CSIRO PUBLISHING

International Journal of Wildland Fire
http://dx.doi.org/10.1071/WF16020

Recovery and adaptation after wildfire on the Colorado Front Range (2010–12)

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Abstract. Following the loss of homes to wildfire, when risk has been made apparent, homeowners must decide whether to rebuild, and choose materials and vegetation, while local governments guide recovery and rebuilding. As wildfires are smaller and more localised than other disasters, it is unclear if recovery after wildfire results in policy change and adaptation, decreasing assets at risk, or if recovery encourages reinvestment in hazard-prone areas. We studied three wildfires on the Colorado Front Range from 2010 to 2012 that each destroyed over 150 homes, describing policy response and characterising the built environment after wildfire. In each location, we found some adaptation, through better-mitigated homes and stronger building and vegetation mitigation standards, but also extensive reinvestment in hazard-prone environments, with governmental support. Despite suggestions that disaster can lead to substantial policy change and elevate the role of land-use planning, we saw only modest reforms: local governments did not revise land-use regulations; a statewide task force considered but did not require standards for building and vegetation mitigation; and only one jurisdiction strengthened its building and vegetation mitigation standards. Experiences in Colorado suggest that time after wildfire either does not provide extensive opportunities for adaptation in the built environment, or that these opportunities are easily missed.

Additional keywords: communities, planning, post-fire impacts, risk, wildland–urban interface, WUI.

Received 5 February 2016, accepted 22 July 2016, published online 21 September 2016

Introduction

The wildland–urban interface (WUI), where homes meet or intermingle with wildland vegetation, currently contains a third of all homes in the United States (Martinuzzi *et al.* 2015). WUI expansion intensifies the challenges of wildfire management, causing more ignitions and creating more infrastructure to protect during fire (Hammer *et al.* 2009). From 1999 to 2014, an average 1372 residences were destroyed annually by wildland fire, despite billions spent on suppression (National Interagency Fire Center 2014). In response to the challenges of wildfire management, the National Cohesive Wildland Fire Management Strategy advocates the creation of fire-adapted communities that can coexist with wildfire, through education, fuel treatments, and planning and management of the built environment (Fire-Adapted Communities Coalition 2013).

The built environment in a fire-adapted community must be purposefully designed and managed to reduce wildfire risk. At the level of individual homes, fire-resistant materials and appropriately selected and maintained vegetation can lower the risk of wildfire (Cohen 2000; Mell *et al.* 2010). At the community level, homeowners can be encouraged to undertake mitigation (materials and vegetation) voluntarily, or required to do so through regulations (hereafter, WUI regulations) (Winter *et al.* 2009; Fire-Adapted Communities Coalition 2013). Zoning and land-use regulations can also reduce the risk of wildfire loss by guiding the spatial extent and pattern of development (Bhandary and Muller 2009; Buxton *et al.* 2011; Paveglio *et al.* 2013; Syphard *et al.* 2013). However, land-use regulation remains unpopular in many areas (Muller and Schulte 2011). Where they do exist, fire-related land-use regulations often focus on safety (e.g. egress and water access), rather than restrict development (Harris *et al.* 2011; Muller and Schulte 2011). Neighbourhoods today reflect decades of development and management decisions, with many homes already built in fire-prone locations during eras when wildfire risk was not considered when building. Therefore, although land-use and WUI regulations could reduce wildfire losses, it is not clear whether communities will use these tools to become more fire-adapted

(McCaffrey 2015). At the level of the individual home, voluntary programs are much more common than WUI regulations, but may not be sufficient to reduce risk.

The recovery process after a wildfire may present an opportunity for adaptation in the built environment, including WUI and land-use regulations, and number, placement and mitigation (materials and vegetation) of homes. Natural hazards often become salient on the policy agenda after disasters occur, opening a 'window of opportunity' for changes in policy (Solecki and Michaels 1994; Birkland 2006). Indeed, WUI regulations are often adopted after wildfires that destroy houses and lives (Duerksen *et al.* 2011). Similarly, after wildfires and other natural disasters, residents may re-evaluate risks and make changes to reduce risk (after fire, improve accessibility, mitigate vegetation, relocate, or decide not to rebuild if a home is lost) (Flint 2007; Brenkert-Smith *et al.* 2012; Champ and Brenkert-Smith 2015; Mockrin *et al.* 2015).

