

*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 – yiiihi

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.**

25 October – 4 November, 2003

15 deaths, 6000 firefighters, 2232 homes, 273246 acres,  
many evacuations, ... (All  $\pm$ )

Santa Anna conditions

A disaster

Large amounts of data, but ...









J. Gibbons

## 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

$$\mu_X(x,y) = E\{\sum \delta(x-x_i, y-y_i)\}$$



Perhaps Y a subset of X (e.g. destroyed)

Ratio of rates

$$p(X,Y) = \mu_Y(x,y) / \mu_X(x,y)$$

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*

Logit{Prob[destroyed|explanatories]}

=  $\alpha_j$  with  $j$  vegetation class

=  $\beta(x,y)$  with  $(x,y)$  location

=  $\gamma(s)$  with  $s$  slope

=  $\delta(a)$  with  $a$  assessed improvement value

=  $\alpha + \beta + \gamma + \delta + (\alpha\beta) + \dots$

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,...



## San Diego Firestorm 2003

6219 4113 133216

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**TAX RECORD DATA** – all houses

AREA PERIMETER PARCEL\_ PARCEL\_ID PARCELID OVERLAY\_JU POSTID  
POSTDATE SUBDIVID GRAPHSRC CONFACTR APNID APN\_POSTID  
APN\_POSTDA PENDING APN **APN\_8** MULTI OWN\_NAME1 OWN\_NAME2  
OWN\_NAME3 FRACTINT OWN\_ADDR1 OWN\_ADDR2 OWN\_ADDR3 OWN\_ADDR4  
OWN\_ZIP ASR\_SITENA LEGLDESC ASR\_LAND ASR\_IMPR ASR\_TOTAL ACREAGE  
TAXSTAT OWNEROCC TRANUM ASR\_ZONE ASR\_LANDUS SUBMAP SUBNAME  
UNITQTY **ADDRNO** ADDRFRAC ADDRUNIT ROADPDIR **ROADNAME** ROADSFX  
JURIS ZIP **X\_COORD Y\_COORD** SITUS\_ADDR SITUS\_FRAC SITUS\_SUIT  
SITUS\_PRE\_ SITUS\_NAME SITUS\_SUFF SITUS\_POST YEAR\_EFFEC  
**TOTAL\_LVG\_** BEDROOMS BATHS ADDITION\_A GARAGE\_CON GARAGE\_STA  
CARPORT\_ST POOL PAR\_VIEW USABLE\_SQ\_ OBJECTID

SUMMARY							RESIDENTIAL	
Report Number	Community	Street Number	Street Name	GPS Location	Photos	Assessor Parcel No.	Sq ft	COUNTY Assess Valuation
5012	Alpine	502	S. Glen Oaks		disk 1 #12	40307501	1600	\$ 127,500
5015	Alpine	2198	Larkspur		disk 2/photo : #####		1584	\$ 114,444

AL & COMMERCIAL STRUCTURES				OTHER LOSS				
Replacement Cost Per Sq Ft	Structure Damage			Out Building Damage, Other Improvements			Vehicles, Travel Trailers, Tractors	
\$150	DS	DM	Pct.	DS	DM	Loss \$\$ (\$20/sq ft)	DS	DM

\$ 240,000 1  
\$ 237,600 1

1  
2

Boats, Vehicles, etc.	Structure Contents % of Rep. Cost	COMMENTS
\$\$ Loss	50%	

\$ 120,000 utility shed  
\$ 118,800 patio cover 2

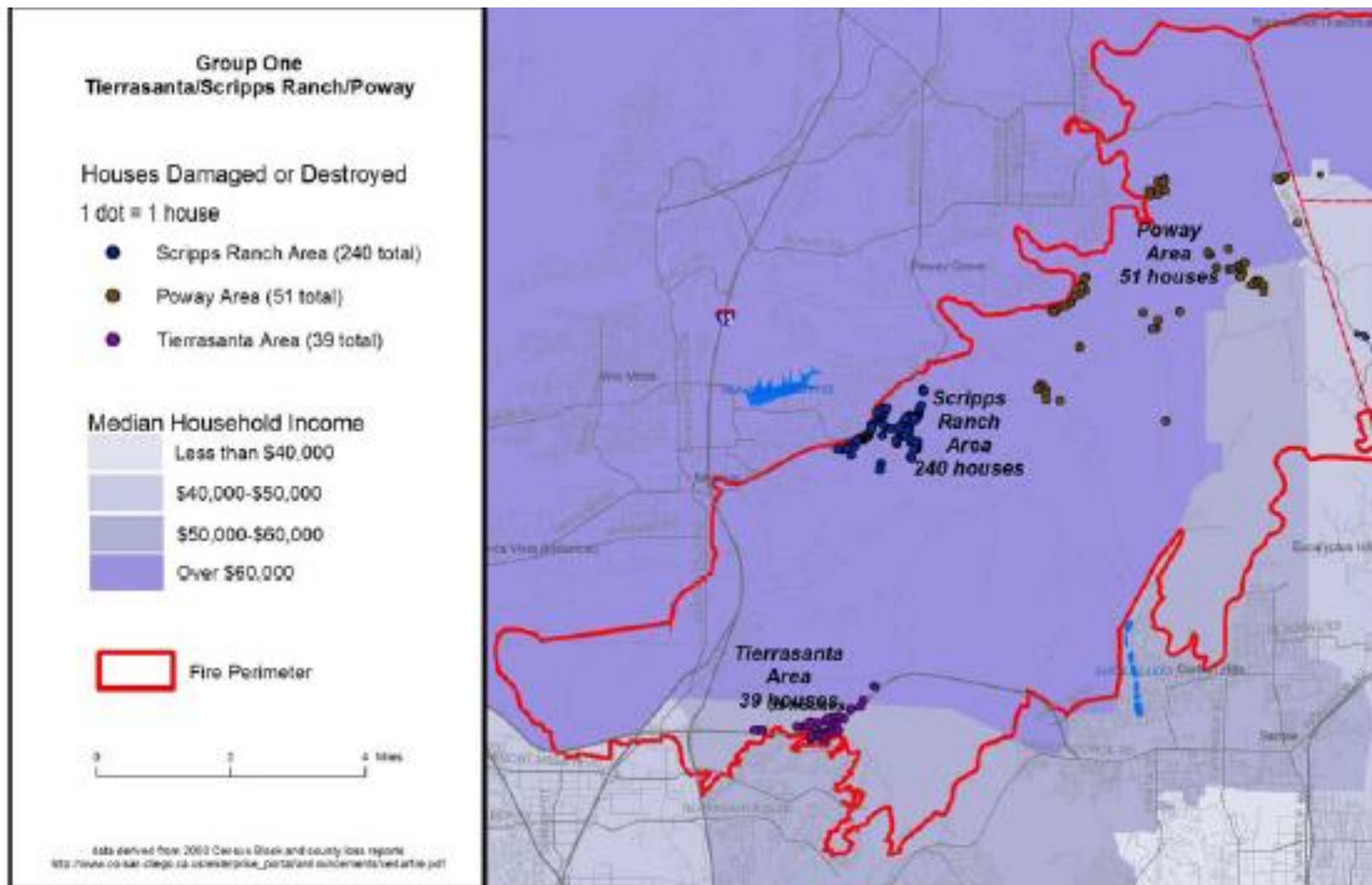




Damage Assessment

R. Martin

CN	Fire Name	Photo Log	Foundation Number	Address Number	Street Name
	Add'l Location Info		Latitude	Township	Range
	Owner Name	Insurance Carrier	Structure Type	Construction Type	Fire
Rated?	Occupancy Type	Type of Business	Property Use	#Dwellings Damaged	
	#Dwellings Destroyed	#Dwellings Saved	#outbuildings damaged	#Outbuildings	
Destroyed	#Outbuildings Saved	#Vehicles Damaged	#Vehicles Destroyed	#Vehicles Saved	
	Structure Condition	Structure Status	Defensible Space	Defensive	
Actions Taken?	By Whom?	Roof Covering	Ground Floor Length	Ground Floor	
Width	SF	Number of Stories	Construction Quality	Year Built	Property
Management	Civilian Injuries	Civilian Deaths	FF Injuries	FF Deaths	Area of Fire
Origin	Area: Level of Certainty	Area: INFO SOURCE	Form of Heat of Ignition	Form: Level of	
Certainty	Form: INFO SOURCE	Structural Factors	Vegetation Factors	Logistical Factors	
	Environmental Factors	Operational Factors	HYDRANT?	Location Slope	
	Property Line Setback	Adjacent Structure Setback	Prevailing Vegetation Type	Veg	
Specific	Veg Distance	Veg Condition	Access Grade	Access Width	
	Access One Way?	Access Dead End?	Access Turnaround?	Driveway Grade	
	Driveway Width	Driveway Vertical	Driveway Passing Lane?	Driveway	
Turnaround?	Wall Const.	Deck/Porch	Window Glass Type	Window Frame Type	Attic/ Subfloor
Vents	Skylight Present?	Skylight Surface Area	Skylight Type	Door: Sliding Glass Type	
	Door: French Type	Door: Other Type	Eave Const.	Overhang Width	
	Rain Gutter Construction	Address Present?	Visible from Road?	Contrasting?	
	Letter Height	Letter Width	Stroke Width	Greenbelt or Fuelbreak Present?	Fuelbreak Width
	Fuelbreak Length	Fuelbreak Observed	Effect Type	Type of Water Supply	Fire Sprinklers
Present?	Interior or Exterior	Sprinkler Type	Remarks	Observations	
	with Address and Damage info		Observations with GPS and Damage info		



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

str(L)

List of 3

\$ shp:List of 2

..\$ shp : num [1, 1:4] 1 309373 -549829 1

..\$- attr(\*, "dimnames")=List of 2

..\$ : NULL

..\$ : chr [1:4] "record" "x" "y" "shape.type"

