Predicting spatial ignitions patterns of ignitions in Mediterranean ecosystems of southern California

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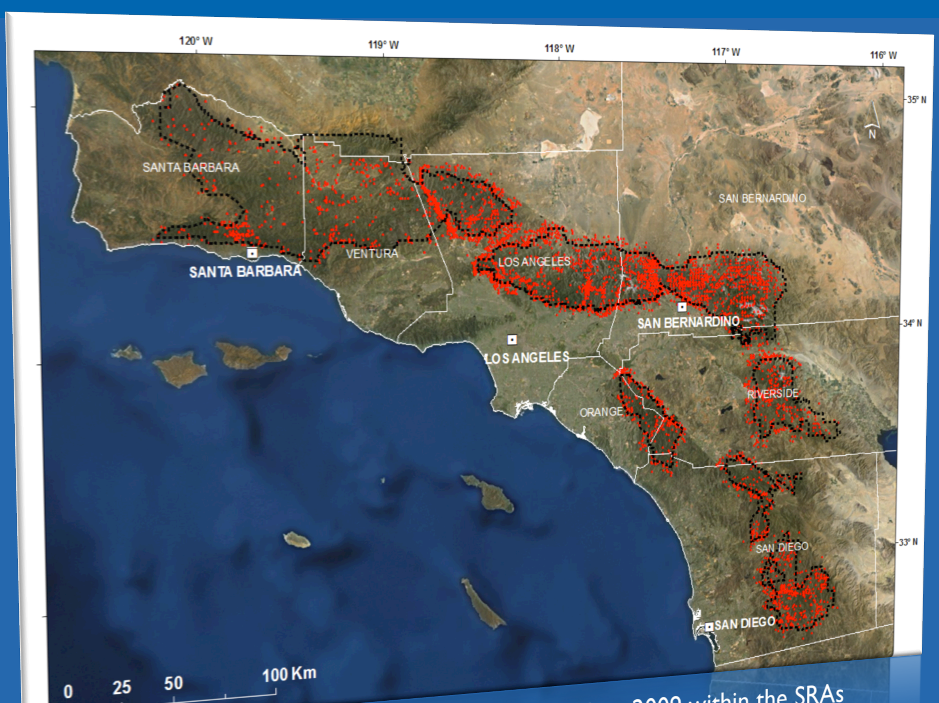
Introduction

