How risk management can prevent future wildfire disasters in the wildland-urban interface

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Recent fire seasons in the western United States are some of the most damaging and costly on record. Wildfires in the wildland-urban interface on the Colorado Front Range, resulting in thousands of homes burned and civilian fatalities, although devastating, are not without historical reference. These fires are consistent with the characteristics of large, damaging, interface fires that threaten communities across much of the western United States. Wildfires are inevitable, but the destruction of homes, ecosystems, and lives is not. We propose the principles of risk analysis to provide land management agencies, first responders, and affected communities who face the inevitability of wildfires the ability to reduce the potential for loss. Overcoming perceptions of wildland-urban interface fire disasters as a wildfire control problem rather than a home ignition problem, determined by home ignition conditions, will reduce home loss.

risk assessment | fuel treatment | home ignition zone

During the past two decades, many parts of the globe have experienced significant, damaging wildfire events. These events are not without historical reference; however, high-loss events appear to be occurring with increasing frequency (1). High-value, developed assets located in areas prone to wildfire hazards, along with more frequent, extreme weather events possibly caused by global climate change (2), have implications to society, national governments, and the global insurance industry. For example, the "Black Saturday" event of February 7, 2009, in Victoria, Australia, in which 173 people lost their lives, has been identified as a transformative event, resulting in long-lasting political, media, and public interest. In light of this, the Australian government established a Royal Commission to review its bushfire policy with calls for fundamental transformation of policy and improved risk sharing (3).

A transformative event such as the Black Saturday bushfires has not occurred in the United States, although there have been multiple high-loss wildfire events in recent history. Between 2002 and 2011, wildfire-related insured losses in the United States totaled \$7.9 billion—a \$6.2 billion increase vs. the previous decade (4). On the Colorado Front Range, three of the past four fire seasons have set state records in numbers of structures burned (5). Furthermore, when homes and communities are threatened, aggressive suppression response exposes wildland firefighters to the dangers of the fireline, tragically exemplified by the 19 Granite Mountain Hotshots who were killed while protecting the community of Yarnell, AZ, on June 30, 2013.

Although wildfires are inevitable, the destruction of homes, ecosystems, and lives is not. How can land management agencies, first responders, and affected communities who face the inevitability of wildfires reduce the potential for loss? By doing what other institutions, both private and public, across sectors, have done in the face of complexity and uncertainty: turn to the principles of decision science and risk management.

Similar to other forms of risk management, the management of wildfire risks begins with an assessment of the probability of a wildfire event and the susceptibility of highly valued resources and assets to wildfire (6, 7). Strategic risk management in the wildfire context involves many complicating factors, including, but not limited to: *i*) Many wildlands are historically predisposed to periodic fire; *ii*) wildfire is a dynamic ecological process that contributed to the development of most North American ecosystems; *iii*) wildfire is a spatial process: fuel continuity is critical in fire spread, and burned areas may be considerable distances from the ignition point; *iv*) many communities have developed within or adjacent to fire-prone ecosystems; these communities vary widely in their levels of wildfire exposure and susceptibility; and *v*) sociopolitical expectations regarding wildland fire management and community fire protection may not be realistic under current and expected future conditions.

Collectively, these factors present challenges to wildfire risk mitigation, although careful application of decision science principles could help inform identification of an effective suite of mitigation investments. Critically, the evaluation of risk mitigation options begins with the questions of what are appropriate wildfire management objectives, and how risk mitigation options realistically vary in terms of cost, likely effectiveness, and the appropriate identification of who bears the responsibility.