..\$ header:List of 12

..\$ file.code : int 9994

..\$ file.length : int 64

..\$ file.version: int 1000

..\$ shape.type : int 1

..\$ xmin : num 309373

..\$ ymin : num -549829

..\$ xmax : num 309373

..\$ ymax : num -549829

..\$ zmin : num 0

..\$ zmax : num 0

..\$ mmin : num 0

..\$ mmax : num 0

\$ shx:List of 2

..\$ index : num [1, 1:2] 50 10

..\$- attr(\*, "dimnames")=List of 2

..\$ : NULL

..\$ : chr [1:2] "Offset" "Length"

..\$ header:List of 12

..\$ file.code : int 9994

## **Looking at the point process data.**

Unincorporated SD County + Scripps Ranch

Fire boundary

Locations (destroyed and not)

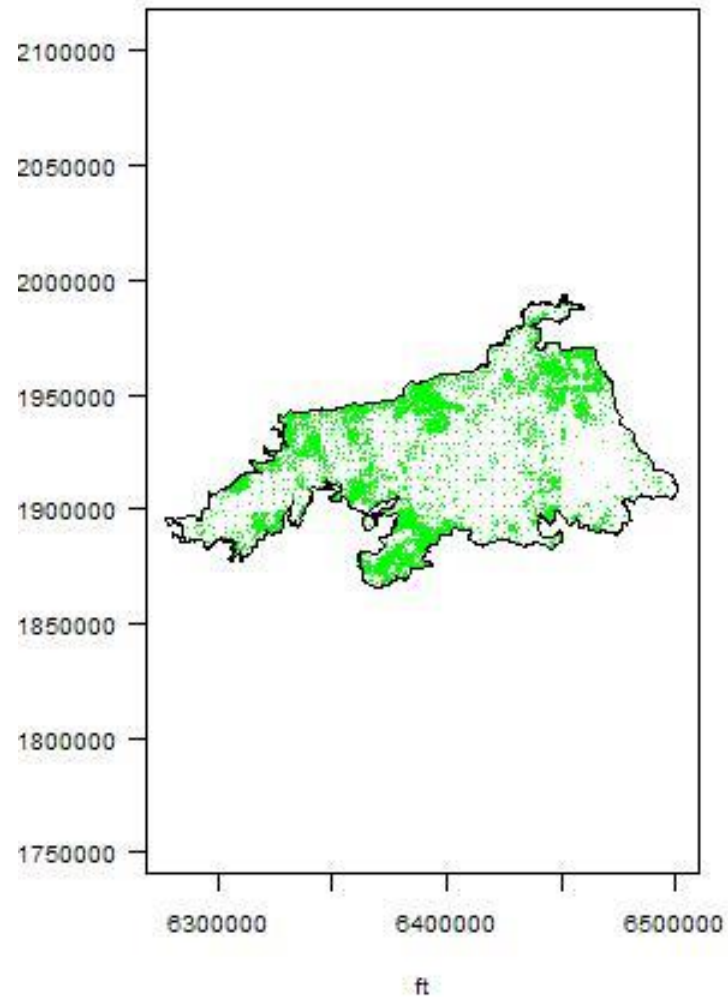
Rates/intensities and ratio



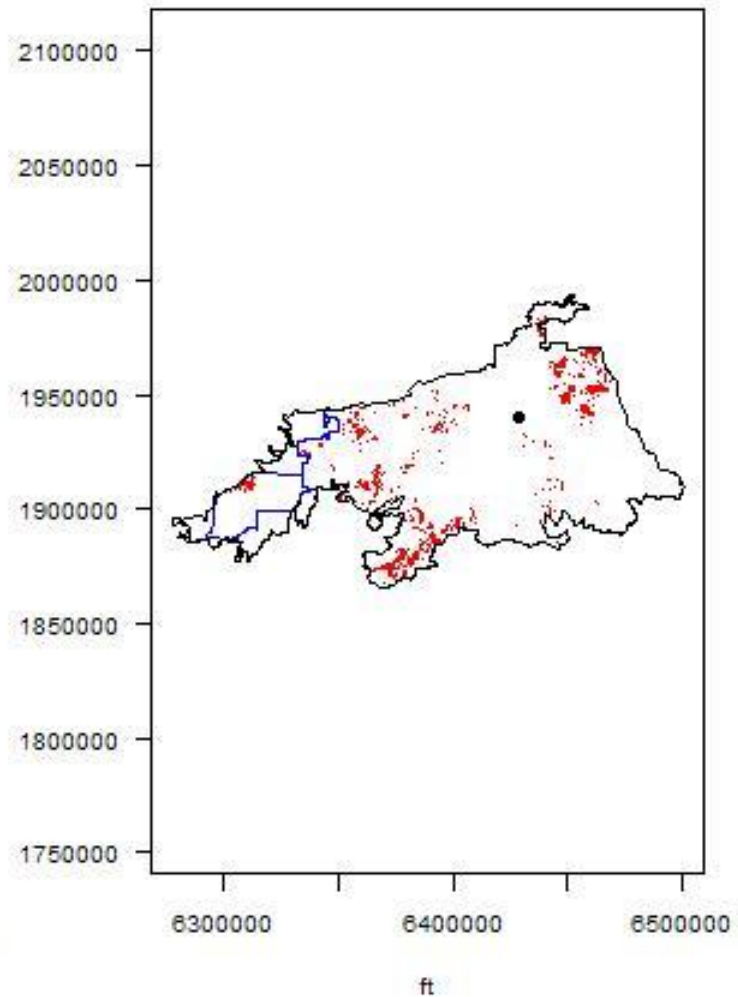




All Cedar houses prefire



Destroyed - unincorporated SD and Scripps Ranch



## Looking at the continuous data.

m.p.p. : area of house (square feet)

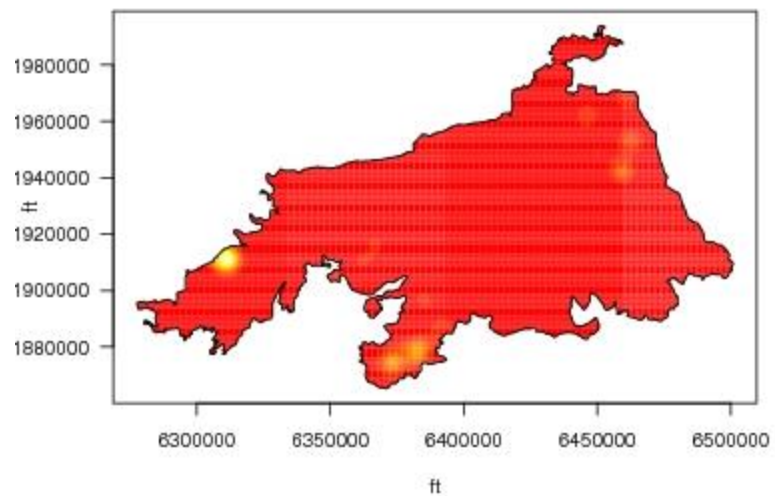
a cost proxy (\$150/sqft)

Smoothed sqrt(squared feet)

