Preventing Residential Fire Disasters During Wildfires

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Abstract

The problem of houses burning during extreme wildfires has become a national level concern in the United States and in a number of European countries. This issue is called the wildland-urban interface fire problem or some similar variation. A wildland-urban interface fire disaster occurs under the extreme fire conditions that overwhelm fire suppression efforts. Using modeling, experiments, and investigations of actual wildland-urban interface fires, research has determined that the home and its immediate surroundings within 30 meters principally determine a home's ignition potential during extreme wildfire conditions. The research findings have implications for assessing a home's vulnerability to ignition, for mitigations that reduce a home's ignition potential, and for the responsibility for implementing effective mitigations. In each case, the respective considerations must occur within the home ignition zone. This suggests an approach to reducing wildland-urban interface fire risk: prevent home ignitions by reducing structure ignitability rather than necessarily stopping the fire from encroaching on the community.

Introduction

The spectacle of hundreds of homes destroyed by fire during wildfires has become a principal issue with fire agencies and land managers. Home destruction during wildfires has come to be known as the wildland-urban interface fire problem (or a similar variation). The problem of wildfire threatening residential development has become a common denominator for current policy documents in the United States, e.g., the revised Federal Wildland Fire Management Policy, the 10-Year Comprehensive Strategy, the National Fire Plan, and the President's Healthy Forests Initiative and its pending complementary legislation. The international workshop for which this article was presented indicates that European countries also consider wildfires threatening residential destruction an important issue. The European Union project WARM (Wildland-Urban area Fire Risk Management) also provides evidence for this concern.

One might ask, "Is disastrous residential destruction during wildfires a recent occurrence?" In the United States the answer is "no." The current U.S. interest at national institutional levels originated after the 1985 fire season and resulted in the current National and State Interagency Wildland-Urban Interface Program. But disastrous U.S. residential destruction did not begin in 1985. For example, between 1870 and 1920 numerous towns were destroyed and thousands of civilian fatalities occurred during extreme wildfires—a period historian Stephen Pyne calls the "great barbecue" (Pyne 1982). Although this period produced significantly greater destruction of property and lives than currently occurs, this period did not generate a national response to prevent disastrous residential destruction during wildfires. The occurrence of destroyed homes during wildfires is not new, but our current social response is new. This suggests that our societal perceptions, expectations and desires significantly contribute to the wildland-urban fire problem. Although the following discussion focuses on how homes ignite during extreme wildfires, the physical aspect of wildland-urban interface fire is just one part of the problem.

Wildland-Urban Fire Disasters: Context

Hundreds of homes destroyed and threatened with accompanying life safety concerns characterize disastrous wildland-urban interface fires. Typically, available fire resources are capable of effectively containing a single structure burning. But when many structure fires simultaneously occur, fire protection capabilities decline. Wildland-urban fire disasters occur within a specific context that has the following characteristics.

Severe fire conditions: The combination of the fuels, weather, and topography provide the potential for extreme wildfire behavior.

Wildland fire: Given an ignition, the wildfire produces high intensities that result in high rates of area involvement due to rapid spread rates and particular from the broadcast of firebrands.

Urban fire: Given the existence of residential development vulnerable to ignition, homes simultaneously ignite resulting in numerous burning homes.

Fire protection: The numerous simultaneously burning homes overwhelm the fire suppression effort. The combination of extreme fire behavior and large area involvement of both wildland and residential areas produces a situation that out-scales suppression efforts and poses significant firefighter safety concerns. In general, this results in reduced fire suppression effectiveness with many structures left unprotected.

Home destruction: The lack of home ignition resistance combined with reduced fire protection results in the total destruction of many homes—a wildland-urban fire disaster.

This sequence of conditions describes a situation where standard firefighting operations fail. In this extreme case, the standard approach of stopping the fire from spreading to a community is not an option. The extreme fire behavior overwhelms fire protection; thus, the operational fire suppression factors that logistically support community fire protection no longer significantly contributes to preventing a residential fire disaster.

For example, fire hydrants, access, road widths and the nearest distance to a fire station do not contribute to preventing homes from burning because fire protection is either not available and/or ineffective. Although firefighters may successfully prevent some houses from burning and fire from spreading to other residential areas, hundreds of homes in other locations may burn at the same time. Thus, tactical successes occur, but the residential fire disaster results in a strategic protection failure.

Note that the sequence leading to a wildland-urban fire disaster depends on homes burning (Urban fire). If homes are sufficiently ignition resistant such that many homes do not simultaneously burn, then fire protection remains effective. Thus, for a residential development having high ignition resistance, the disaster sequence is broken. If homes do not ignite, homes do not burn; if homes do not burn, a wildland-urban fire disaster does not occur. An intense wildfire can occur but an associated residential fire disaster does not. This indicates that a wildfire occurrence does not necessarily equate to a wildland-urban fire disaster; the residential fire disaster depends on the ignitability of the residential development. This generally defines the wildland-urban interface fire problem in terms of home ignition potential. It prompts the question of "how do homes ignite related to wildfire characteristics?"