In this manuscript, we reframe the question of how to prevent future wildland-urban interface (WUI) disasters by applying strategic risk management and decision science concepts, and examine their application in a recent high-loss wildfire event. First, we review how the success, or lack thereof, of wildfire management paradigms is largely predicated on how the problem is perceived and how objectives are defined. We next provide a brief review of wildfire home destruction and risk mitigation opportunities, in particular focusing on reducing hazardous fuel loads and home ignition susceptibility. These two mitigation options offer a stark contrast in terms of components of risk that are targeted (probability and susceptibility), costs, responsibilities,

Significance

Recent wildfire events throughout the world have highlighted the consequences of residential development in the wildland-urban interface (WUI) including hundreds to thousands of homes burned during a single wildfire to, more tragically, firefighter and homeowner fatalities. Despite substantial investments in modifying wildland fuels near populated areas, losses appear to be increasing. In this article, we examine the conditions under which WUI wildfire disasters occur and introduce a wildfire risk assessment framework. By using this framework, we examine how prefire mitigation activities failed to prevent significant structure loss during the Fourmile Canyon fire outside Boulder, CO. In light of these results, we suggest the need to reevaluate and restructure wildfire mitigation programs aimed at reducing residential losses from wildfire.

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the likelihood of reducing loss, and the feasibility of broad-scale implementation. For illustration of these principles, we examine the Fourmile Canyon fire, in particular focusing on the effectiveness of fuel treatments and the home ignition zone (HIZ) related to this recent WUI fire disaster. Last, we review policy implications and outline a pathway for attaining fire adapted communities and reducing WUI losses.

The Wildfire Paradox. Paradoxically, using wildfire suppression to eliminate large and damaging wildfires ensures the inevitable occurrence of these fires (8). Today's wildfire problem is rooted in historical and recently modified vegetation conditions, possibly exacerbated by climate change (9). Before European settlement, wildfires started by lightning or ignited by Native Americans (10) burned under all fuel, weather, and topographic conditions capable of producing fire spread, with highly variable frequencies, intensities, and severities. Grasslands and some shrub lands burned often, whereas high-elevation forests burned infrequently and generally with high intensity. Between these zones were low-elevation pine and mixed-conifer forests where trees often survived reoccurring fires that limited fuel and thus ensured low fire intensities (11–13). Given recurrent ignitions, dry periods and cured vegetation could spread fires into forested areas limited only by fuel, weather, and topographic conditions. By the late 1800s, fires in the western United States were greatly reduced as a result of changing land uses such as grazing, habitation, and fire suppression (12). Fires burning during moderate weather conditions have largely ceased, causing a dramatic reduction in present day annual area burned (14) and commonly resulting in changes to vegetative composition, increasing fuel load, and broad-scale fuel continuity (15–17). The historical fire patterns, burning under all conditions of fire spread, have now been replaced by fires that burn when fire suppression efforts fail as a result of high fire intensities and broad-scale fuel continuity. This shifts fire behavior characteristics to the most extreme in all vegetation zones and across the entire landscape.

This is the wildfire paradox: Wildfire suppression, effective 95% to 98% (18) of the time, inevitably leads to ecologically significant wildfires with higher intensities and rapid growth that are unable to be suppressed (19–21). This, in turn, produces increased wildfire management costs and increased likelihood of escaped, disastrous fires. The wildfire paradox is evidenced by decades of attempted wildfire exclusion without complete success; increasing fire suppression expenditures have not been demonstrated to increase suppression success. It is apparent that fire suppression policy is based on an unachievable fire exclusion premise; yet, eliminating wildfire is neither ecologically nor physically feasible, nor ecologically desirable. Reframing the objectives of fire management to how we best live with wildfire in a fire adapted environment is critical to untangling the wildfire paradox.

WUI Fire Destruction: A Home Ignition Problem. The predominant approach by fire management organizations to wildfires threatening communities, the WUI fire problem, is wildfire suppression and control (20). Aggressive suppression actions when communities are threatened at increased suppression costs (22–25) and emphasis on treating wildland fuels on public lands within and adjacent to communities (26), have demonstrated federal land agencies' commitment to protecting the WUI. However, neither of these actions measurably impacts the susceptibility of homes to ignition and subsequent destruction (22).

