

# Serial and Potential Copycat Intentional Fires and the Magnification of Law Enforcement Efforts in Spain

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# Background

- Intentional wildfires are deadly and costly
- Arson firesetting is illegal
- Intentional wildfires worse than others
- Outdoors fires by juveniles are often “gateway” fires
- Arson is partially predictable
  - Autoregressive (spatial, temporal)
  - Respond to weather and fuel conditions
  - Stable patterns during days, across days, across months or seasons
- Forecasting should work with careful statistics

# Study Overview

- Objective: Evaluate whether intentional wildfires can be forecasted in Galicia, Spain
  - Potential Outcome: A daily wildfire hotspot tool
- Additional objectives
  - Quantify temporal and spatiotemporal autocorrelation, and see if they help in forecasts
  - Evaluate forecast skill—better than CompStat?
  - Evaluate how interventions could change rates

# CompStat Software is Used for Policing

## Identifies Crime Hotspots

- Limited efforts to validate the tool
  - Not forward-looking
  - Routines are variants of random walks
- Blossoming efforts: out-do CompStat
  - Santa Cruz predictive policing (SEPP method)
- Hotspot tools not developed for arson wildfires



The screenshot shows the website for the Lower Mainland District of the Royal Canadian Mounted Police (RCMP). The page features a navigation bar with links for Français, National RCMP, Contact Us, Help, Search, and canada.gc.ca. A search bar is located in the top right corner. The main content area is titled "COMPSTAT Bulletin" and "Upper Fraser Valley". It includes a file number "2012-03-12 10:40 PDT" and a list of three hotspots. The first hotspot is "Exhibition Park East to Young Rd Hotspot Continues" with a detailed location and an outline of property crimes. The second hotspot is "Williams St west to Young Rd (between 1st Ave and Reece Ave) Hotspot" with a location and outline. The third hotspot is "Eleven property crimes from February 6-28" with a location and outline.

Royal Canadian Mounted Police Gendarmerie royale du Canada

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File # 2012-COMPSTAT  
2012-03-12 10:40 PDT

1. Exhibition Park East to Young Rd Hotspot Continues

LOCATION: From Exhibition Park east to Young Rd (Kipp Ave, Corbould St, Wellington Ave, Patten Ave, Mary St, Main St, Spadina Ave, Mill St, Yale Rd, Young Rd)

OUTLINE: Seventeen property crimes from February 9 to March 2 . These include two business B&E's, 1 residential B&E , 2 auto thefts, 11 thefts from vehicle, 1 possession of stolen property.

2. Williams St west to Young Rd (between 1st Ave and Reece Ave) Hotspot

LOCATION: From Williams St west to Young Rd, between 1st Ave up to Reece Ave

OUTLINE: Eleven property crimes from February 6-28. Six residential B&E's, 2 attempted residential B&E's, 4 theft from vehicle. Two B&E's to Newmark storage lockers with the locks cut and tools taken.

# **ARSON BACKGROUND**

# Intentional Wildfires Are Deadly

Arson Wildfire	Deaths	Other Impacts/Notes
Cedar Fire, California (October, 2003)	15	1,135 km <sup>2</sup>
Old Fire, California (October, 2003)	6	370 km <sup>2</sup>
Galicia, Spain (August, 2006)	4	1,900 fires (90% arson) 770 km <sup>2</sup>
Greece Wildfire Outbreak (Summer, 2007)	84	Some fires were intentional
Black Saturday Fires, Victoria, Australia (Feb 7, 2009)	173	Multiple fires, many fires intentional
Station Fire, California (August-October, 2009)	2	648 km <sup>2</sup>

# Intentional Fires are Deadly and Costly

- Arson is the leading cause of all fires
- Annual Average (2003-2006)\*
  - 316,610 intentionally-set fires
  - 437 civilian deaths
  - 1,404 civilian injuries
  - \$1.1 billion property loss
- Economic Impact\*\*
  - Structure fire (30% of arsons): \$86,800/fire
  - Vehicle fire (20% of arsons): \$21,593/fire
  - Outside & Other (50% of arsons): \$1,013/fire
  - ⇒ *Total direct impact of \$5.3 billion/yr*
- Half of arson fires are by juveniles, who are most likely to escalate their firesetting to more dangerous targets



