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Research paper

Can private land conservation reduce wildfire risk to homes? A case study in San Diego County, California, USA

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HIGHLIGHTS

- Private land conservation can help to mitigate fire risk.
- The impact is maximized if high fire areas are targeted.
- Impacts are heterogeneous at the municipal scale.

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ABSTRACT

The purchase of private land for conservation purposes is a common way to prevent the exploitation of sensitive ecological areas. However, private land conservation can also provide other benefits, one of these being natural hazard reduction. Here, we investigated the impacts of private land conservation on fire risk to homes in San Diego County, California. We coupled an econometric land use change model with a model that estimates the probability of house loss due to fire in order to compare fire risk at the county and municipality scale under alternative private land purchasing schemes and over a 20 year time horizon. We found that conservation purchases could reduce fire risk on this landscape, and the amount of risk reduction was related to the targeting approach used to choose which parcels were conserved. Conservation land purchases that targeted parcels designated as high fire hazard resulted in lower fire risk to homes than purchases that targeted low costs or high likelihood to subdivide. This result was driven by (1) preventing home placement in fire prone areas and (2) taking land off the market, and hence increasing development densities in other areas. These results raise the possibility that resource conservation and fire hazard reduction may benefit from combining efforts. With adequate planning, future conservation purchases could have synergistic effects beyond just protecting ecologically sensitive areas.

1. Introduction

The purchase of private land for conservation purposes is one of the most common means of protecting sensitive ecological resources and preserving open space worldwide (Davies, Kareiva, & Armsworth, 2010; Fishburn, Kareiva, Gaston, & Armsworth, 2009). The massive land holdings (fee title and easements) of national and local land trusts now cover more than 20 million ha in the United States alone (Land Trust Alliance, 2011). Most often, private land conservation is justified as a means to preserve biodiversity, scenic beauty, or open space (Merenlender, Huntsinger, Guthey, & Fairfax, 2004; Rissman & Merenlender, 2008; Wallace, Theobald, Ernst, & King, 2008).

Beyond biodiversity protection and scenic values, open spaces provide additional benefits. For example, increased property values (Fausold & Lilieholm, 1999; Geoghegan, 2002), economic growth (Lewis, Hunt, & Plantinga, 2002), and the provision of ecosystem services (Goldman & Tallis, 2009) have all been correlated with the presence of conserved lands in a community. In addition, conserved lands can reduce the human impact of natural hazards such

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as floods, hurricanes, and potentially wildfires (Bihari, Hamin, & Ryan, 2012; Daniels, 2005; Schmidt, Moore, & Alber, 2014; Tang, 2008). While these benefits are acknowledged by scientists and practitioners alike, the potential benefit of hazard reduction is less commonly used to drive private land conservation decision-making in the selection of where conservation takes place.

Traditional motivations for land conservation and the need for hazard reduction meet head on in the wildland urban interface (WUI), where houses are adjacent to or interspersed with wildland vegetation (Radeloff et al., 2005). In many fire-prone regions with large numbers of human-caused ignitions, medium housing densities common in the WUI have the highest fire risk (Syphard et al., 2007; Syphard, Keeley, Bar Massada, Brennan, & Radeloff, 2012). These areas provide a unique combination of people to start fires, fuels to burn, and limited firefighting accessibility that lead to high fire risk to homes (Bar Massada, Radeloff, Stewart, & Hawbaker, 2009; Whitman, Rapaport, & Sherren, 2013). This type of housing development- commonly referred to as sprawl-is also one of fastest growing in the United States (Lubowski, Plantinga, & Stavins, 2008; Newburn & Berck, 2011), and many organizations involved in private land conservation attempt to limit it (Brewer, 2004).

The dynamic of active land conservation, high fire risk, and developing landscapes indicate the potential for private land conservation to jointly impact urban sprawl and fire risk in the WUI. The linkages between private land conservation and fire risk reduction, however, are likely to be complex due to land market dynamics (Armsworth, Daily, Kareiva, & Sanchirico, 2006) and the complex spatial determinates of fire risk (Bowman, O'Brien, & Goldammer, 2013; Hardy, 2005). The location of fire risk may be changed if private land conservation displaces development from one area to another area (Lewis, Provencher, & Butsic, 2009) or if it increases housing density in current developments. Likewise, if displaced development moves to areas of higher fire hazard, private land conservation could even increase fire risk. Private land conservation could also change the spatial arrangement and density of housing by limiting areas where housing can be built, and this has been shown to impact fire risk as well (Syphard, Bar Massada, Butsic, & Keeley, 2013). This can impact the fire risk of both new and existing houses. Therefore, for private land conservation to be a useful tool in reducing fire risk, we must understand the dynamics between conserving land, development patterns, and the drivers of fire risk.