Essentially, current management practices have continued with the approach that has led us to the wildfire paradox by framing the WUI fire disaster as a wildfire control problem, instead of focusing on the susceptibility of structures to the inevitability of wildfire exposure. Research demonstrates (20, 22, 27–30) a home's characteristics in relation to its immediate surroundings principally determine home ignition potential during extreme wildfires. The demonstrated inability to suppress wildfires under extreme weather conditions and the fact that many homes are not destroyed when exposed to these wildfires indicates that reducing home ignition potential is key to effectively reducing home destruction. Because home ignitions are primarily determined by conditions on private property, the principal authority, and thus, primary responsibility for preventing WUI home destruction lies with homeowners rather than public land managers. Focusing on wildland vegetation without consideration and mitigation of home ignition susceptibility furthers the illusion that WUI protection does not require homeowner engagement. If wildland fuel treatments and suppression are ineffective and the fire threat to communities continues to be considered a wildfire problem, WUI fire disasters will continue.

Mitigating Wildfire Risk to Human Communities

By using a strategic risk assessment framework enables evaluation of how reducing home ignition potential and reducing fuel loads, among other strategic options, can affect various risk factors, which can in turn guide cost-effective investments in risk mitigation efforts (31, 32). Applying such a framework requires an understanding of the relationship between extreme wildfires, home ignitions, and mitigation opportunities. Any structured decision process for risk mitigation begins with a problem formulation stage articulating the scope of analysis, the decision maker and participants, and the fundamental objectives, risk preferences, desired outcomes, and risk-based evaluation criteria (33). The lack of a well-structured problem statement may lead to difficulty in monitoring outcomes, and, more importantly, may lead to inefficient and ineffective risk mitigation efforts. Managing wildfire entails decisions made at varying spatial scales, at different points in time, by different individuals and organizations in the face of substantial uncertainty and complexity (34). Opportunities and responsibilities for managing risk factors vary across federal and state land management agencies, local planning agencies, incident responders, and private landowners.

A conceptual model of wildfire management allows us to consider fundamental and means-based risk management objectives, as well as the major risk mitigation actions and their pathways for reducing wildfire risk to human communities (Fig. 1). The overarching fundamental objective, reducing the risk of home loss, can be achieved by targeting risk factors through means-based objectives (e.g., reduce susceptibility of home to wildfire loss). The primary risk factors are probability of home exposure to flames and burning embers (firebrands) and home susceptibility to loss, which vary geographically according to environmental and socioeconomic variables. Probability of home exposure to wildfire is in turn influenced by the occurrence of fire, the size and intensity of fire, and the presence of homes in fire-prone areas. Risk mitigation actions vary in terms of which risk factor(s) they are designed to affect, whether they occur before or during a wildfire event, and who has primary responsible for their implementation. There exist many other significant factors driving wildfire risk that are noncontrollable, notably topography, antecedent climatic conditions, historical land and fire management, lightning-caused ignitions, and fire weather.

A particularly common prefire risk mitigation option is fuels reduction on public lands. The two principal risk objectives for fuel treatment are to reduce the wildfire intensity and severity within treated areas, and to reduce the probability of fire occurrence beyond treated areas by limiting fire spread rates and/or enhancing suppression effectiveness. However, fuel treatments will not stop or eliminate fires. For both objectives, the initial step must be to identify the wildfire behavior conditions that represent the greatest threat. Modern fire suppression organizations are highly effective under all but the most extreme weather conditions,