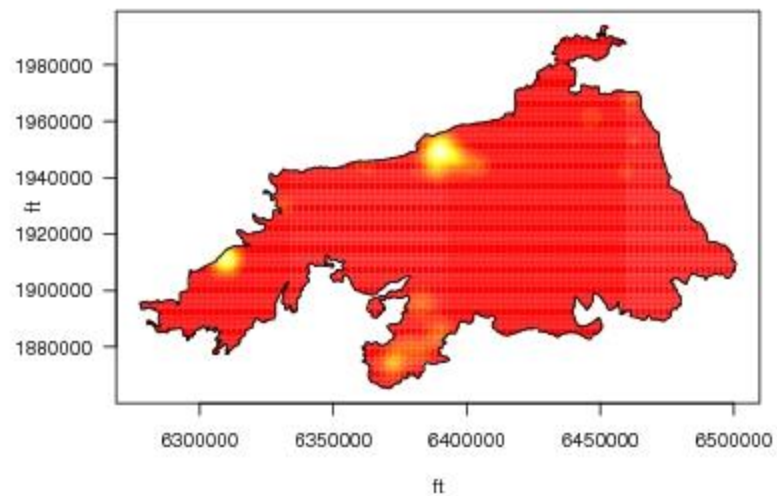
$$\sum Z_i K(x-x_i, y-y_i)$$

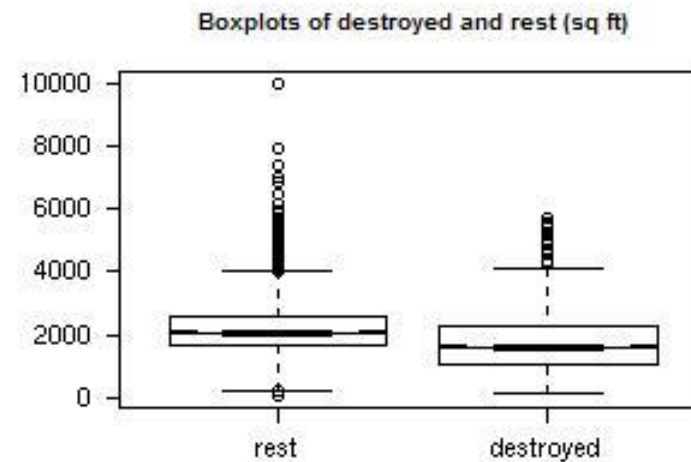
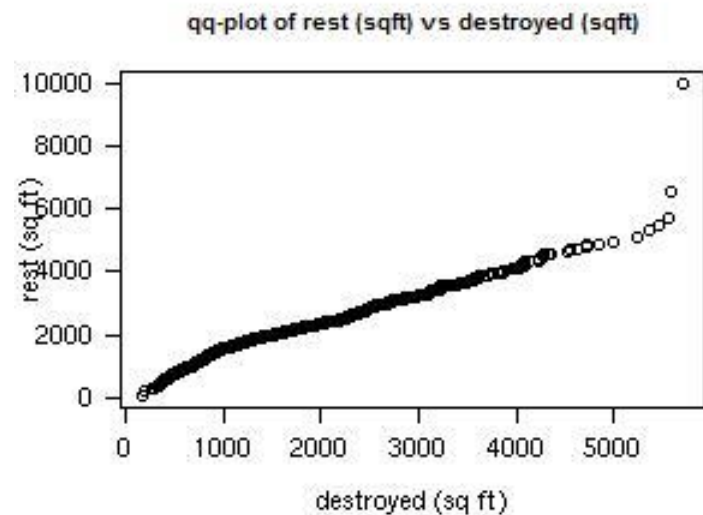
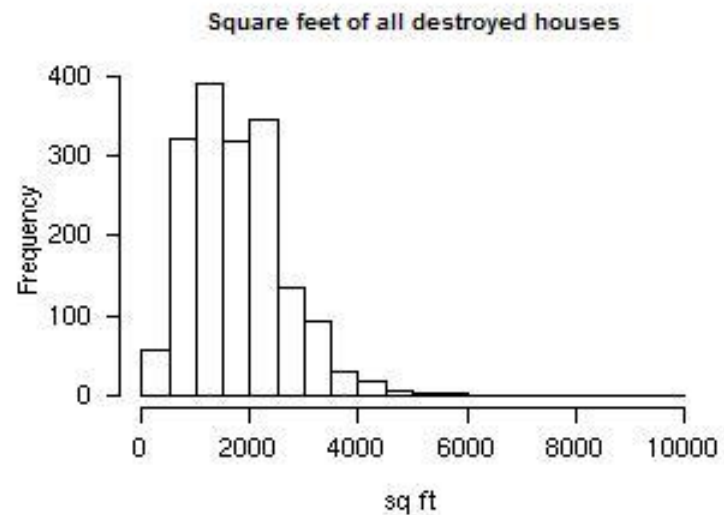
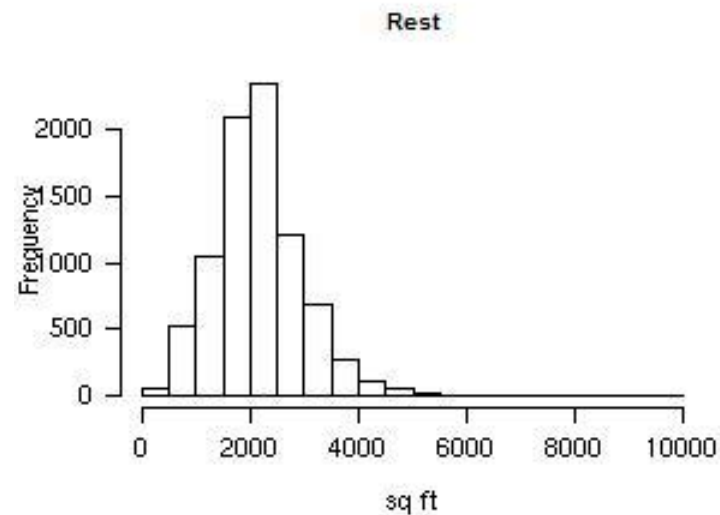
Some descriptive statistics

**Average sqrt(square feet) destroyed**



**Average sqrt(square feet) all houses**





**Inference results.** *Point process case.*

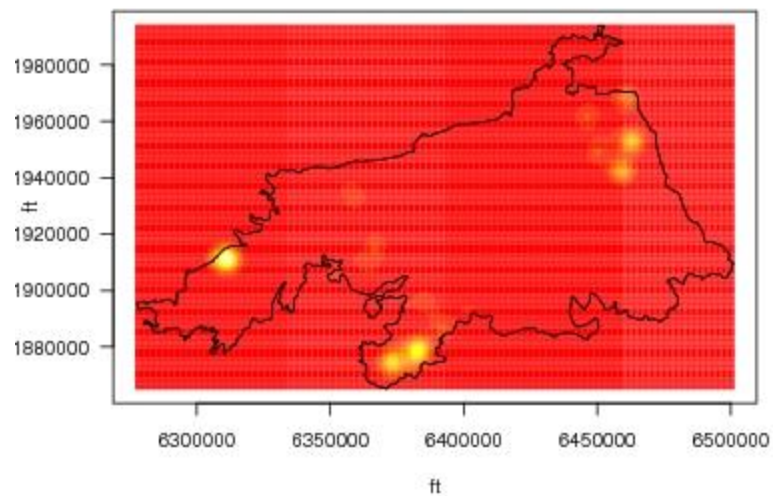
Intensity of houses at  $(x,y)$  initially  $\mu_X(x,y)$

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

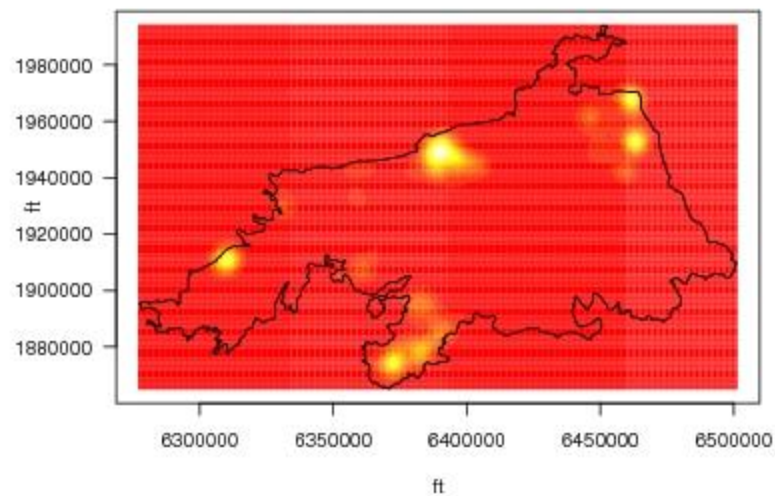
$$p(x,y) = \mu_Y(x,y) / \mu_X(x,y)$$

“probability” of a house’s destruction

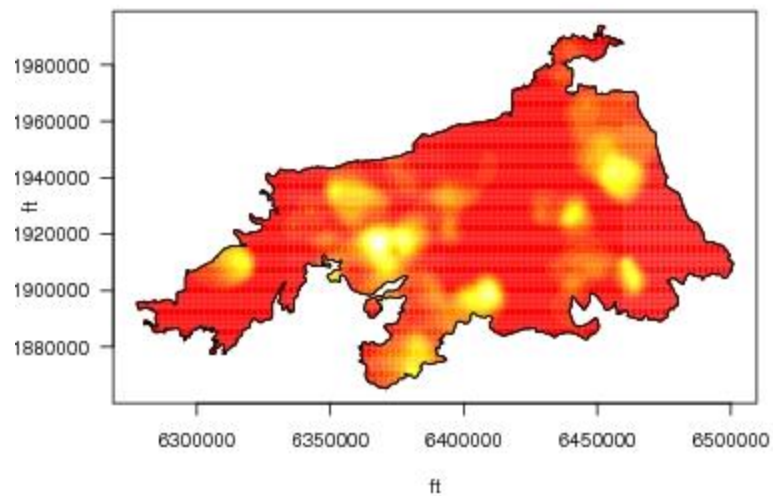
**Destroyed case**



**All houses**



**Ratio of intensities**



**Inference results.** *Continuous case.*

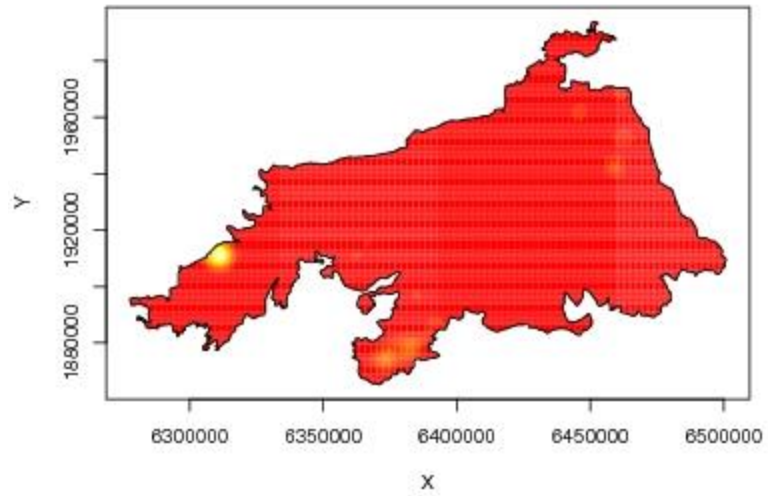
Square feet (from tax records)

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

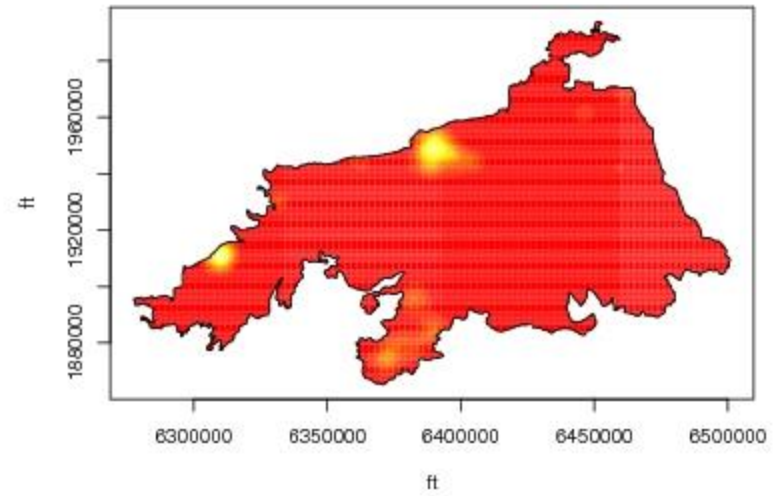
Estimate  $v_V(x,y)/v_U(x,y)$



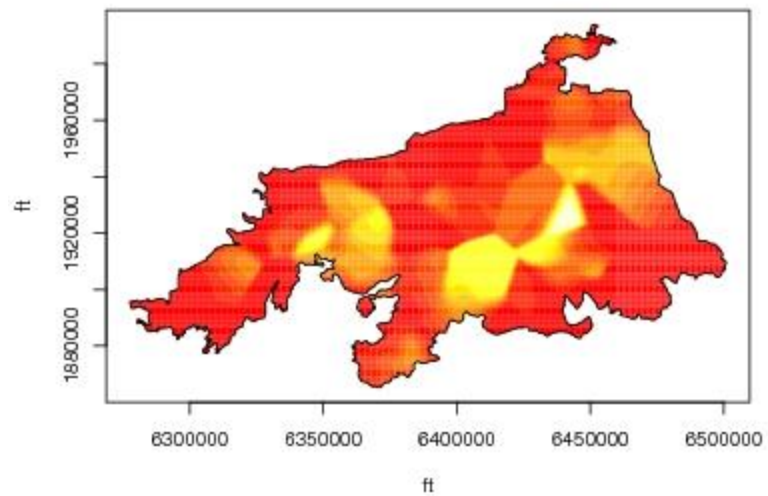
**Average square feet destroyed**



**Average square feet all houses**



**Ratio of averages**



Does size depend on location?