Source: The Daily Mail UK

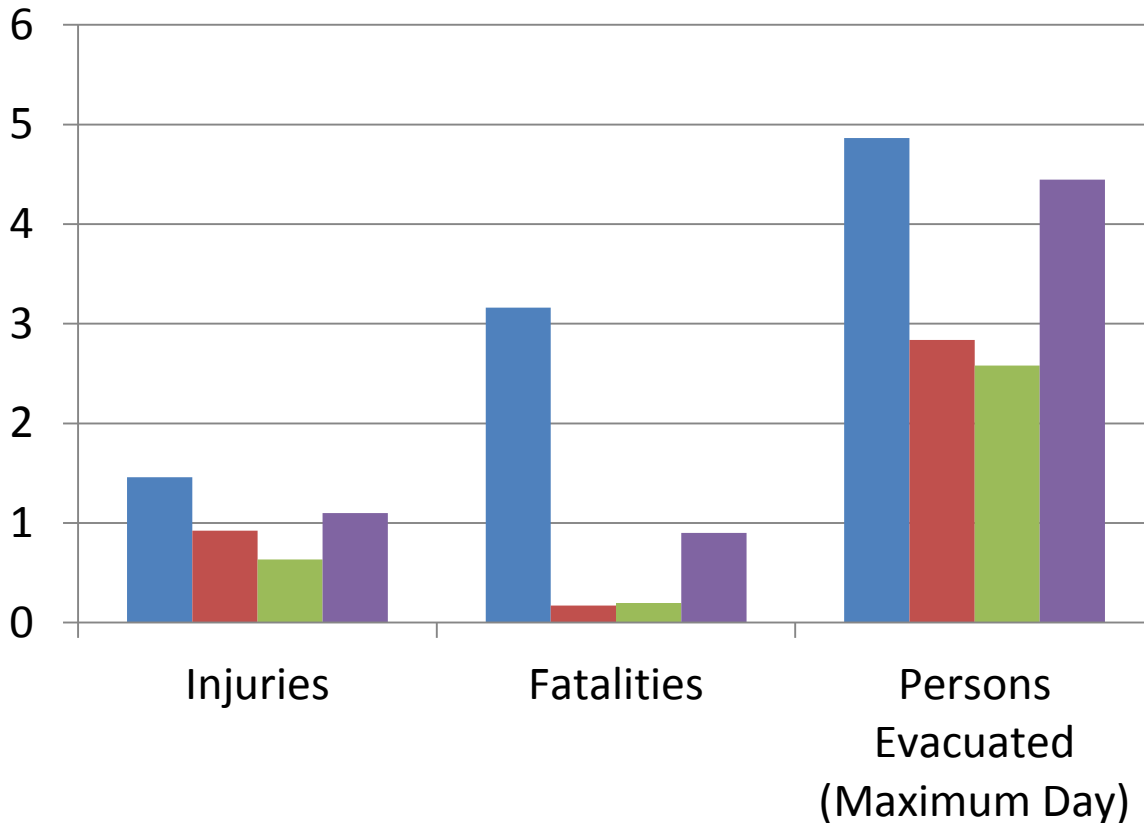
\* Flynn, *Intentional Fires*, NFPA, 2009.

\*\*Based on numbers from Flynn (2009) and using a value of statistical life of \$8.75 million and value of a statistical injury of \$189,198. Percentages from: U.S. Fire Administration, *Arson in the United States*, Topical Fire Research Series, Vol. 1, Issue 8.

# Arson Wildfires are Worse than Other Wildfires

## U.S. National Forest Wildfire Human Impacts

(Persons Per 100,000 Acres Burned)