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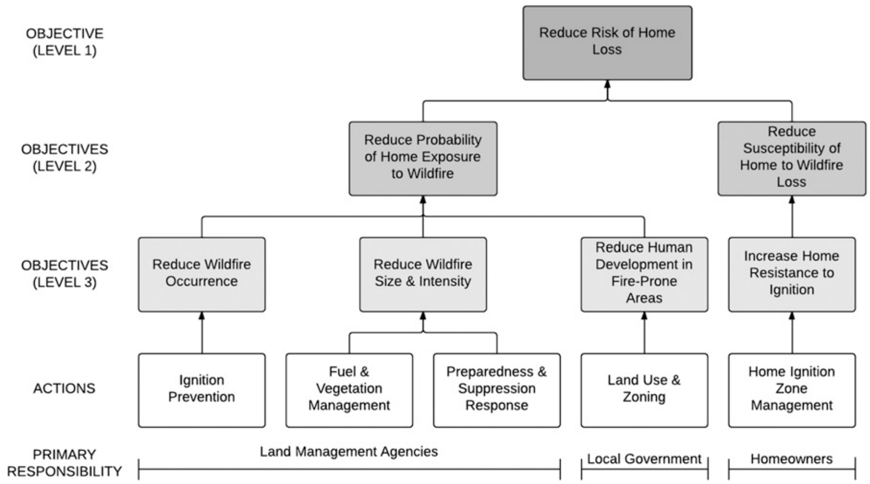

Fig. 1. Conceptual model highlighting the major fundamental objectives (level 1), means-based objectives (levels 2 and 3), and actions for reducing the risk of home loss as a result of wildfire. The risk of home loss is jointly determined by the probability of home exposure to wildfire and the susceptibility of home to wildfire, which in turn are influenced by other factors. Actions and responsibilities for strategically managing risk factors vary across land management agencies, local government, and private landowners.

which, not coincidentally, typically create the largest fires. Approximately 3% of the fires are responsible for 97% of the area burned (35). These fires tend to burn under high winds, with very low fuel moistures, producing high spread rates and intensities. Collectively, these are termed the “target conditions” for the fuel treatment. In other words, effective treatments must be designed to target these fires and conditions to be considered successful. As such, there is little benefit to underestimating target conditions—establishment of the target conditions should identify those conditions under which losses typically occur, with the recognition that, for some resources or assets, fuel treatments might not be effective at protection.

After identifying treatment objectives and target conditions, the next steps in fuel treatment design involve understanding the degree of change possible from different treatment prescriptions under the target conditions. Decades of scientific analysis of fuel treatment effects in many forest types reveals the single most important prescription element involves surface fuel removal by prescribed fire (36). Prescribed fire removes (i.e., burns) the same fuel components on which wildfires depend—largely surface fuels (litter, grasses, and herbaceous fuels)—the amount and condition of which is a major determinant in fire ignition, spread, and ultimately burn severity (24, 37, 38). In contrast, most mechanical treatment practices (thinning, chipping) tend to focus on large woody material that contribute only a limited portion of the fuel available to burn in wildfires. Prescribed burning may require added mechanical activities to improve the result or the practicality of conducting prescribed burns. Estimates of how much a given set of treatment prescriptions may alter potential fire behavior under the target conditions are made by using computer models or experience.

The level of fire behavior change needed depends on the values being protected within the treatment area. For example, many trees can survive fires that do not ignite the foliage (crown fire), and flame lengths less than approximately 4 ft facilitate firefighting effectiveness and safety. If the objectives for the treatment are restricted to the treated area itself, no further considerations are needed. If, however, the risk objectives for fuel treatment are intended to reduce the probability of fire, the treatments must change the way fires move across the relevant landscape. The relevant landscape extent refers to how far away fires can start and move to areas of concern. Treatment effects depend on the amount and proportions of treated area and sizes of treatment units within the landscape extent. Observations of wildfires in wilderness areas show dramatic responses to patterns of previous burns, which accounted for 40% to 50% of the study landscape (39–41). Computer modeling suggests random patterns of fuel treatments begin to collectively restrict fire movement at more than 15% to 20% treatment and at lower percentages if treatments are oriented specifically to impede fire movement (42). Increased treated area further reduces potential spread. Changing the probability of large wildfires impacting a particular area therefore requires spatial planning of multiple treatment units for perhaps several kilometers in the upwind direction of high wind events. The challenges to accomplishing landscape-level modifications become almost intractable with dispersed residential development because the multiplicity of land ownership and small parcel sizes prevent coordinated treatments at meaningful scales.