$$dN(x,y,z)/dxdydz = \sum \delta(x-x_i, y-y_i, z-z_i)$$

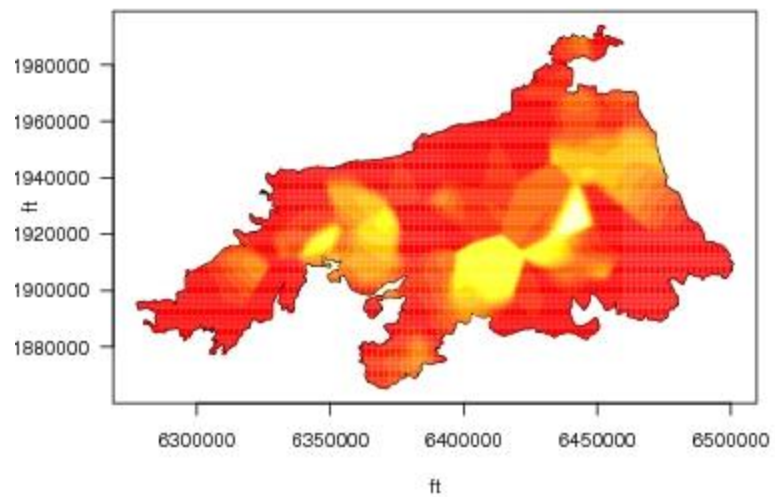
$$\sum z_i \delta(x-x_i, y-y_i, z-z_i)$$

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

$$\gamma(x,y,z) = \gamma_1(x,y) \gamma_2(z)$$

Consider  $\gamma(x,y,z)/\gamma_1(x,y)$

Ratio m.p.p. intensity to p.p. intensity



*Explanatories.*

Vegetation type (15 categories)

Slope

Assessed improvement value

Destroyed

Structure location

Square feet














...



2003  
So Cal Fires  
Cedar

October 2003

**Pre-Fire Vegeta**

-  Agriculture
-  Chaparral
-  Coastal Sage Scrub
-  Coastal Sage/Chaparral S
-  Developed
-  Disturbed
-  Eucalyptus Woodland
-  Forest
-  Grasslands/Meadows/Ver
-  Open Water
-  Riparian
-  Unvegetated
-  Scrub
-  Woodland
-  Fire Perimeter

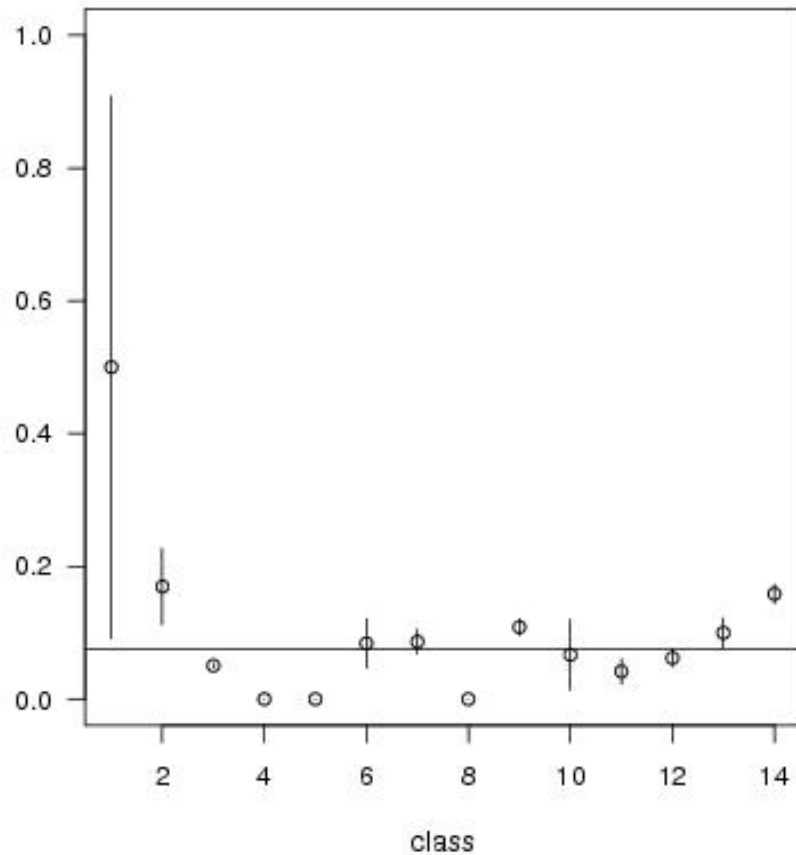


The data represented in this map were gathered from maps and aerial photography which may vary in accuracy, scale and date. This map is for informational purposes only and not an official declaration of boundaries or ownership.