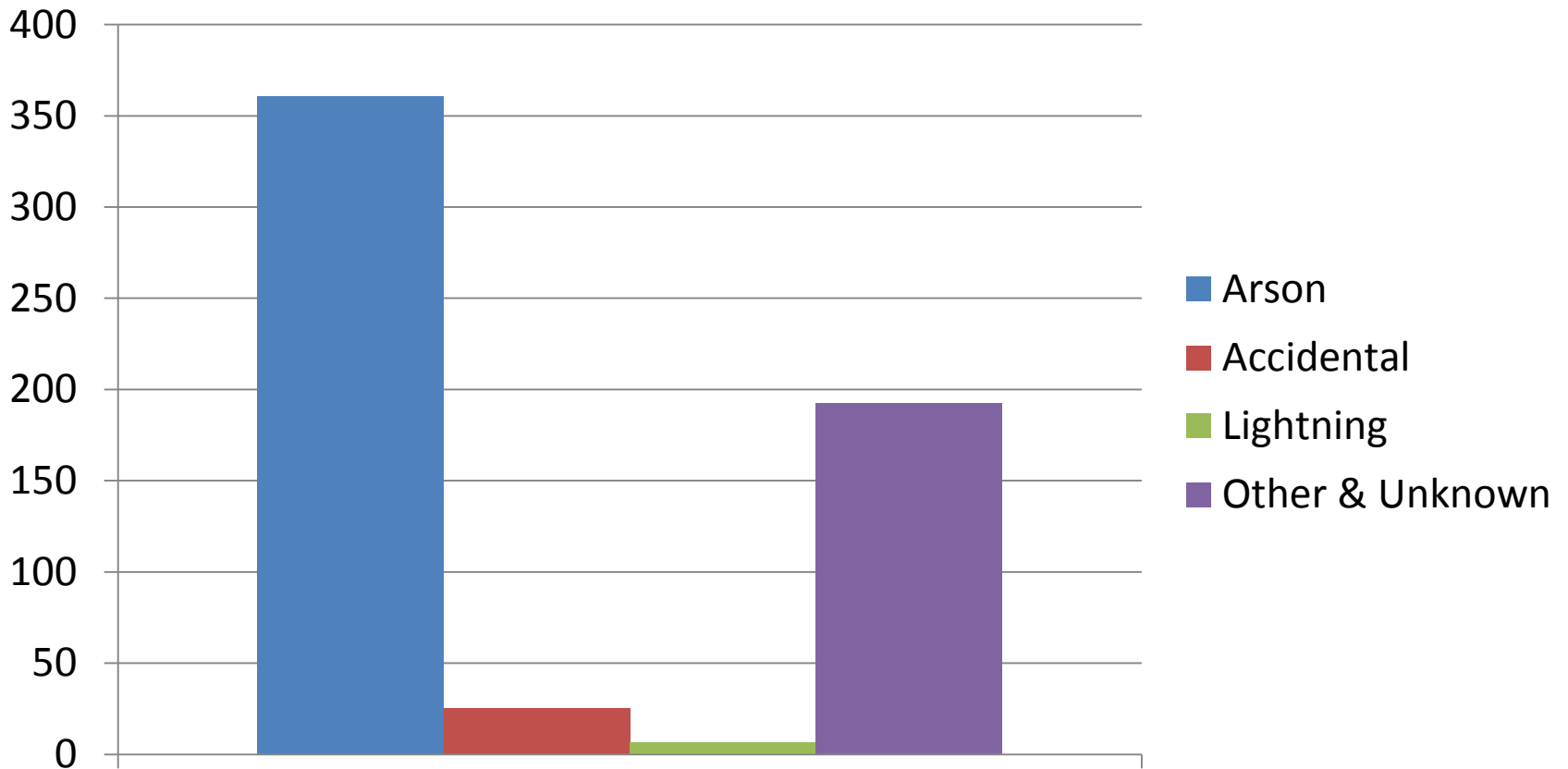
Greece, 2007. Athens News Agency

- Arson
- Accidental
- Lightning
- Other & Unknown



# Arson Wildfires are Worse than Other Wildfires

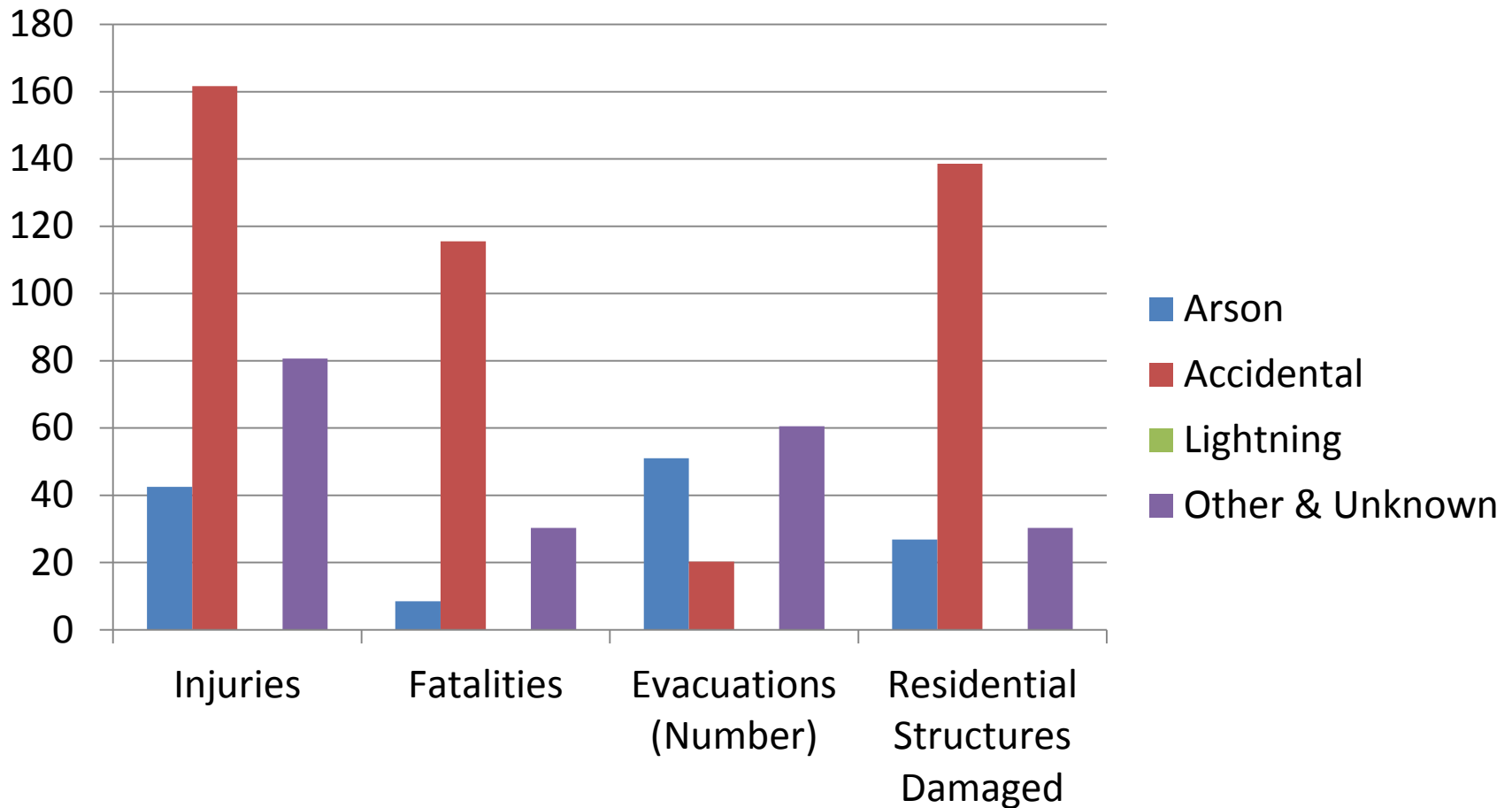
U.S. National Forest Structures Impacts  
Residential and Commercial Buildings Destroyed  
(per 100,000 Acres Burned)



Data for 1,988 Large Wildfires, 2001-2008; courtesy of Jon Yoder and Karen Abt

# Intentional Wildfires May not be Worse in Galicia, on a Per-Fire Basis

(Per 100,000 Fires Burned)



Data for Galicia, 1999-2008.

Source: Spanish Forest Service and the Rural Affairs Department of the Regional Government (Xunta de Galicia)

# Arson is a Major, Part I Crime

Part I Crime	Rate in the US in 2010 (per 100,000 Residents)
Murder	4.8
Forcible Rape	27.5
Aggravated Assault	119.1
Robbery	252.3
Burglary	699.6
Larceny-Theft	2,003.5
Motor Vehicle Theft	238.8
Arson (all targets)	19.6

**ARSON**  
is a crime!

Forest arson  
is NOT a victimless crime.  
Arson fires cause an increase in  
health problems, loss of property  
value, and endangers lives.  
**It's up to you to stop it!**