Identifying opportunities for reducing wildfire activity is but one component of a multifaceted approach for mitigating wildfire risk to human communities (Fig. 1). Critically, mitigation efforts need to consider not only the natural hazard itself, but also the susceptibility of developed assets to the hazard. In fact, as we argue in this paper, managing the susceptibility of homes to ignitions is a necessary prerequisite for reducing home loss. To appropriately analyze and mitigate WUI fire destruction risk, we must first understand how wildfires cause home ignitions, and how disastrous home destruction occurs during wildfires.

A sequential schematic for how WUI disasters unfold is depicted in Fig. 2, in which the upper three boxes describe necessary conditions and the lower three boxes a chain of consequences resulting in destruction of numerous homes. The probability of home destruction during wildfires is derived from the nested probabilities of extreme burning conditions leading to flame and lofted burning ember (firebrand) exposures, of home ignition, and of unsuccessful firefighting efforts. Given the combination of extreme fuels, weather, and topography, the size, burning intensity, and proximity of wildfire to residential development determine the initial extent and intensity of WUI ignition exposure, primarily from firebrands. Flame and firebrand exposures increase commensurately with fuels that support higher burning intensities and growth rates, with drier and windier weather conditions, and with steeper topography. However, during the extreme wildfire conditions of WUI fire disasters, nonintuitively, most home destruction within residential developments occurs with low-intensity flame exposures (20, 30). This is evidenced by unconsumed, often green vegetation adjacent to totally destroyed homes. Instead of high intensity flames, most homes ignite as a result of firebrands igniting lower-intensity surface fires adjacent to and/or spreading to contact the home, as well as firebrand ignitions directly on the home.

The likelihood of home ignition during extreme wildfire conditions is principally determined by the HIZ: the home's materials,

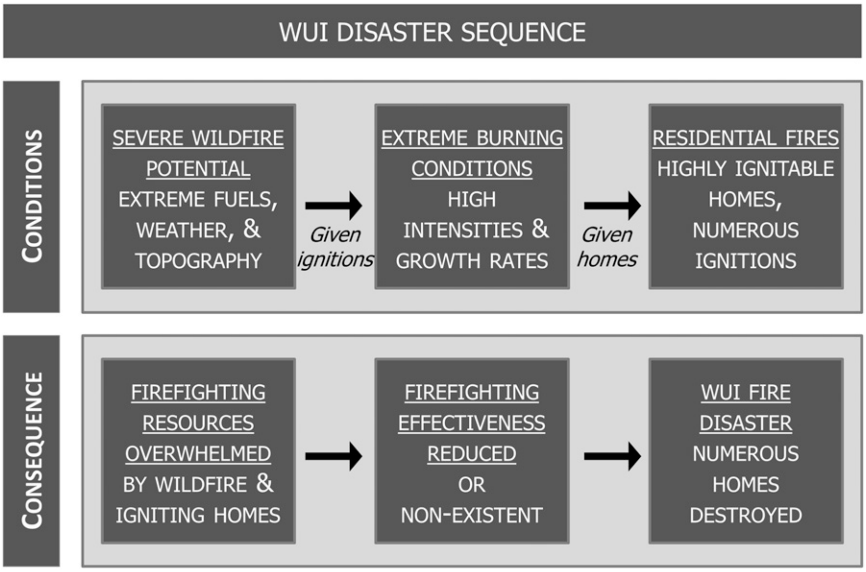

Fig. 2. WUI disaster sequence. Each box corresponds to a factor that critically contributes to high numbers of destroyed homes during a WUI fire. Note that, if homes are ignition-resistant and numerous home ignitions do not occur (step 3), structure protection effectiveness is greater for home ignitions that do occur, thereby preventing disastrous losses.