**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.

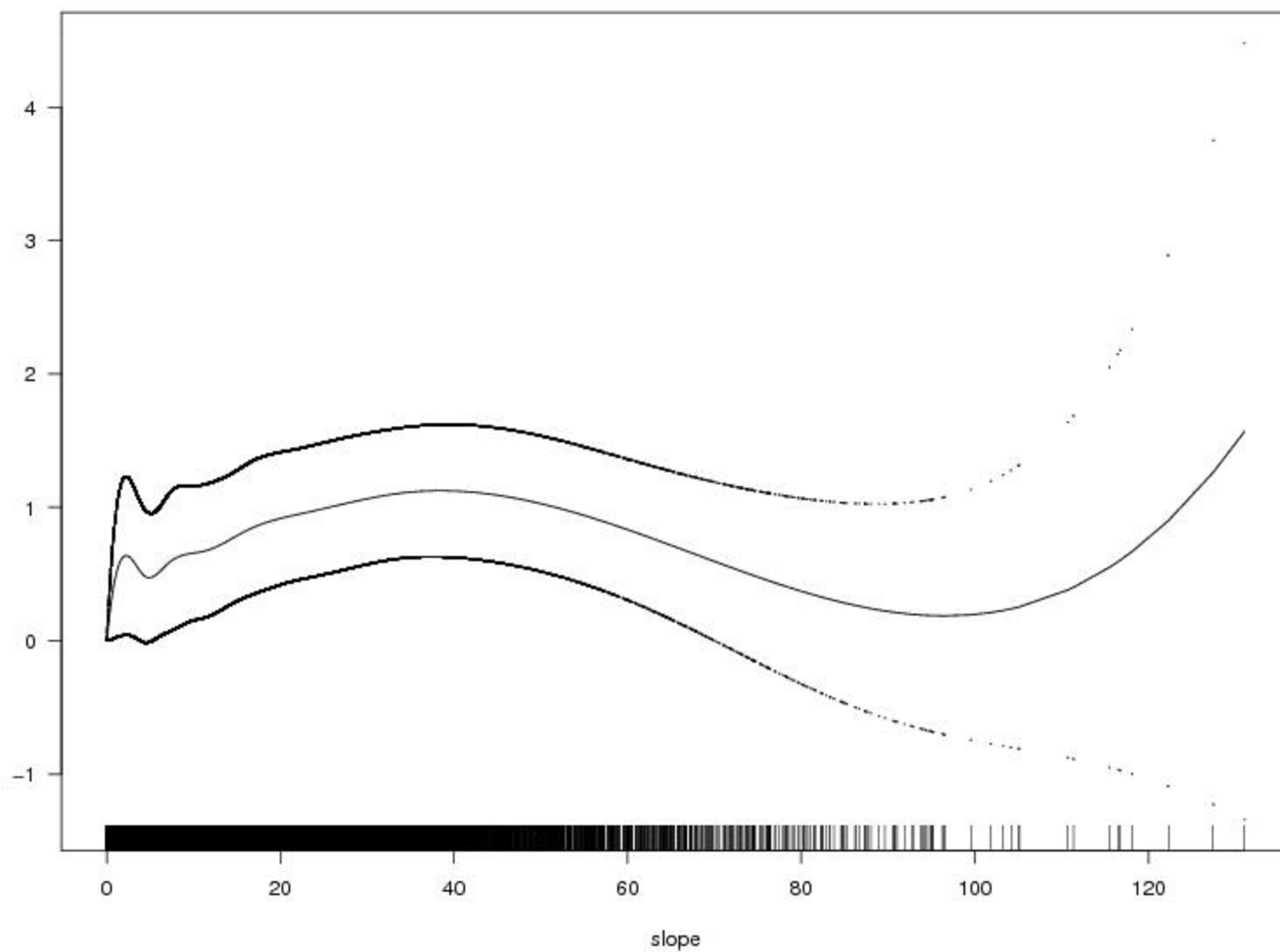
Logit{Prob[destroyed|explanatories]}

=  $\gamma(s)$  with  $s$  slope

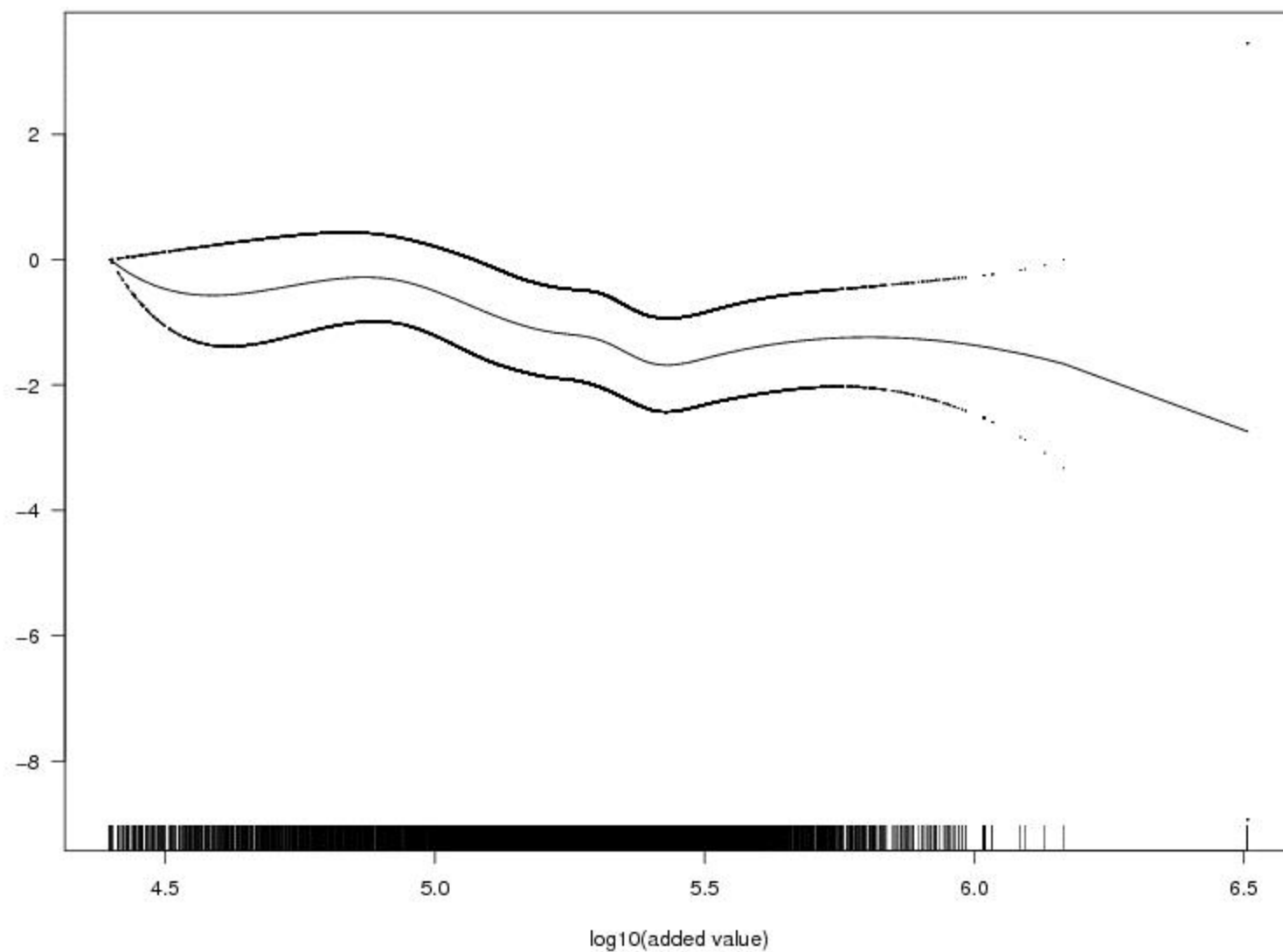
$\gamma$  smooth



Estimated re-expression of slope



Estimated re-expression of assessed Improvement value



## **Spatial-temporal results.**

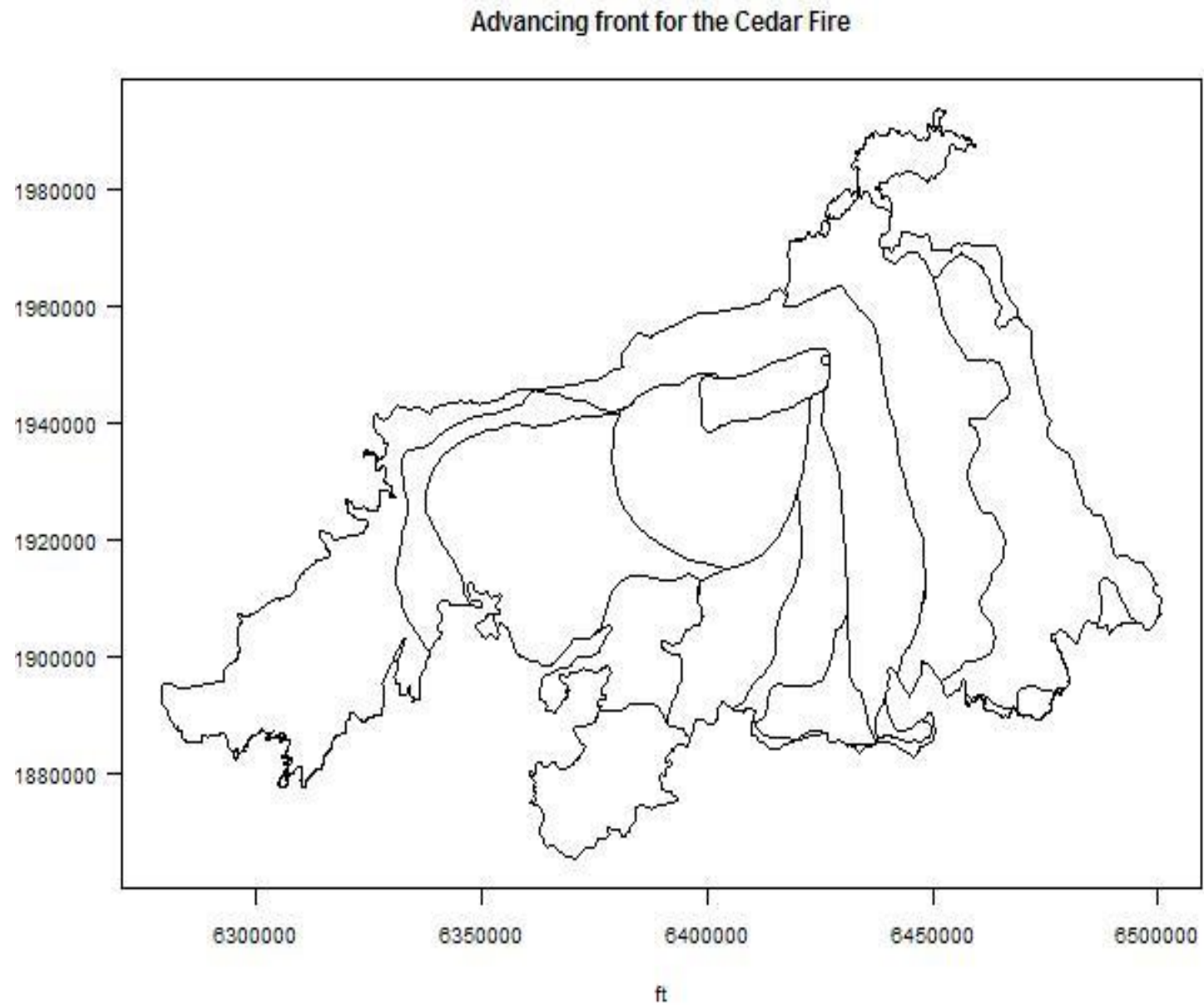
polygons

wavefront

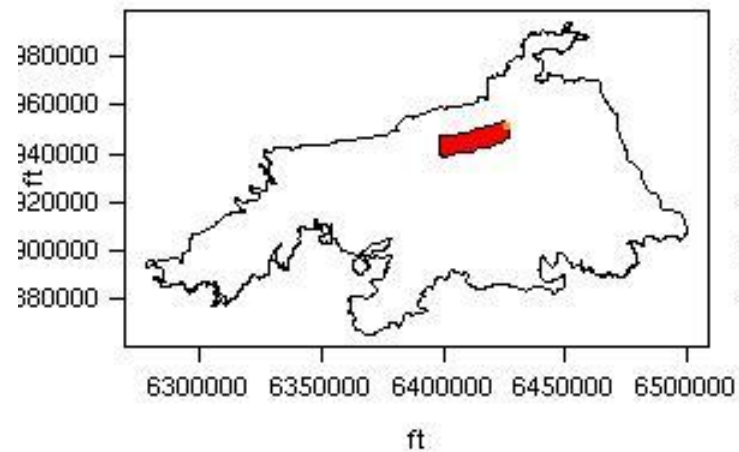
How quantities in polygons depend on time