We address the potential congruencies between private land conservation and fire risk reduction in San Diego County CA, USA, a fast-growing and fire-prone region, where private land conservation plays an important role in land use planning and natural resource protection (Land Trust Alliance, 2015). We combine the dynamics of housing growth, private land conservation and fire risk to empirically estimate the impact of private land conservation on fire risk to current and new homes. We accomplish this by simulating land development, conservation purchases and fire risk to houses over a 20 year time horizon given a fixed conservation budget and constant rate of housing growth. Further, we integrate multiple site selection algorithms into our simulation technique in order to identify which features (monetary costs, likelihood of development, or wildfire hazard) are most important when selecting parcels to conserve in a way that reduces fire risk in the most cost-effective manner. Our approach addresses three research questions:

At the county scale, can private land conservation be used to reduce fire risk to homes over a 20 year time horizon?

What are the impacts of the county-level conservation program on municipal-level fire risk?

What private land conservation selection strategies reduce fire risk to homes the most, given a budget constraints?

2. Methods

2.1. Study area

Our study area was the South Coast ecoregion of San Diego County, which covers about 80% of the county (Fig. 1). San Diego County is characterized by a Mediterranean climate, which results in hot dry weather during late spring, summer and early autumn. Every autumn, when fuels are driest, Santa Ana wind events, lasting several days and gusting over 110 km/h, with low humidity create extreme fire weather conditions. Fires that occur during these wind events spread rapidly and have resulted in massive areas burned both historically and recently. In the last decade, Santa Ana wind-driven fires have been responsible for the destruction of thousands of homes in San Diego (Keeley, Fotheringham, & Moritz, 2004; Keeley, Safford, Fotheringham, Franklin, & Moritz, 2009). San Diego also boasts a large and expanding WUI (San Diego County, 2011; Syphard, Clarke, Franklin, Regan, & McGinnis, 2011). Although some parts of the county fall squarely into undeveloped or densely developed areas, many of the more recently developed areas are at low to medium housing densities (Hammer, Radeloff, Fried, & Stewart, 2007).

To help preserve its native ecosystems (San Diego County has the most endemic plants and threatened and endangered species of any county in the continental U.S. (Regan et al., 2008)), San Diego County has been purchasing private land for conservation since the 1990s. Private land conservation references the purchase of land for conservation purposes, by private actors. Typically in San Diego County this work is done by Land Trusts, which are not for profit groups who specialize in holding land. There are at least 14 member organizations of the Land Trust Alliance who are actively protecting land in the County (Land Trust Alliance, 2015). Under the Multi Species Conservation Program, local governments have a goal of protecting 172,000 acres, much of it through land purchases (San Diego County, 2015). In many cases, government grants are available to land trusts in San Diego County to provide funds for conservation purchases.

2.1.1. Simulating future growth, private land conservation, and fire risk

To understand the impact of private land conservation on fire risk, we use a coupled simulation framework where models of land development, selection algorithms that choose what parcels should be conserved, and models that predict fire risk are combined. We use this combined modeling framework to simulate land development, land conservation and fire risk, over a 20 year time horizon, in five year increments. We address each component model in turn and discuss their integration.

2.2. Land development model

To determine the likelihood that a given parcel will develop over the 20 year time horizon of our study, we developed an econometric model of parcel subdivision using parcel data over three time periods: 2004, 2010, and 2014. We parameterized our model using a random effects probit model where the dependent variable is binary (1 if a subdivision occurs, 0 otherwise) (Wooldridge, 2011). We included independent variables that have been shown to impact land owner decisions to subdivide in similar settings (Carrion-Flores & Irwin, 2010; Irwin et al., 2009; Syphard et al., 2013). These variables included: lot size, a number of dummy variables to account for non-linear impacts of lot size, zoning type, municipality identification variables, elevation and slope of parcel, as well as distance from the ocean, the nearest sewer line, freeways, public park, floodplain, and nearest lake. All data came from San Diego Association of Governments (SANDAG, www.sandag.org).