design, and maintenance in relation to its immediate (within 30 m) surroundings (20, 22, 27–30). Characteristics of susceptible HIZs include the presence of ignitable building materials and flammable debris. Wildland fuel treatments that fail to address the HIZ will likely be inefficient because fuel treatments outside the HIZ reduce intensities not capable of igniting flammable materials, and ineffective because these fuel treatments do not reduce ignitions from fires within the HIZ and/or firebrands that can originate several kilometers from residences to ignite fires within the HIZ (22). For example, a wildland fuel treatment within the 2007 Angora fire in California reduced fire intensities for Jeffrey pine (*Pinus jeffreyi*) survival (43) but did not reduce the HIZ ignition potential of adjacent homes, resulting in high loss.

Last, given a sustained home ignition (or ignitions), the probability of home destruction is influenced by the effectiveness of fire protection efforts in suppressing the structure fire. The disaster sequence (Fig. 2) shows that, although some WUI fire protection tactics might succeed, these standard response tactics fail to prevent residential fire disasters with highly ignitable communities. Areas of high-density suburban development can lead to additional fire risk through home-to-home ignition. Thus, effective fire protection depends on ignition resistant homes during extreme wildfires.

The following is a summary according to the WUI disaster sequence in Fig. 2: Extreme wildfire behavior and a fire start (steps 1 and 2) expose numerous, ignition-susceptible homes (step 3), resulting in simultaneous burning homes (step 4). The high-potential ignition exposure and multiple burning homes overwhelm firefighters and many homes go unprotected (step 5), resulting in numerous homes totally destroyed (step 6). In terms of home destruction risk as a conditional probability, the first two steps of the sequence relate to the wildfire exposure probability, the third step relates to home ignition probability, the next two relate to protection probability, and the last step relates to the overall destruction probability. In a 2010 study by Cohen, the WUI disaster sequence occurred for each of the 14 wildfires examined in which more than 100 homes were destroyed (20).

Case in Point: The Fourmile Canyon Fire

The Colorado Front Range has experienced several highly damaging wildfires in recent history. However, these fires were not without precedent and were consistent with the characteristics of large, damaging, interface fires that threaten communities throughout much of the Western United States. The Fourmile Canyon fire ignited on September 6, 2010, burning 2,500 ha and 168 homes, resulting in $220 million in ensured loss. High spread rates and long-distance spotting (0.8–1.6 km) combined to produce rapid growth rates accompanied by high-intensity burning, with most home destruction occurring very early in the fire progression. The high costs and losses associated with the fire prompted Senator Mark Udall of Colorado to request a scientific review (44). Findings from the review echoed early reviews of fires on the Front Range, including the Hayman (38) and Black Tiger fire reviews (45). Extreme (but not uncommon) fire weather, continuous fuels, an ignition, and dispersed, ignition-susceptible residential development overwhelmed structure protection capability, resulting in substantial private property loss.

Before the Fourmile Canyon fire, many residents had reported conducting wildfire hazard reduction activities on their property (46). Further, county, state, and federal mangers had engaged in various wildland fuels reduction treatments. Using the lenses of risk assessment and decision science, and key findings from the Fourmile Canyon postfire review (44), we evaluate pertinent information regarding the establishment of objectives for these programs, investigate if and how risk assessment entered into the design of mitigation strategies, and examine the effectiveness of these activities. Our analysis will follow the WUI disaster sequence (Fig. 2), beginning with an evaluation of the role of fuel treatments in this WUI disaster.

Land ownership within the Fourmile perimeter is heavily fragmented and primarily private (67%). Federal ownership accounts for 27% of the area, and the remaining 6% is composed of other nonfederal ownership. Within the area burned by the fire, ∼250 ha of fuel treatments had been performed within the previous 7 y. High wind speeds and low relative humidity during the fire are common weather conditions associated with large wildfires along the Front Range foothills. Thus, recognition of these conditions is critical when developing fuel treatment prescriptions. However, the description and documentation of fuel treatments performed in this area did not mention the weather conditions under which they were intended to be effective, or the methods for maintaining surface fuels in a treated condition. That is, the target conditions for the fuel treatments and supporting prescription elements were not identified.