Home Ignition: a local process

Ignition and fire spread, whether on structures or in wildland vegetation is a combustion process. Fire spreads as a continuing ignition process whether directly associated with flames or spot ignitions from firebrands with subsequent fire spread. A fire does not spread as a mass engulfing objects in its path, as does an avalanche or a flash flood. Fire spreads because the requirements for combustion have been satisfied along its path. Combustion requires a sufficiency of fuel, heat and oxygen. An insufficiency of any one component and ignition/combustion will not occur—fire will not spread. Observations reveal that the requirements for combustion during an intense, active spreading crown fire occur over relatively short distances. One can commonly observe unburned, uncharred patches of forest vegetation within 30 meters of areas that burned as an intense crown fire.

The requirements for combustion apply equally to homes during extreme wildland-urban fires. In the context of wildland-urban interface fire, the home becomes the fuel that ignites. All the adjacent flammables surrounding a home (the fuel) contribute the heat. Sufficient heat may be supplied directly from flames or from firebrands that deposit directly on a home. A wildland fire cannot spread to homes unless the homes and their adjacent surroundings meet the requirements for combustion.

Reducing wildland-urban interface fire losses, that is, preventing residential fire disasters, involves the reduction of the heat (surrounding burning materials) in relation to the fuel (the home) sufficient to prevent ignition. If a hypothetical home has a noncombustible exterior, then clearly an insufficiency of fuel occurs. But given that a home has wood exterior components, how much reduction in heat must occur to prevent ignition? This question may be more practically stated; "how close must an intense crown fire be to a wood wall to meet combustion requirements—that is, to ignite the wall?"

Home Ignition Research

I approached the home ignition question by examining the requirements for combustion. Typically wildland-urban fire disasters do not reveal the details of their occurrence through statistical inference. The extreme wildland-urban fires are episodic (infrequent), and the disaster occurs under conditions specific to the particular event. Full-scale experimental wildland fires have the same limitations. My home ignition research used three independent approaches that included modeling, crown fire experiments, and investigations of actual wildland-urban fire disasters. I used this diverse-methods approach to the problem to enable me to inductively and deductively infer how homes ignite during extreme wildfires.

Modeling

The home ignition modeling (Cohen 1995, Cohen and Butler 1998) principally consisted of the calculations estimating the radiation and convection heat transfer from flames incident to a wood wall. Given this incident heat flux and its duration at the wall, the model calculated whether or not the exposure met the requirements for ignition. The model was used to estimate the maximum flame-to-wall distance at which an ignition occurs.

Any model requires simplifying assumptions of actual conditions. When modeling home ignitions, I chose worst or severe case assumptions. The flame size was characteristic of intense crown fires. The flames transferred energy as a thermally homogeneous ideal object at a temperature near peak flame temperatures. Flaming durations were longer than actual durations and the flame-wall orientation enhanced the radiation heat transfer. I used assumptions that attempted to over-estimate the flame-to-wall distance that would produce ignition.

The model results indicated that the flame-to-wall distance must be closer than 30 meters to meet the requirements for ignition. Because data do not exist to test the model output and because human burn injury occurs at intensities significantly less than those required for wood ignition, the model results could not be judged without conducting experiments.

Experiments

Full-scale experimental crown fires during the International Crown Fire Modeling Experiment (Alexander and others 1998) were used to examine how much heat wood walls would receive and whether that heating would produce ignition (Cohen 2000). The wood walls were placed at 10, 20, and 30 meters from the edge of the forested crown fire plots (2.25 hectares, square). Measurements at the walls occurred for seven separate experimental crown fires.

The experimental crown fires indicated that the home ignition model over-estimated the distance at which ignitions would occur on wood walls. The experimental crown fires produced radiation, convection, and firebrand exposures at the wall sections. Four of the seven crown fires did not result in wall ignitions. Only walls at 10 meters had ignitions with no ignitions or charring on the wall sections at 20 and 30 meters. The crown fire burning duration at the downwind plot edge lasted for about 50 seconds. When the crown fire burned out, those walls that did ignite could not sustain flaming combustion.

The experimental crown fires produced full-scale, high intensity fires. These fires, however, did not necessarily produce conditions that can occur during extreme wildfires. The experimental crown fires occurred during moderate weather conditions on flat terrain. The crown fires were limited to the 2.25-hectare plots without intense fire burning on the sides and behind the wall sections. Thus, actual wildland-urban fire disasters must be examined to include the range of conditions that exist during extreme wildfires.

