
- Underestimation: This reflects only one dimension of value.
• Downward trend in chance of destruction as assessed value increases.
Other thoughts.

Damaged houses
Other explanatories
Other models
Other fires
Spatial correlation
Uncertainties
...
...
Discussion.

Limitations

“they are ‘messy’ datasets and do require a bit of massaging to make sense” … “the damage assessment we performed … was a rapid assessment. There were 18 … teams. … we used a variety of GPSs of varying accuracy. The individual team members also had varying degrees of competency.” J. Batchelor (SD County)

Just one fire, lurking variables/proxies

GISs – Cedar fire areal time success for the GIS industry

Can grab shapefile data for R analyses

Would robust/resistant methods have helped?
Summary.
A work in progress, a story

Difficulties of getting, cleaning and employing data

Used statistical package, R, with Sangis data layers
Acknowledgements.

SanGIS, SDSU, SDCounty, SDFoundation, SDCity, …

A. Ager (USFS), J. Benoit (USFS), C. Hunter (Rancho Santa Fe), D. Sapsis (State of Ca), P. Spector (UCB), C. Westling (SD County), K. Wright (USFS), J. Batchelor (SD County), R. Martin (SD County), M-H. Tsou (SDSU), D. Gilmore (SD County), …