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

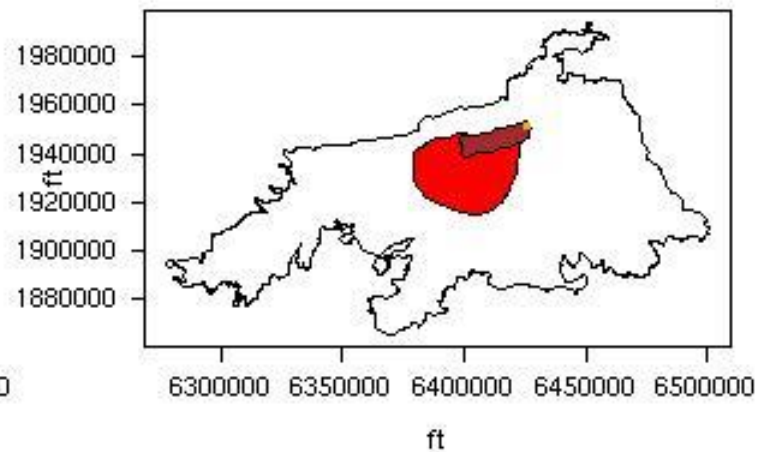
## Observed fire boundaries



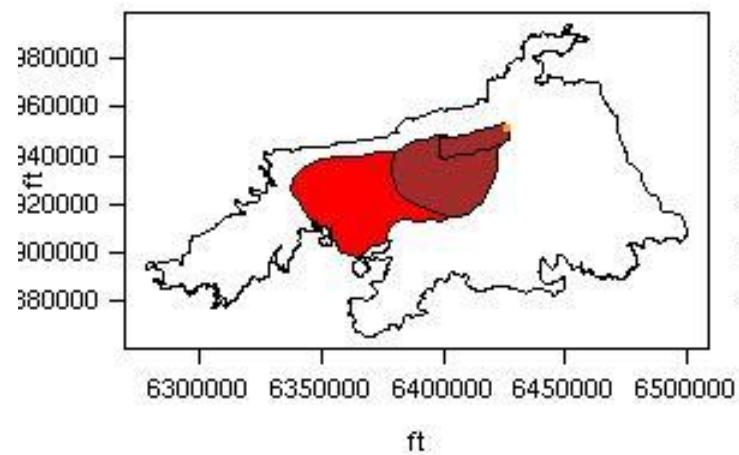
10-25 2400



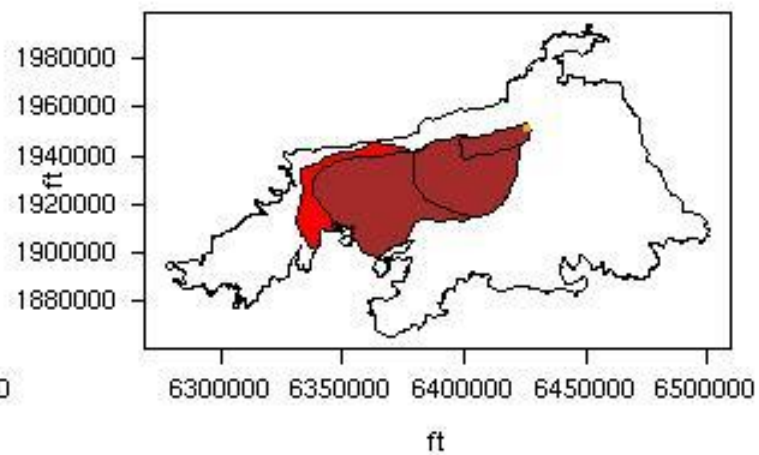
10-26 0200



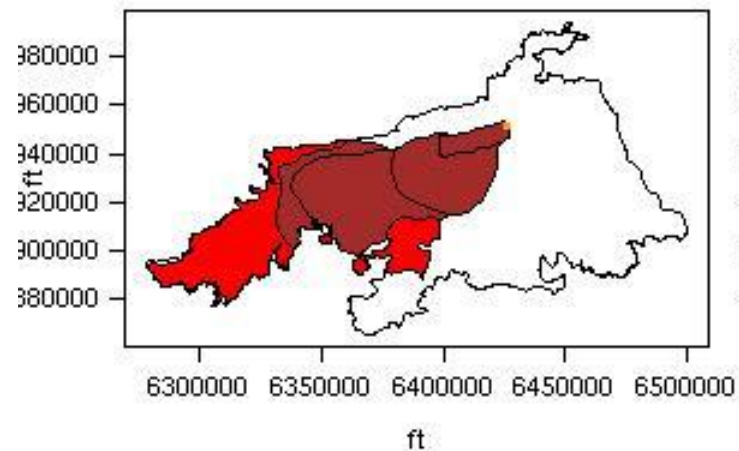
10-26 0300



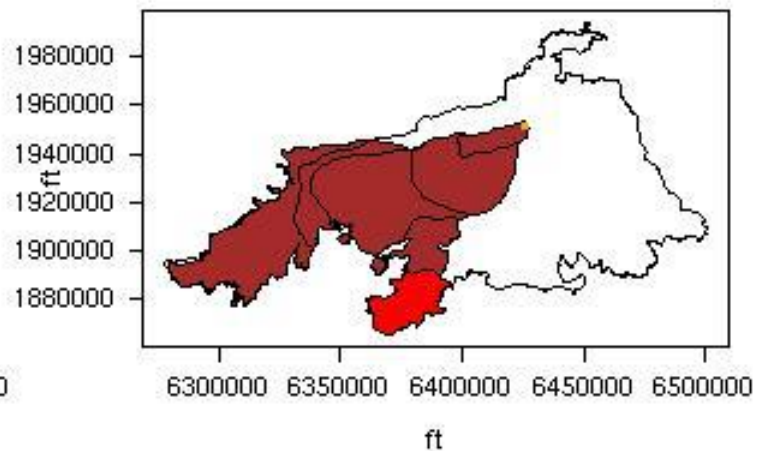
10-26 0600



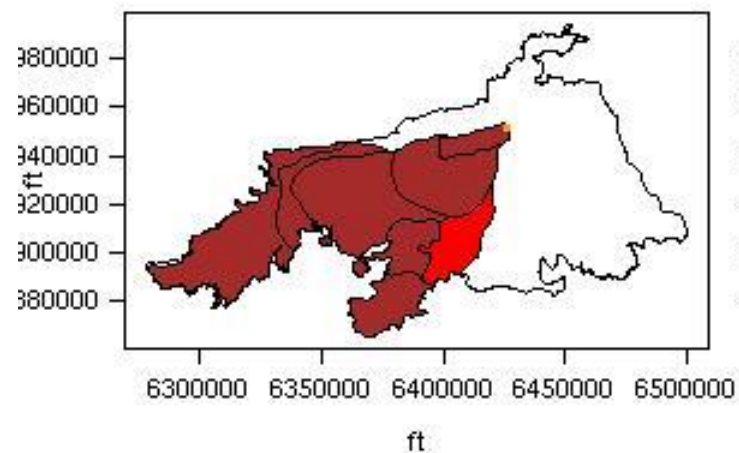
10-26 1000



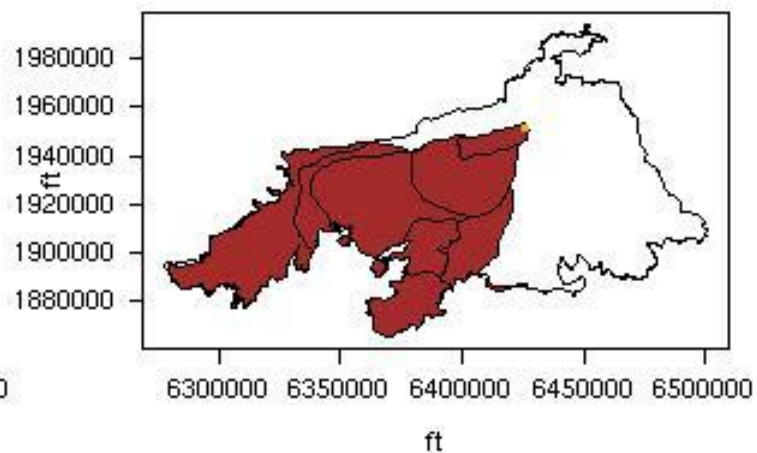
10-26 1900



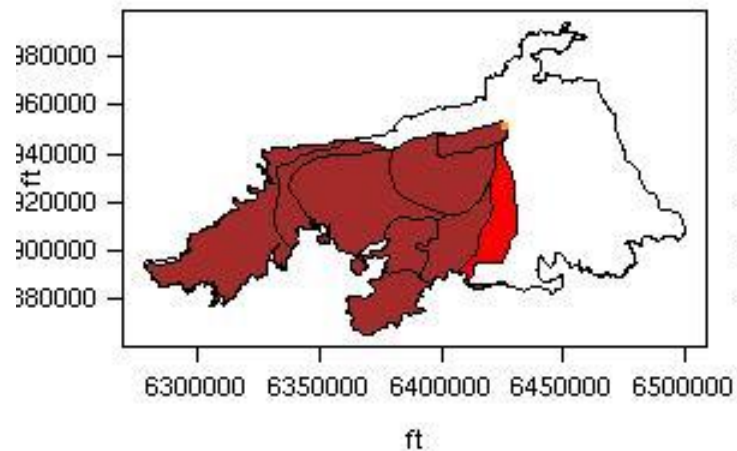
10-26 2100



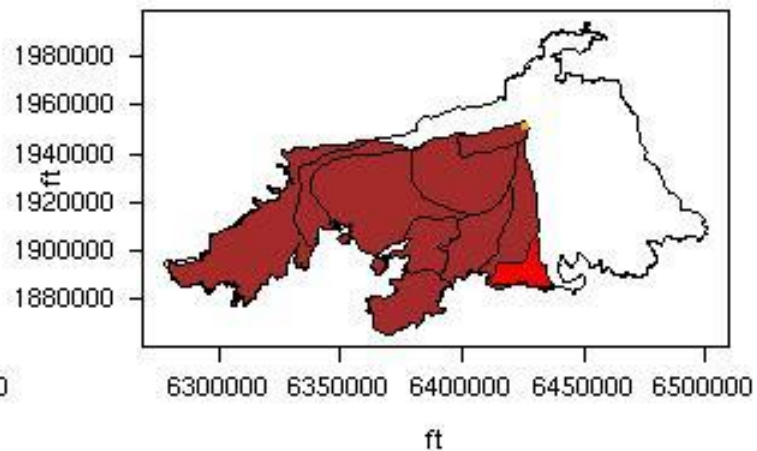
10-26 2200