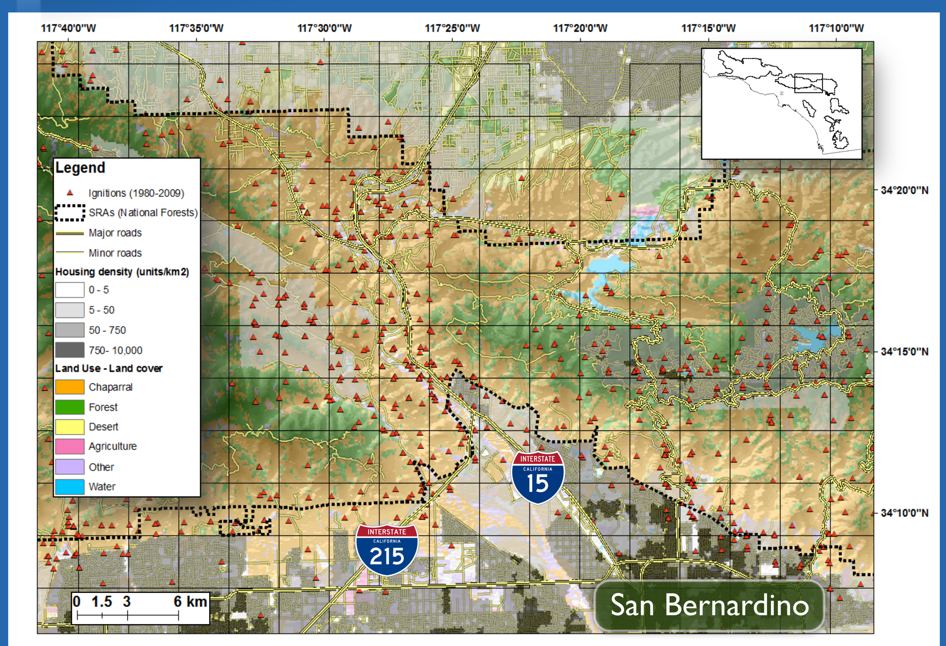

Arson-caused Santiago Fire burned 28,000 acres in Orange county (*Photo by Jebb Harris*, 2007)

Fire is a natural process regulated by different environmental controls and ignition agents. Mediterranean ecosystems are subject to constant change as the human footprint on landscapes, climate and natural disturbances increases. Since 1980, fire ignitions in southern California have exceeded their historical range of variability due to increasing human population and territorial expansion of metropolitan areas. $105 billion of property is currently located in areas of high wildfire risk. Understanding of how fire ignitions are spatially distributed and how they are affected by human and biophysical factors is becoming critical to identify values at risk and implement prevention and suppression fire management strategies.


Destroyed housing in San Diego County following the Rice Fire (*ImageCat*, 2007)

Modeling fire risk in southern California


Wildfire ignitions recorded from 1980 to 2009 within the SRAs



3km grid framework used to summarize ignition records and associated predictors

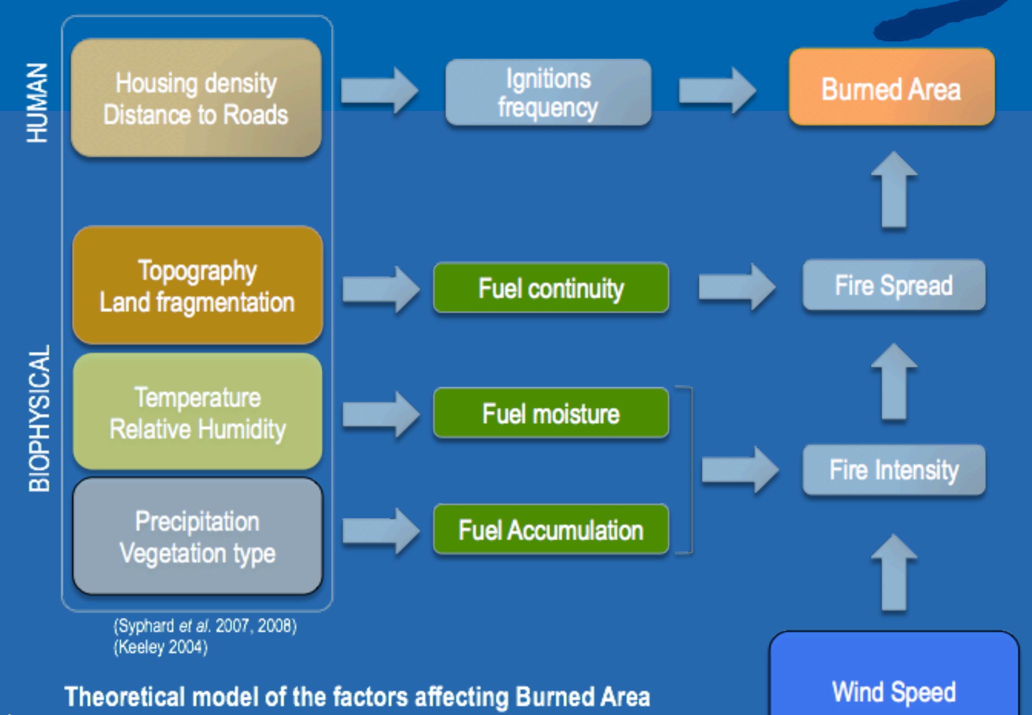
Current fire risk models use hydroclimate and biophysical factors as explanatory variables but much less is known about how human activity controls the spatial patterns of fire ignitions. The multiple ways human impact fire regimes (e.g., ignition sources, fire suppression) makes the prediction of fire risk highly challenging in southern California. Our research goal is to determine which factors dominate and to predict their combined influence on fire activity.

