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Research paper

A national approach for integrating wildfire simulation modeling into Wildland Urban Interface risk assessments within the United States

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HIGHLIGHTS

- Employs a probabilistic exposure analysis to identify the likelihood of populated places interacting with wildfire.
- Classified at-risk areas according to a risk matrix comprised of population density and burn probability categories.
- Risk matrix allows planners and managers a quick way to identify where the risk is located spatial, and to qualify the driving factors of the risk (population or burn probability or both).
- Suggests a number of ways that managers and planners can use this information for decision-making, fuels modifications and residential planning.

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ABSTRACT

Ongoing human development into fire-prone areas contributes to increasing wildfire risk to human life. It is critically important, therefore, to have the ability to characterize wildfire risk to populated places, and to identify geographic areas with relatively high risk. A fundamental component of wildfire risk analysis is establishing the likelihood of wildfire occurrence and interaction with social and ecological values. A variety of fire modeling systems exist that can provide spatially resolved estimates of wildfire likelihood, which when coupled with maps of values-at-risk enable probabilistic exposure analysis. With this study we demonstrate the feasibility and utility of pairing burn probabilities with geospatially identified populated places in order to inform the development of next-generation, risk-based Wildland-Urban Interface (WUI) maps. Specifically, we integrate a newly developed Residentially Developed Populated Areas dataset with a stochastic, spatially-explicit wildfire spread simulation model. We classify residential population densities and burn probabilities into three categories (low, medium, high) to create a risk matrix and summarize wildfire risk to populated places at the county-level throughout the continental United States. Our methods provide a new framework for producing consistent national maps which spatially identifies the magnitude and the driving factors behind the wildland fire risk to populated places. This framework advances probabilistic exposure analysis.for decision support in emergency management, rural and urban community planning efforts, and more broadly wildfire management and policy-making.

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1. Introduction

Human development and public safety are threatened when wildfires burn in proximity to populated communities. Many fires in the United States over the last decade have caused significant residential property loss, most recently the Waldo Canyon (2012) and Black Forest (2013) fires proximal to Colorado Springs, CO which resulted in 507 and 346 primary residences destroyed respectively. Wildfires can further, in tragic circumstances, lead to fatalities, for instance 14 deaths were associated with the 2007 Southern California fires. Fatalities and property loss from wildfire are certainly not isolated to the US, for instance the 2009 Black Saturday bushfire events in Australia resulted in 173 fatalities, 414 injuries and over 2000 homes destroyed. Given the potential for highly adverse consequences, it is critical for planners and managers to have the ability to characterize wildfire risk to populated places, and to identify geographic areas with relatively high risk (Murnane, 2006). Identifying high risk communities can help prioritize areas for risk mitigation efforts to reduce the likelihood of residential disasters. Reducing wildfire risk can in turn translate to reduced risk to the public and to firefighters, whose safety is the highest priority guiding federal wildfire management and incident response.

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Table 1
Federal Register WUI Community Definition.

Urban wildland interface community definition			
Category	Structures per acre	Population density: people per square mile	Description
Interface	"usually" ≥ 3 (with shared municipal services)	≥250	1. Where structures directly abut wildland fuels 2. There is a clear line of demarcation between structures and wildland fuels; wildland fuels do not generally continue into the developed area. 3. Fire protection is generally provided by a local government fire department with the responsibility to protect the structure from both an interior fire and an advancing wildland fire.
Intermix	≥ 1/40 acres (from 1 per 40 acres to "very close together")	28–250	1. Where structures are scattered throughout a wildland area 2. No clear line of demarcation; wildland fuels are continuous outside of and within the developed area. 3. Fire protection districts funded by taxing authorities normally provided life and property fire protection and may also have wildland fire protection responsibilities.
Occluded	The development density for an occluded community is usually similar to those found in the interface community, but the occluded area is usually less than 1000 acres in size	1. Where structures abut an island of wildland fuels, often within a city (park or open space). 2. There is a clear line of demarcation between structures and wildland fuels. 3. Fire protection is normally provided by local government fire departments.	

Adapted from Mell et al. (2010).

The wildland urban interface (WUI) is defined as "the area where structures and other human developments meet or intermingle with undeveloped wildlands" (USDA & USDI, 2001). This definition has been further divided into subcategories based on structure and/or population density and their location within or proximate to wildland fuels (Table 1). Even though the Federal Register defines a community to be at risk to wildland fire if it resides within the WUI, there is no criteria for a measure of exposure or fire likelihood (Mell, Manzello, Maranghides, Dutry, & Rehm, 2010), a key component in a risk assessment.

Wildfire risk can be characterized as a composite function of fire likelihood, fire intensity, and fire effects (Finney, 2005). That is, a wildfire risk assessment considers both the probability and magnitude of wildfire-related impacts. This definition is consistent with classical economic theory (Knight, 1921) as well as with contemporary ecological risk assessment frameworks (Thompson & Calkin, 2011). In broad terms the primary analytical components of wildfire risk are exposure analysis and effects analysis. Wildfire exposure analysis is premised on the integration of maps of resources and assets (in this case human communities) with wildfire modeling outputs (Ager, Buonopane, Reger, & Finney, 2013; Salis et al., 2012; Scott, Helmbrecht, Thompson, Calkin, & Marcille, 2012a). Exposure is often quantified in terms of burn probability (BP), where BP represents the likelihood of a given location experiencing wildfire during a defined period of time. Our focus in this manuscript is incorporating risk-based information into WUI mapping products, thereby advancing probabilistic exposure analysis for decision support in emergency management, rural and urban community planning efforts, and more broadly wildfire management and policy-making.

1.1. *Delineating populated places*

Historically, WUI mapping has taken a geospatial approach to identify where people or structures come in contact with potential fuels and has focused on interacting census-based housing or population data with vegetation mapping (Radeloff et al., 2005; Theobald & Romme, 2007; Wilmer & Aplet, 2005). One of the significant limitations identified with the census-based approach occurs where public lands are included within a census block resulting in large, sparsely settled areas where the housing density may be too low to be considered WUI, even when a small cluster of homes is surrounded by uninhabited public lands (Stewart et al., 2009). Bar Massada, Radeloff, Stewart and Hawbaker (2009) addressed the problem of large census blocks resulting in coarse resolution of housing data in rural, northern Wisconsin by manually digitizing individually built structures from aerial photographs for their study area. However, mapping structures at a national level through the use of aerial photography would be very time-intensive and can lead to large inaccuracies, especially in areas of dense canopy coverage, and therefore to date no such dataset exists nationally. Dasymetric mapping, a technique in which population data that is organized by a large or arbitrary area unit (e.g. census block) can be more accurately distributed within that unit through the use of overlays of other geographic boundaries, has been demonstrated to address these issues (Theobald & Romme, 2007). The overlay boundaries exclude, restrict, or confine the population to the most appropriate locations and commonly consist of uninhabitable data layers, including water bodies, steep slopes and protected areas such as National Parks.

LandScan USA™ (Bhaduri, Bright, Coleman, & Urban, 2007) is a nationally consistent population dataset which employs dasymetric mapping to further locate populations within a census block. This dataset utilizes information on various geographic layers, including structure locations where available, to map people in their nighttime residential locations at a 90 meter scale nationwide, and is further discussed in the methods section. We utilize this dataset as our population layer due to its national coverage, fine scale resolution, and its ability to match populations with their residential homes.