If target fire conditions had been identified for the high-loss events typical in the Colorado Front Range, successful fuel treatments would have required considerably different arrangement, extent, and prescriptions. Fragmented, primarily private ownership, resulting from mining claims interspersed with municipal and federal lands, made large-scale treatment efforts difficult. The mechanical chipping of trees and brush used in the fuel treatments may have ultimately benefitted tree survival if it were followed by burning of the chip material after it was distributed across the ground surface. The narrow linear fuel breaks along roads (presumably intended to provide a defensive barrier) were ineffective under the regularly occurring target weather conditions of high winds and low humidity along the Colorado foothills, resulting in long-range spotting of 1 km or more. As it were, existing treatments had no discernible influence on reducing fire spread or in aiding suppression effectiveness.

A total of 474 homes were located within (or within 30 m of) the final perimeter of the Fourmile Canyon fire. This fire is similar to previous WUI fire disasters in that most of the home destruction occurred during relatively brief episodes of extreme burning conditions, with relatively few homes burning afterward (20, 28). Among the homes destroyed, 83% were associated with surface fire and 17% with crown fire. As a result of rapid growth rates, the wildfire quickly spread to dispersed, residential areas, resulting in wide-ranging flame and firebrand exposures to hundreds of homes. This led to simultaneous home ignitions that overwhelmed suppression efforts and structure fire protection capabilities. Relatively low home density and significant spacing between homes prevented house-to-house fire spread. During the wildfire, most homes with sustained ignitions freely burned to total destruction because no one extinguished the initial burning (most residents were evacuated, and firefighters were unable to protect most homes).

A recent survey helps shed light on the degree to which residents in the area had considered or invested in HIZ management (46). Brenkert-Smith and Champ conducted a survey in 2007 of wildfire mitigation efforts and risk perceptions of residents of Larimer and Boulder Counties, including 127 individuals evacuated during the Fourmile Canyon fire (46). A majority (83%) of respondents within the evacuated area reported being aware of wildfire occurrence, and most (61%) had previously experienced wildfire within 16 km of their property. A large majority (96%) reported having done some kind of wildfire mitigation activity. However, mitigation effectiveness is questionable. Most respondents (>80%) did not recognize that the characteristics of their homes and immediate surroundings (i.e., HIZ) principally determined the likelihood of home destruction during wildfires (46). Thus, although it appears most WUI residents and professionals recognize the necessity of activities to mitigate the results of wildfires, the sufficiency of implementation is unclear.

Discussion

Increasing damages and management costs of wildfires (47, 48), combined with the inability of agencies charged with wildfire management to describe the return on investments from wildfire mitigation and suppression, suggests the need to fundamentally review the current approach to managing wildfires—particularly when those fires threaten populated areas. In response to recent costly wildfires, Congress approved the Flame Act in 2009, calling on the Secretaries of Agriculture and the Interior to develop a cohesive strategy on wildfire management with partners at the state and local level. The strategy centers around three key themes: fire adapted communities, wildfire response, and resilient landscapes (49). These elements are functionally linked in a proper wildfire risk framework, which can be used to identify measures and magnitudes of mitigation that produce the desired risk reduction. However, risk management can be effective only if the objectives for risk reduction are clearly specified.

If our problem statement is defined as keeping wildfire out of the WUI, it is unobtainable, and large wildfires and residential disasters will continue, and likely increase. Fuel treatments do not stop fires (just change behavior), and treatment alone without HIZ treatment means that inevitable wildfire exposure will result in structure loss. Also, landscape treatment programs managed by public land management agencies suffer from (*i*) lack of available funds at the federal level to treat sufficient area to reduce wildfire transmission, (*ii*) lack of influence over treatment of private lands [the Fourmile Canyon fire began on private land and burned only a small proportion of federal ownership—33% of the area was nonprivate, and only 9.7% was treated (44)], and (*iii*) the challenge of liability issues associated with prescribed burns escaping onto neighboring land. If the problem is identified as reducing the proportion of wildfires entering the WUI, it will take time, significant increase in public and private investment, and a change in social acceptance and liability rules for burning near inhabited areas until the benefits are realized. By contrast, if the problem is identified as home ignition, mitigation of the HIZ is the most cost-effective investment for reducing home destruction, and this can be augmented with other investments (Fig. 1).