Data & Methods

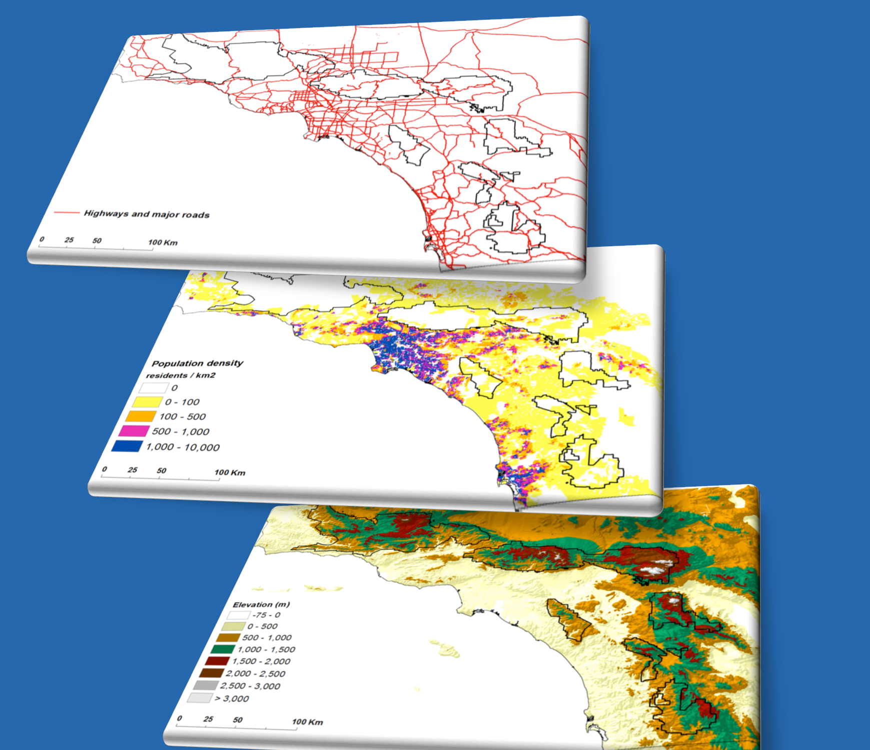
We characterized ignitions patterns from 1980 to 2009 (FIRESTAT database) within a 3x3km grid mesh that overlaid the State Responsibility Areas (National forests).

We performed a spatial regression analysis of this temporal sequence using human variables: *distance to major/minor roads, roads density, distance to housing, population density* and biophysical variables: *elevation, slope, south-westness, vegetation type cover, temperature and precipitation*.

We then quantified the influence of explanatory variables on ignition occurrence and frequency using logistic and Poisson regression methods. We further improved the modeling approach and used the most significant explanatory variables to produce predictive maps of ignition frequency for southern California.