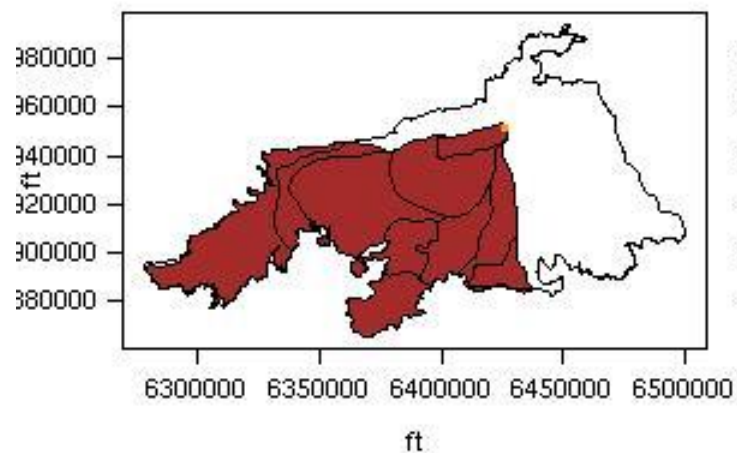
10-26 2400



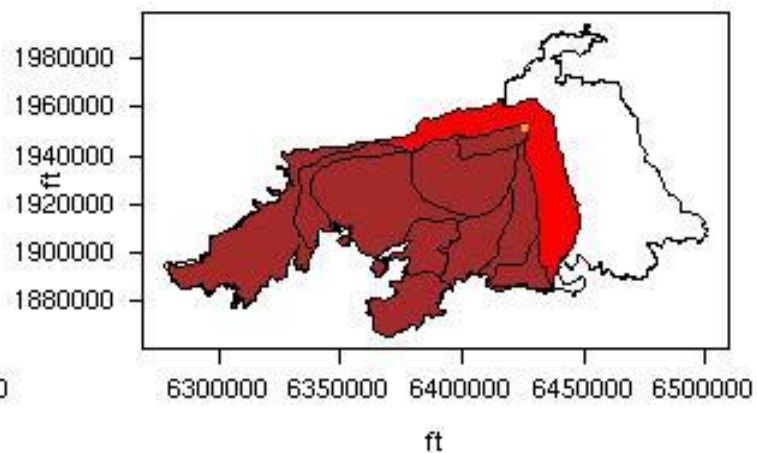
10-27 0600



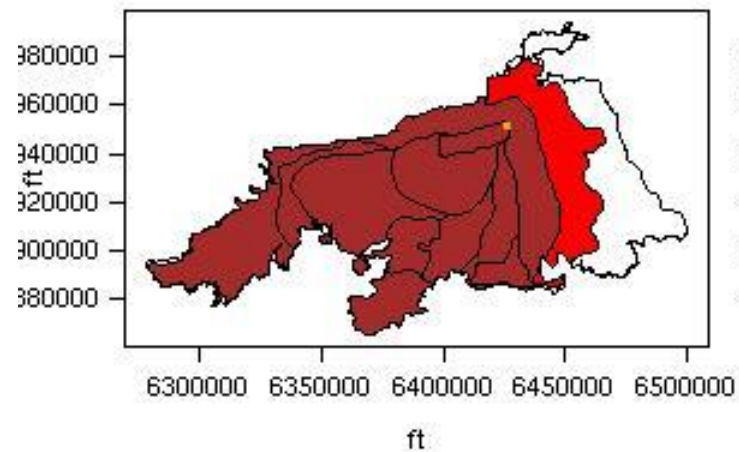
10-27 0900



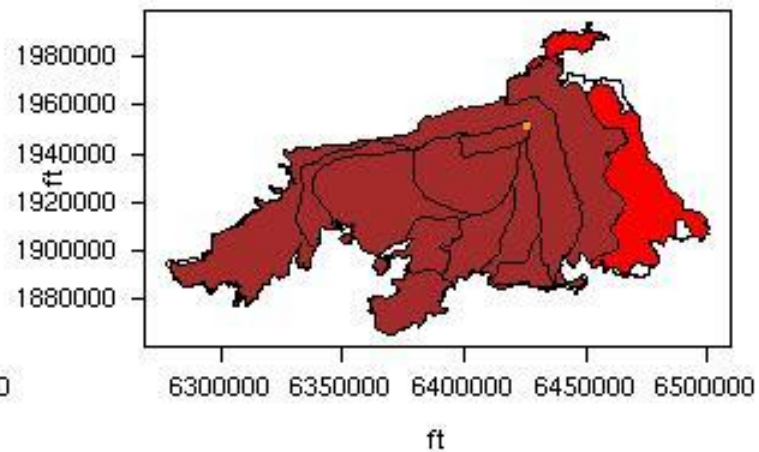
10-27 2200



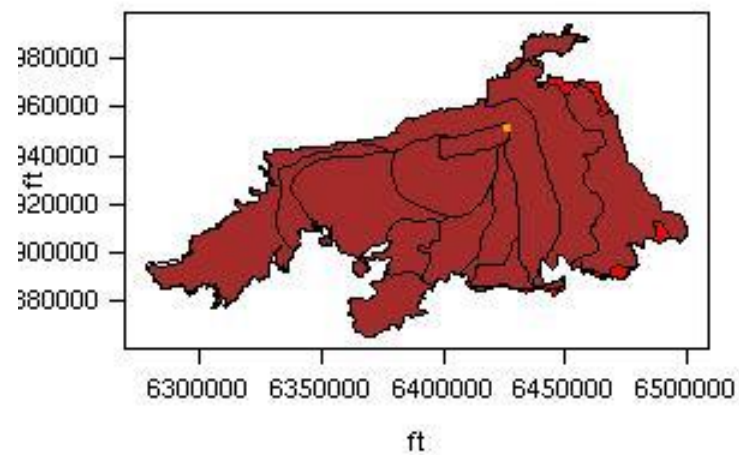
10-28 1600



10-29 1900

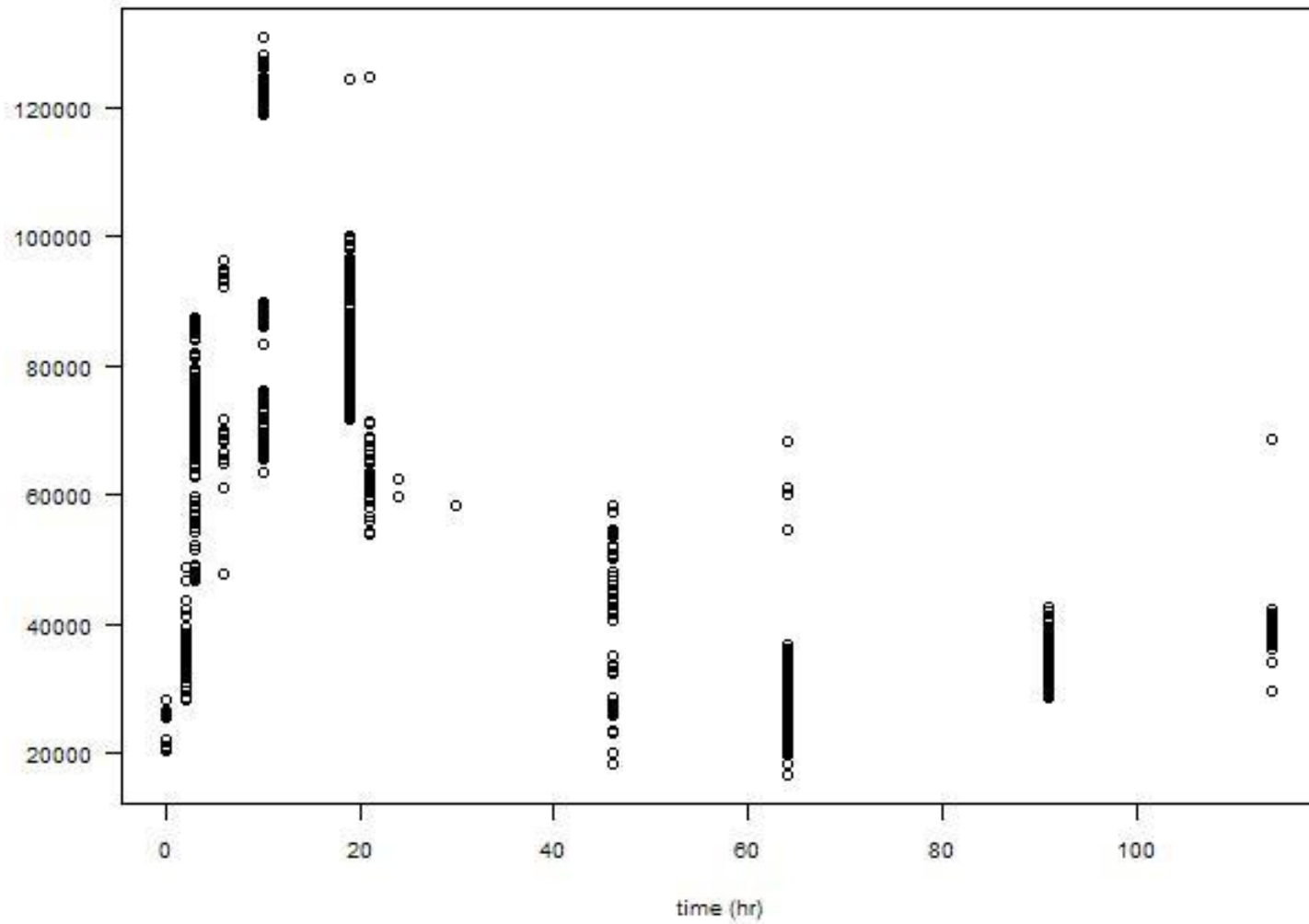


10-30 1800

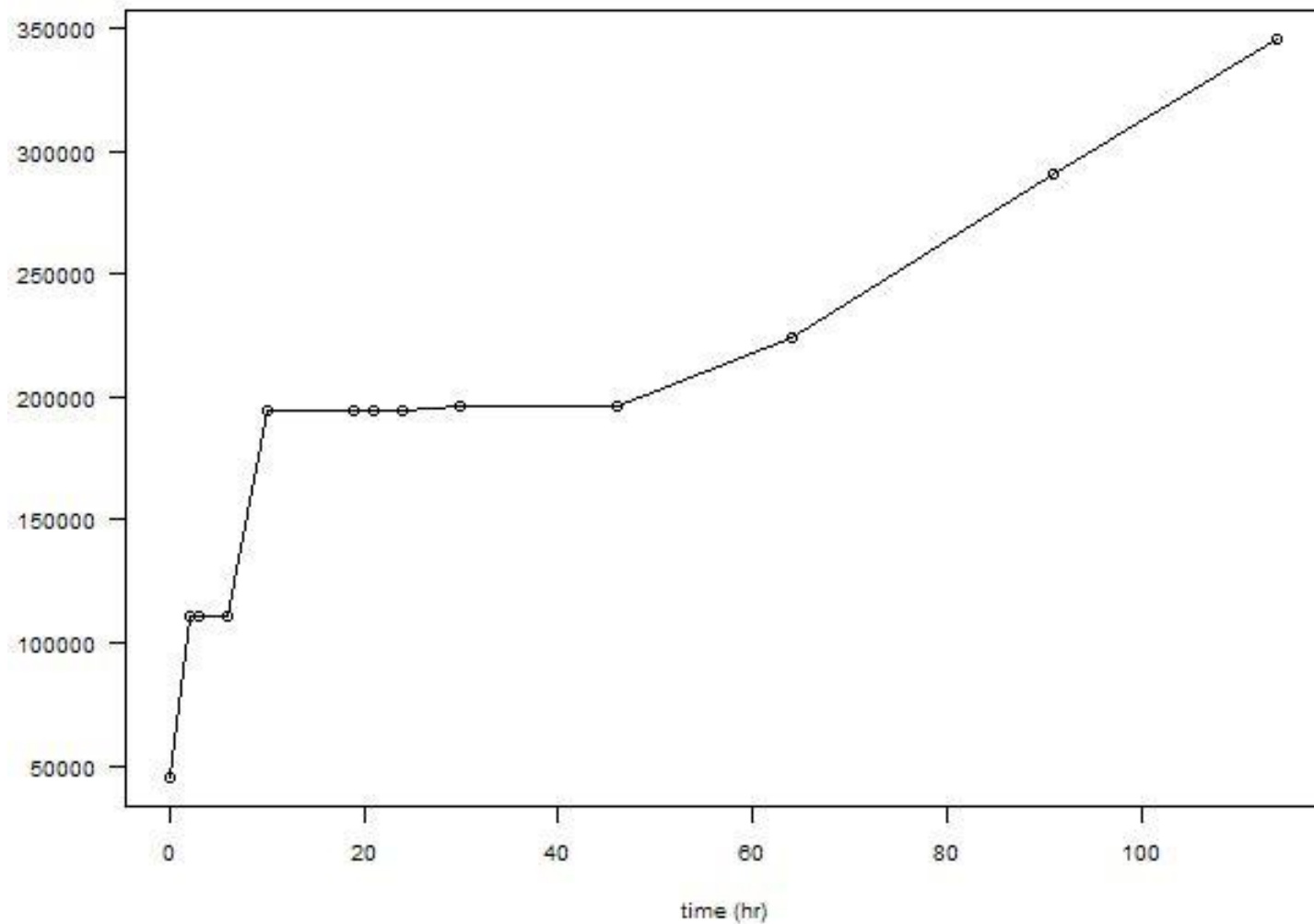




### Distance from source vs. time



Cumulative loss (sq ft)



## 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

# Social cost - loss of Chaparral

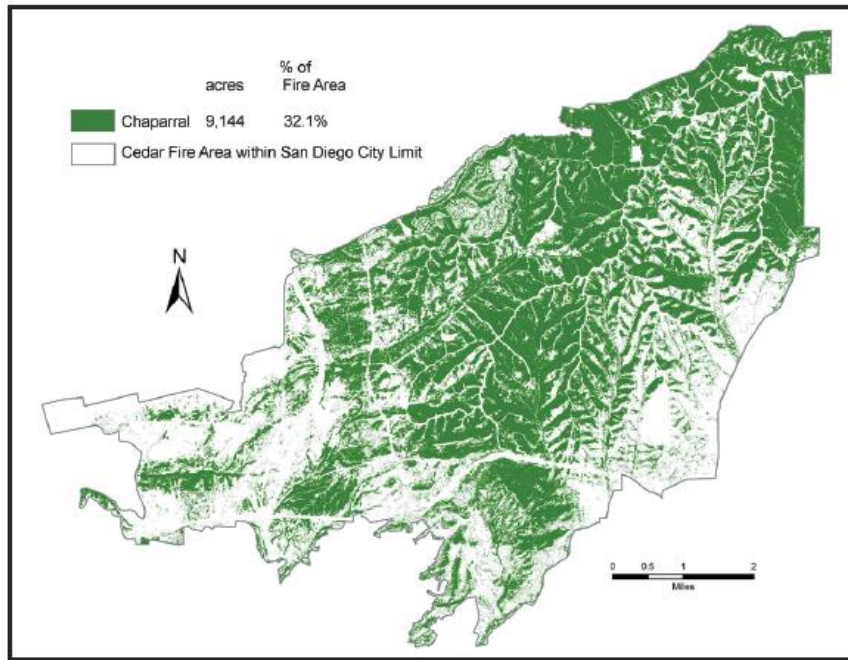