Investigations
I have done my own investigations of wildland-urban fire disasters as well as examined 2 other analyses. The 2 case studies done by others stratified the proportion of homes that survived the wildfire based on simple characteristics. For one of the case studies, homes with a nonflammable roof and 10-18 meters vegetation clearance had 95% survival within the Bel Air Fire of 1961 (Howard and others 1973). The other case study found that homes with a nonflammable roof and 10 meters of clearance had 86% survival within the Painted Cave Fire of 1990 (Foote 1994). My investigations indicate that high intensity crown fires at distances further than 30 meters from homes do not ignite the home directly from the flames. Most of the destroyed homes ignite from surface fires spreading to the structure or from firebrands directly on the structure. For example, my investigation of the 2000 Los Alamos wildland-urban fire disaster (Cohen 2000) indicated that the associated high intensity crown fire did not directly ignite homes. Low intensity surface fires spread to contact homes and firebrands ignited adjacent surface fuels that spread to homes as well as firebrand ignitions directly on homes. In many cases, burning structures ignited adjacent structures.

Research Conclusions
The diverse research methods identify the general scale that determines home ignition occurrence. The crown fire experiments and wildland-urban disaster investigations indicate that the model over-estimates the flame-to-wall distance that will result in wall ignitions directly from flames. Wildland-urban fire investigations reveal that surface fires and firebrand ignitions on a structure destroy most homes rather than the direct influence of high intensity crown fires. The results of the diverse research methods indicate that given an extreme wildfire, a home's characteristics in relation to a home's immediate surroundings within 30 meters principally determine the home ignition potential. I call this area—a home and its immediate surroundings within 30 meters—the *home ignition zone*.

Implications for Preventing Wildland-Urban Fire Disasters

The home ignition zone identifies the distance scale of the factors that determine a home's ignition potential during an extreme wildfire. The home ignition zone includes a home and its immediate surroundings within 30 meters. High intensity fire behavior beyond the home ignition zone does not transfer enough energy directly from its flames to ignite a wood wall. The fuels surrounding a home within the home ignition zone principally determine the potential for directly igniting the home. Firebrands lofted from extreme wildfires must directly ignite on a structure to be an effective ignition source. If firebrand ignitions occur in the fuels surrounding a home, then those fuels determine the home's ignition potential. Thus, regardless from how far firebrands travel, a home's exterior materials and design principally determine its ignition potential from firebrands. This implies that a home's location does not determine its ignition potential, the condition of the home ignition zone determines the ignition potential. This, in turn, implies that the assessment of home and community risk, the mitigation of that risk, and the responsibility for that mitigation must be consistent with those factors that determine home ignition potential within the home ignition zone.

Wildland-Urban Fire Risk Assessment

Home and community risk assessment relative to the potential for a wildland-urban fire disaster must occur within the home ignition zone. The assessment relates all the potential burning materials within 30 meters of the home to the home's exterior characteristics. Although an assessment includes the potential for firebrand exposure that originates outside the home ignition zone, the assessment must consider the materials and design characteristics of the home related to firebrand ignitions. The risk of a wildland-urban fire disaster can only be evaluated after assessing home ignition zone characteristics.

Wildland-Urban Fire Disaster Mitigation

Since the home ignition zone principally determines a home's ignition potential during an extreme wildfire, the necessary and sufficient mitigations to prevent a wildland-urban fire disaster can be conducted within the home ignition zone. This implies that fuel reduction done outside the home ignition zone may be inefficient and ineffective in reducing home ignition potential. Fuel reduction beyond the home ignition zone may be inefficient because more vegetation removal occurs than is necessary to reduce the direct flame heating below ignition requirements. Fuel reduction beyond the home ignition zone may be ineffective in eliminating community ignitions by firebrands. Ignitions within an unmitigated home ignition zone may occur from firebrands originating more than 1 kilometer from the home during extreme wildfires.

The home ignition zone suggests a wildland-urban fire strategy and tactics directed toward reducing home ignition potential rather than a strategy of keeping wildfires from encroaching on residential development (Cohen 2001). Currently most fire organizations approach wildland-urban fire by addressing the fire potential outside the home ignition zone rather than focusing attention to reducing ignition potential within the home ignition zone. Thus, instead of constructing fuel breaks around the outside of a community, the new approach would make the community become the fuel break.

This approach does not exclude the fuel reduction benefits beyond home ignition zones for sustaining values derived from ecosystems. The wildland-urban fire strategy recognizes the opportunity to separate the management of fire impacts on ecosystems from the fire impacts on residential development.

Responsibility for Mitigation

The home ignition zone extends 30 meters from the home. This largely places the home ignition zone within private ownership. Home ignition zones may overlap ownership boundaries, but the collective home ignition zones largely fall within private ownership. Thus, the authority and corresponding responsibility for mitigating the home ignition zone must reside with homeowners. That demands that homeowners participate in a partnership with fire agencies for the prevention of wildland-urban fire disasters.

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