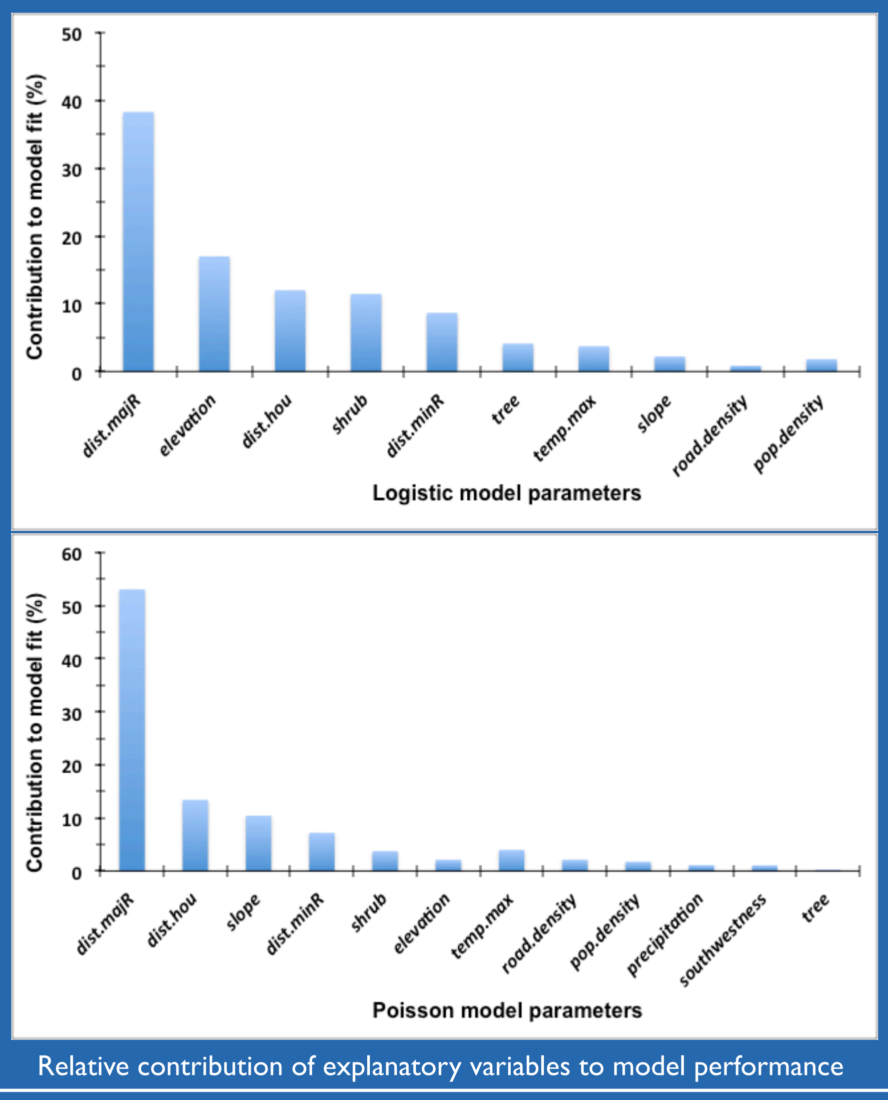


Theoretical model of the factors affecting Burned Area
adapted from Archibald et al. (2009)