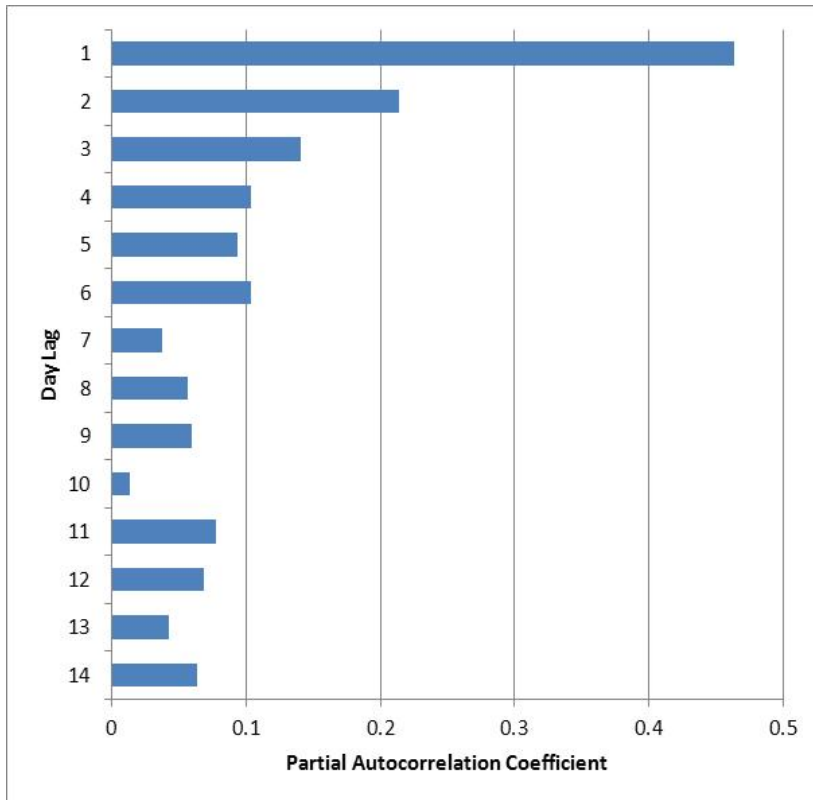
**Call 1-800-27-ARSON**  
Up to \$1,000 Reward  
You Can Remain Anonymous

make 'em  
pay!