An appropriate application of wildfire risk management would incorporate the functional relationships between extreme-weather wildfires, landscape conditions, and home ignition/destruction. Starting with homes, their susceptibility is a direct function of their ignitability, which is dependent on the relatively small area of the HIZ. The HIZ is independent of fire behavior in the nearby wildlands, meaning that proper care of the HIZ separates home losses from wildland fire behavior, regardless of the other elements of wildfire risk (fire behavior and its likelihood). Therefore, the scope of mitigation responsibility must be centered on homeowners. WUI fire disasters cannot be prevented without homeowners actively creating and maintaining HIZs with low ignition potential. The HIZ provides opportunities for effectively mitigating WUI fire risk without necessarily controlling wildfires (e.g., without eliminating or reducing the wildfire exposure probability). The WUI disaster sequence (Fig. 2) indicates that increasing ignition resistance would reduce the number of homes experiencing simultaneous ignition; extreme wildfire conditions can exist that do not result in WUI fire disasters. This requires homeowners and professionals to understand how the HIZ determines home ignition potential and then focus risk mitigations within the HIZ. Thus, there is a need to redirect future efforts toward risk communication and risk sharing across land management agencies, first responders, and the public. Effective HIZ management improves the safety of emergency responses (protection, ingress, egress), again, largely independent of the wildland fire occurrence or behavior beyond the HIZ. Thus, if homes are the sole concern of community fire disaster problems, then they can be technically separated from the wildland fire problem.

However, landscape condition cannot be ignored to realize fire-adapted communities because, by definition, WUI communities consist of more than homes. The wildland component defines the environmental context and values for communities, including views, recreation, watershed, and lifestyle benefits to the inhabitants. HIZ practices that save all homes from wildfire but ignore severe impacts to the surrounding landscape cannot be wholly successful in creating a fire-adapted community. In fact, wildland values may be harder to restore, take longer, and be more expensive than reparations to the developed infrastructure. Thus, the goal of creating a fire-adapted WUI community is not achievable by focusing solely within the HIZ, but must encompass the land management options afforded by the ecological requirements of the wildland ecosystems. Low-elevation forests are amenable to treatments that supplement the ecological dependency on fire and also mitigate effects and spread of wildfires under extreme conditions. Fires in grasslands, shrub lands, and high-elevation forests do not offer mitigation opportunities that align easily with ecological requirements. With such vegetation-imposed constraints on landscape management, the remaining options for risk mitigation are those that protect structures and improve community preparedness for inevitably extreme fire behavior and effects. Wildfire risk in places like the Colorado foothills, however, can greatly benefit from landscape treatment that reduces the probability of wildfire spread, severity of watershed impacts, and the likelihood of loss of wildland and developed assets provided that the treatment amounts, locations, and prescriptions are well targeted toward realistic wildfire conditions.

In conclusion, if the goal is to have fire-adapted communities, successful and efficient wildfire response, and resilient landscapes, an integrated risk-sharing approach is required. Communities and private property owners must address the HIZ. Without risk sharing from at-risk communities, public land managers are subject to increased professional exposure under the rare conditions when prescribed fire escapes and wildland firefighters are put at higher exposure when wildfires occur within the WUI. However, if HIZs are well maintained, public land managers can focus on expanded burning (prescribed and beneficial natural fire) and begin to reduce wildfire-related losses of developed and natural resource values, and thereby untangle the wildfire paradox and reduce home loss within the WUI.

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