Spatial influence of several human and biophysical drivers

Controls of fire ignitions in southern California

Ignition occurrence vs. ignition frequency

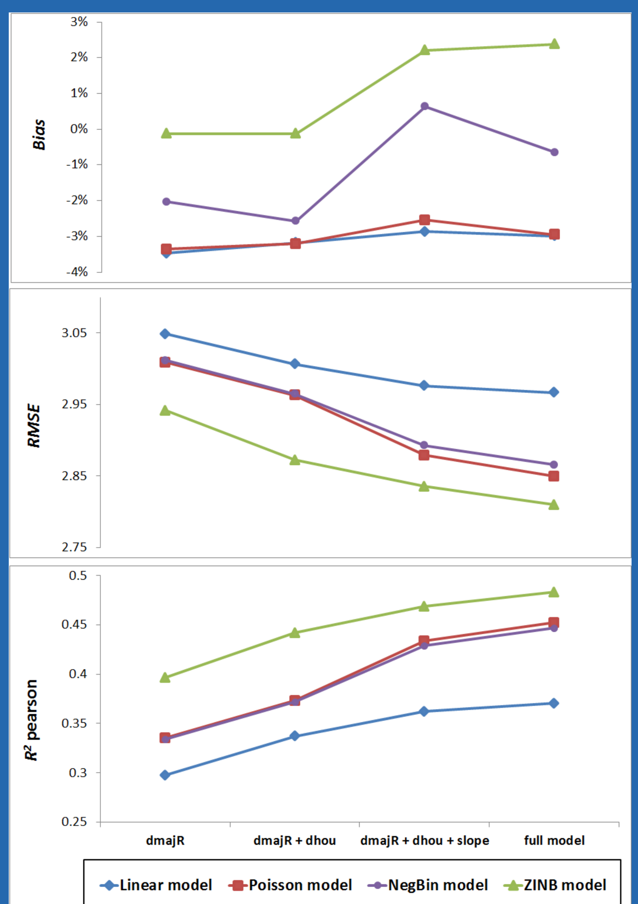


Relative contribution of explanatory variables to model performance

- Proximity to urban areas and to transportation network were predominant in controlling ignition patterns: ≥ 60% of ignitions were located within 1km distance from roads and 5 km from housing.
- The variables d_{MajR}, *elevation*, d_{Hou}, *shrub* and d_{minR} explained 87% of the variance in ignition occurrence.
- Logistic model correctly predicted 67% of observed ignitions (AUC= 0.721)

- Ignition frequency decreased exponentially with increasing distance to roads and housing development.
- The variables d_{MajR}, d_{Hou}, slope and d_{minR} explained 85% of the variance in ignition frequency and were used for further model improvement.