**Source:** U.S. Dept. of Justice, Federal Bureau of Investigation. 2011. Crime in the United States, 2010.

# Arson Fire Characteristics

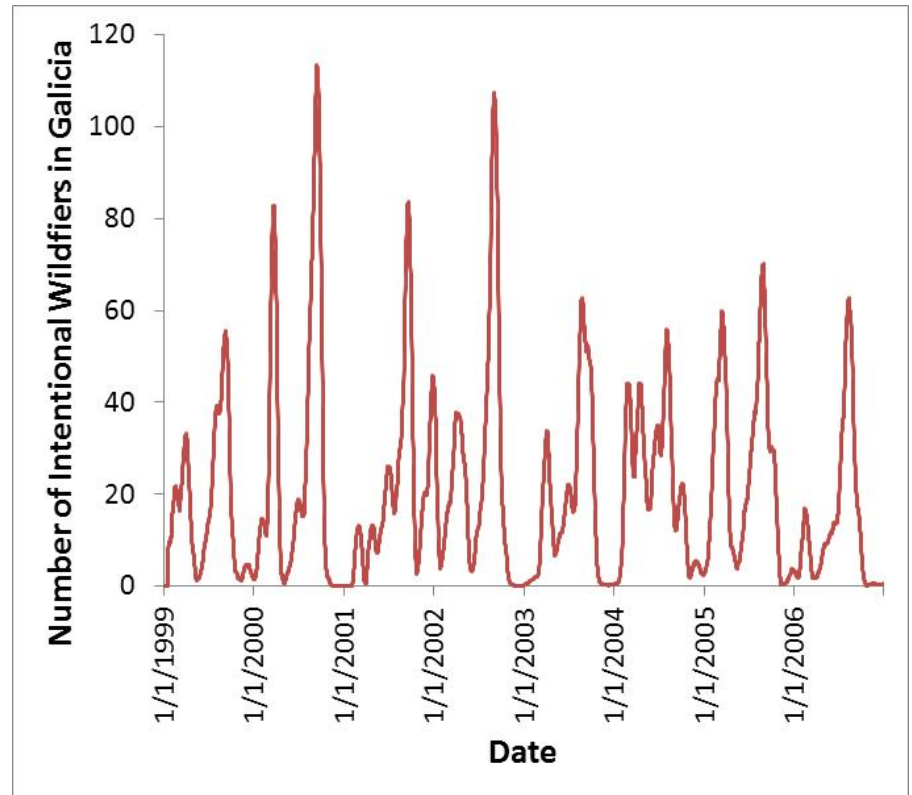
Fire counts are autocorrelated



Northeast Florida counties, 1981-1999

Source: Florida Division of Forestry wildfire statistics

Fire counts are seasonal



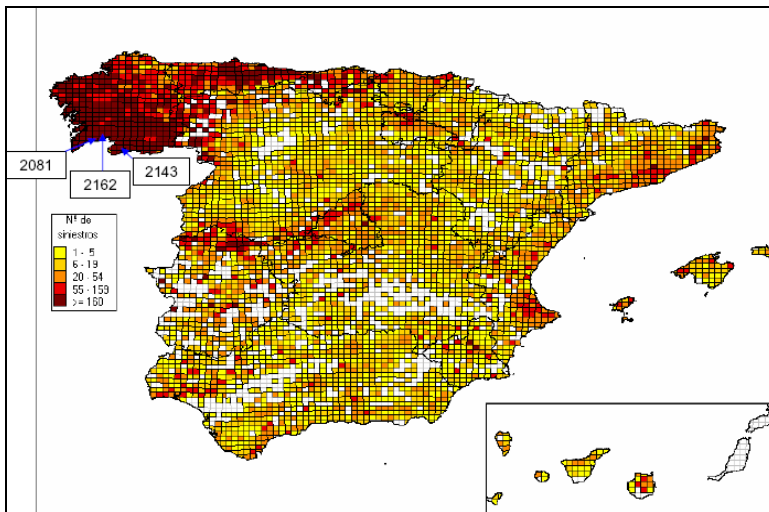
Galicia, Spain, 1999-2006

Source: Spanish Forest Service and the Rural Affairs Department of the Regional Government (Xunta de Galicia)

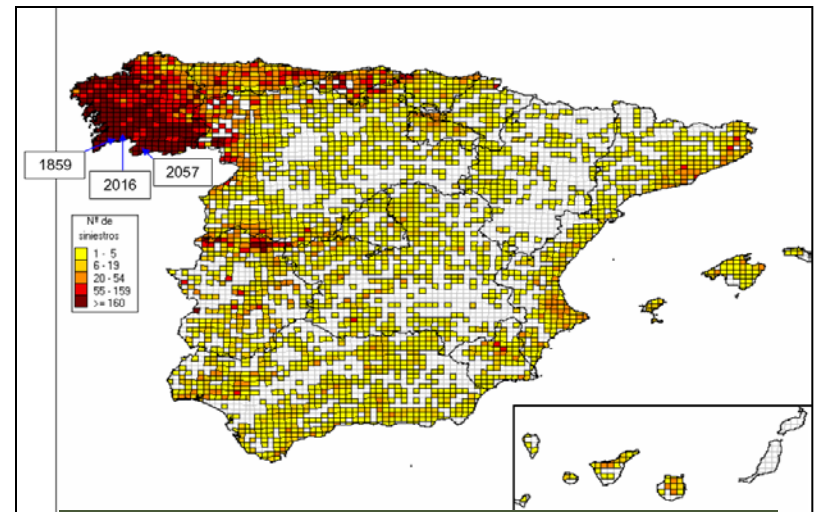
# Arson Wildfires in Spain



- In Spain, wildfires are a recurring phenomenon
  - 21,000 fires/yr
  - 140,000 ha burned/yr
  - 2006 was a very bad year
- Half of Spain's wildfires are in Galicia, which is 6% of Spain's land area.
  - 82% of Galicia's fires are intentional (arson by our definitions in the US)
- The Galician people have a long tradition of fire use, and much of that has been deemed unlawful in recent decades



Number of fires: 1996-2005



Number of arson fires: 1996-2005

# Modeling Approach

- Estimate 19 count models, by Forest District
- Daily data, 1999-2003
- Poisson autoregressive models of order  $p$ —the PAR( $p$ ) model
- Model structure based on
  - Rational Choice Theory
    - Routine Activities Theory from criminology (Cohen and Felson 1979)—focuses on characteristics of the crime
    - Economic model of crime (Becker 1968)—focuses on trade-offs between offending and not offending
  - Understanding of wildfire ignition processes