Figure 2: Chaparral coverage in the Cedar Fire - pre fire 2002

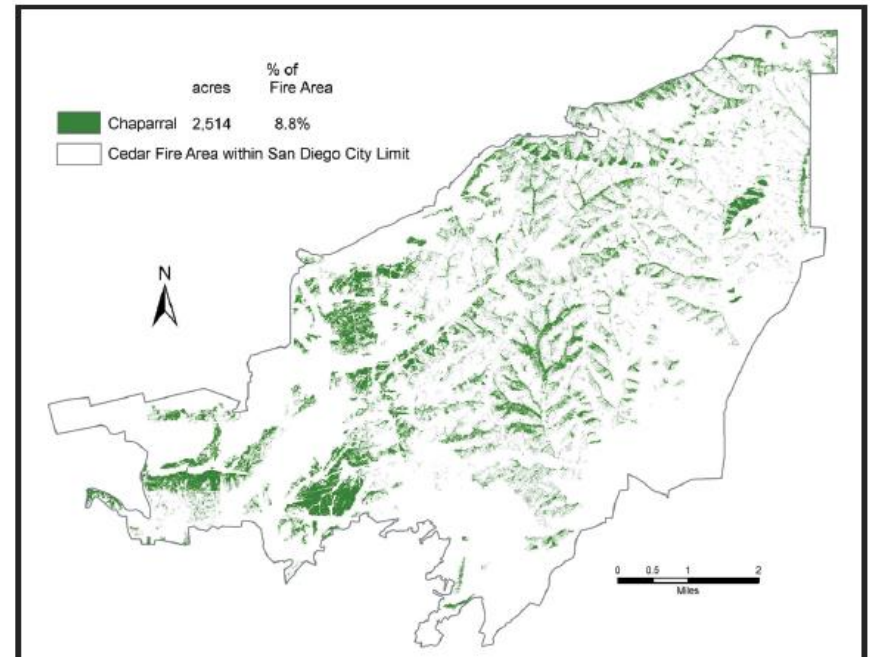
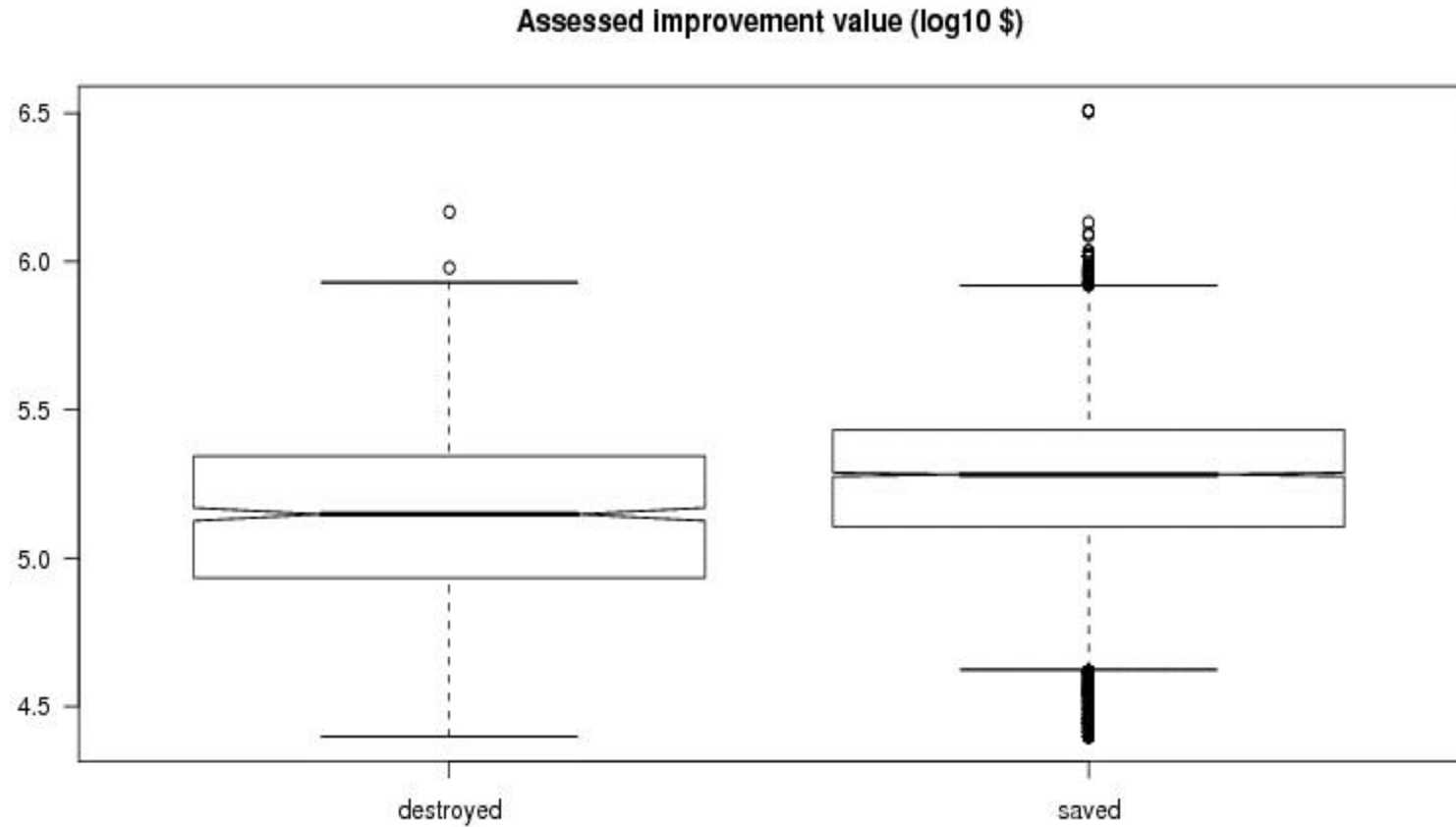


Figure 3: Chaparral coverage in the Cedar Fire - post fire 2004

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 assesment 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,  
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A. Ager (USFS), J. Benoit (USFS), C. Hunter  
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County), M-H. Tsou (SDSU), D. Gilmore (SD  
County),...