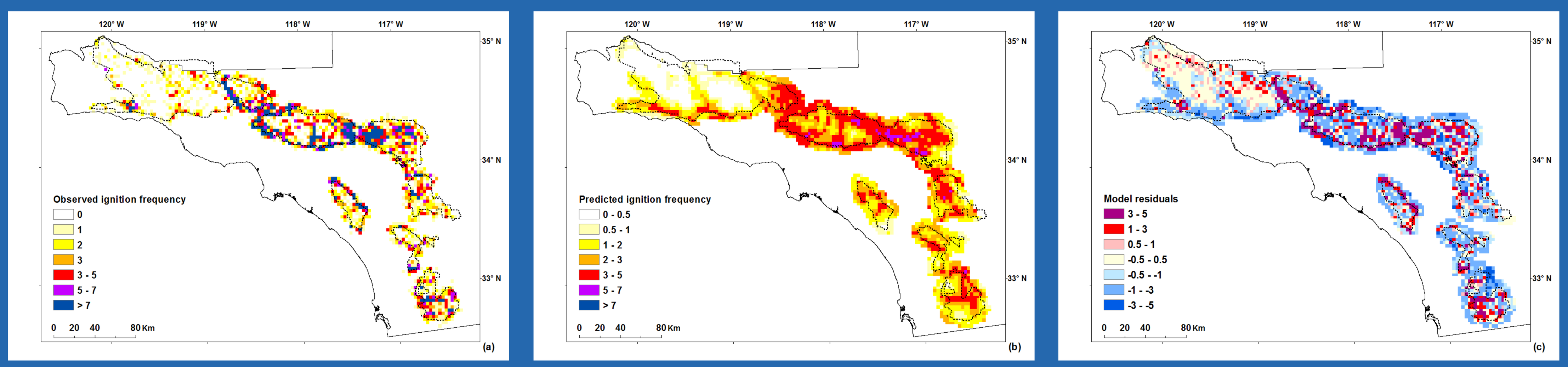
Comparison of fire frequency models



Model predictors	Linear Model	General Linear Models: Poisson	General Linear Models: Negative Binomial	Zero Inflated Negative Binomial
(Intercept)	2.10 ± 0.06	1.00 ± 0.03	0.97 ± 0.07	1.28 ± 0.07
dist. majRoads	-0.83 ± 0.08	-0.14 ± 0.007	-0.11 ± 0.01	-0.12 ± 0.01
dist. housing	-0.49 ± 0.07	-0.04 ± 0.003	-0.04 ± 0.004	-0.04 ± 0.005
slope	0.58 ± 0.07	0.03 ± 0.001	0.03 ± 0.003	0.02 ± 0.003
dist. minRoads	-0.28 ± 0.09	-0.28 ± 0.03	-0.25 ± 0.04	-0.26 ± 0.04
(Intercept)				4.82 ± 1.57
elevation				0.003 ± 0.001
Shrub				-3.31 ± 0.83
Temp. min.				-0.24 ± 0.12
Precipitation				-1.93 ± 1.30
Deg. of freedom	5	5	6	10
log Likelihood	-5322.3	-4120.7	-3223.4	-3173.2
AIC criterion	10656.7	8251.4	6446.7	6368.4
Dispersion φ	-	3.43	0.78	1.08

ZINB regression model showed better performance with highest R^2, lowest standard error and reduced bias. The model was found adequate to capture both overdispersion and zeroes excess of the dataset.

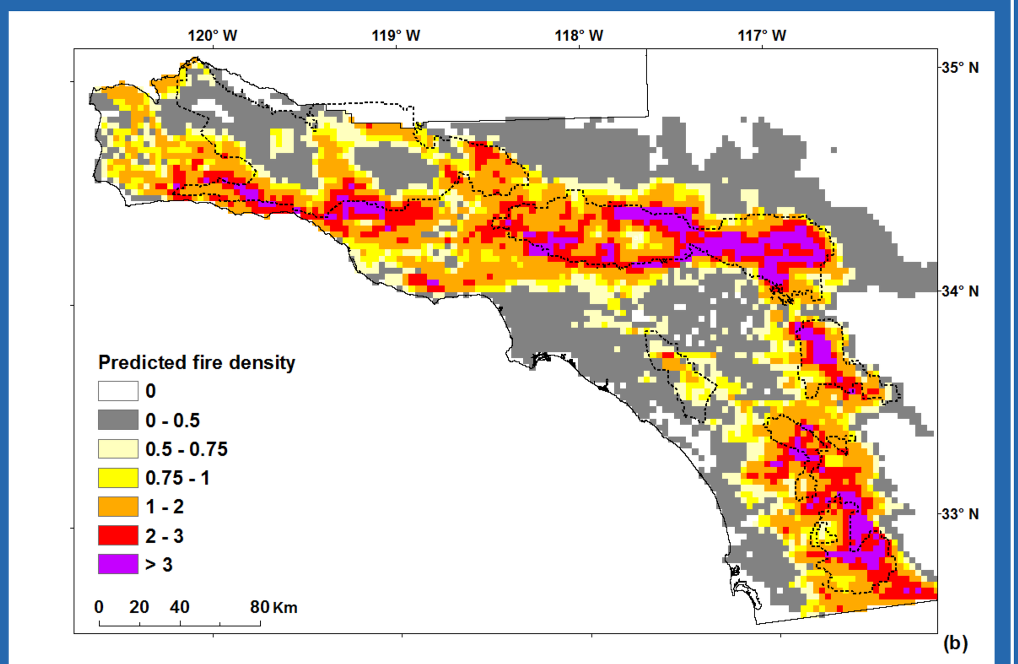
Predictive mapping of fire risk in southern California



i) Predictive maps produced for the SRAs are synthetic measures of the pattern in fire likelihood for the current state of the landscape.

- Maps showed that the ZINB model successfully captured the clustering of ignitions around urban development and transportation axes (Fig. a, b).
- However, contrasting human influences related to housing patterns or traffic volumes are partly responsible for model underestimates (Fig. c).

ii) predictions for the entire region successfully explained 41% of the variability in burned area perimeters, suggesting external influence of other factors but also that areas with a high potential ignition risk have not necessarily burned recently.



This study offers a first regional-scale assessment of wildfire ignition risk for southern California.

- useful tool to infer ignitions probabilities where no records are available
- applications in other Mediterranean areas under intense human pressure
- implications for wildfire risk mitigation and conservation management

Acknowledgements

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