# Galicia Forest Districts



# Modeling Approach (Continued)

- Regressors
  - Meteorological variables
    - MFWI, Max Wind, Min RH (t-1)
  - Socioeconomic variables
    - Unemployment, Income, Income per Capita
  - Arrests
    - Galicia-wide, running 365-day total, and within the District, previous year total
  - Month dummy variables
  - Day dummies
    - Friday, Saturday, Sunday, non-weekend holidays
  - Spatio-temporal dummies indicating intentional fire occurrences in (1) contiguous and (2) distant Forest Districts
    - Captures serial and copycat elements, ceteris paribus



# Modeling Approach (Continued)

- Forecasts
  - Daily arson counts, 2004-2006
  - Compared accuracy against
    - Non-autoregressive Poisson
    - Random-walk (a “CompStat” approach)
    - Constant rate
  - Accuracy statistics
    - Bias
    - Root mean squared error (RMSE)

# Arrest Application

- Evaluated using the in-sample data
- Quantified effect of 1 additional arrest on counts in each Forest District
  - Own District Impact
    - Ignores spatio-temporal correlations
  - Non-District Impact
    - Assumes spatio-temporal correlations indicate causality

# Notable Results

Variable	Cases of Significance at 5% (out of 19)
Saturday	10 positive
Sunday	12 positive
March	12 positive
April	7 positive, 1 negative
July	3 positive, 6 negative
August	7 positive, 1 negative
September	8 positive, 2 negative
October	7 negative
Modified Fire Weather Index, t-1	15 positive
Relative humidity, t-1	17 negative
Maximum wind speed, t-1	13 negative

## Summary:

- (1) Weekends are higher probability
- (2) Split seasonality
- (3) Weather and fuel conditions matter, in ways expected

# More Notable Results

Variable	Cases of Significance at 5% (out of 19)
District Arrests, t-1 to t-365	1 positive, 4 negative
Galicia Arrests, $\tau-1$	14 negative
Fires-Contiguous Districts <sub>t-1</sub>	17 positive
Fires-Distant Districts <sub>t-1</sub>	14 positive
Fires-Contiguous Districts <sub>t-2</sub>	11 positive
Fires-Distant Districts <sub>t-2</sub>	1 positive
$\rho_1$	19 positive
$\rho_2$	11 positive
$\rho_3$	1 positive

## Summary:

- (1) Arrests reduce intentional fires
- (2) Spatio-temporal lags are positively related to fires occurrence, previous 2 days
- (3) Distant district effects may be indicative of a copycat effect
- (4) Temporal lags are positively related to fire occurrence, previous 3 days

# Forecast Evaluation

Statistic	Model	In-Sample Data	Out-of-Sample Data
Bias	PAR(p)	-0.12	-0.17
Bias	Poisson	0.00	-0.02
Bias	Random-walk	0.00	0.00
Bias	Constant	0.00	-0.04
RMSE	PAR(p)	1.75	1.83
RMSE	Poisson	1.91	1.96
RMSE	Random-walk	2.01	2.05
RMSE	Constant	2.74	2.82

## Summary:

- (1) The PAR(p) explains more variation, the AR terms are needed, so it's better for inference
- (1) The PAR(p) model outperforms other models, RMSE is 6.8% smaller than Poisson
- (2) Dropping the spatio-temporal lags would increase RMSE out-of-sample by 2.3%

# Effects of One Arrest Anywhere in Galicia

Effects*	Daily Count for One Year	Annual Total Count
Within-District	-0.383	-139.6
Spatio-Temporal	-0.066	-24.1

\* Sum of effects across Forest Districts with significant effects at 95% confidence, based on bootstrapped standard errors.

## Summary:

- (1) Within-District effect is equivalent to an elasticity of -0.94
- (2) Spatio-temporal effect would exist ONLY if causality is assumed.

# Summary and Conclusions

- Intentional wildfires have regular temporal patterns that can be exploited to forecast
  - Days, especially weekend spikes
  - Seasons
  - Autoregressivity
- Galician intentional wildfires demonstrate the same patterns as observed for arson in the US
  - Temporal autoregressivity, but shorter perhaps
  - Spatio-temporal autoregressivity
  - Influence of law enforcement efforts

# Summary and Conclusions

- We found distant spatio-temporal autoregressivity
  - May hint at copycat influences in firesetting
- Autoregressive Poisson models forecast better
  - Better than embedded routines used in CompStat



# Q & A



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