However, such realignment also may not occur at community and homeowner levels (Solecki and Michaels 1994; Platt *et al.* 2002; Birkland 2006; Collins and Bolin 2009). Recovery following other disasters demonstrates that meaningful land-use change, including limiting rebuilding based on anticipated future hazard, is rare (Olshansky 2001; Highfield *et al.* 2014). Local officials are pressured to facilitate a quick 'return to normal', often at the expense of long-term adaptation (Olshansky *et al.* 2012). Adaptive policy responses are challenging to design; quickly developed policies may be ineffective and unenforceable (e.g. Ingram *et al.* 2006), but delaying recovery to assess policy options may be politically infeasible (Platt *et al.* 2002; Nelson 2014). Pressure to rebuild, institutional arrangements (e.g. local regulation, insurance payouts, construction financing, disaster relief) and hastily enacted policy changes can combine to create perverse incentives, encouraging rebuilding without reducing risk (e.g. relaxing building regulations) (Solecki and Michaels 1994; Platt *et al.* 2002; Collins and Bolin 2009; Schultz and Elliott 2013). After hurricanes, tornadoes and floods, affected areas often experience increases in population, housing and housing price, rebounds lauded by local government as a visible sign of recovery (Pais and Elliott 2008; Schultz and Elliott 2013).

Although it may seem logical that exposure to hazards would encourage residents to adapt, previous disaster experience has variable effects on risk perception and mitigation action (Lindell and Perry 2000; Tierney *et al.* 2001). For some people, risk perception is heightened and mitigation is more likely after fire, but for others, wildfire diminishes perceived risk and discourages or has no effect on mitigation (Collins and Bolin 2009; McGee *et al.* 2009; Carroll *et al.* 2011; Champ and Brenkert-Smith 2015; Mockrin *et al.* 2015). Residents may remain attached to a place or lifestyle (Adger *et al.* 2009; Stevenson *et al.* 2010), or experience denial of risk or fatalism (McCaffrey *et al.* 2013).

The recovery period after wildfire is therefore an important time for changes in the built environment and the regulations that shape it, but current understanding of wildfire recovery is limited. Recovery and rebuilding research has so far focused on hurricanes, floods and tornadoes, which destroy many more homes (Pais and Elliott 2008; Zhang and Peacock 2009). These disasters often exceed the resources of state and local governments, and communities receive federal assistance through 'Major Disaster Declarations'. For the worst disasters, individuals who have experienced property loss or damage receive direct assistance via federal grants (FEMA 2016*a*, 2016*b*) intended to fill the gap between needs and private resources including insurance (Zhang and Peacock 2009). In contrast, there is rarely federal assistance for individuals following wildfire. Three wildfires from 2010 to 2015 received Major Disaster Declarations, yielding individual assistance for 2627 households (FEMA 2015). Unlike the federal floodplain regulations and insurance programs that restrict or discourage rebuilding after flooding (Burby 2001; Thomas and Leichenko 2011), there are no such federal programs for wildfire. Local institutions guide wildfire recovery and rebuilding, and homeowner losses are covered by standard homeowners' insurance. Insurance losses from wildfire are relatively small compared to other hazards, so insurance coverage is generally not limited because of fire risk (Massey and Lehmann 2013).

Past studies of wildfire impacts have focused mostly on social processes and community function (Paveglio *et al.* 2015*a*), finding some evidence of adaptation, namely, landscape-level fuel treatments and planning for evacuations (Goldstein 2008; Jakes and Sturtevant 2013; Abrams *et al.* 2015). We have limited information on changes in the built environment, and how policy responses and regulations vary across settings and contribute to homeowners' rebuilding decisions. Remotely sensed imagery demonstrates that building of structures after wildfire is highly variable; nationally from 2000 to 2005, after 106 fires where at least one building was lost, rebuilding occurred after 39 fires (between 8 and 100% of structures lost rebuilt within 5 years) (Alexandre *et al.* 2015). However, after 74 of those same fires, new construction outpaced rebuilding. Proximate housing growth rates outside fire perimeters were less than or equal to those within fire perimeters for 75% the fires studied, suggesting that fires do not restrict, and may stimulate, growth (Alexandre *et al.* 2015). Case studies demonstrate that at the household level, decisions to rebuild and mitigate are complex, reflecting individual circumstances (finances, risk perception) as well as local government policies (McGee *et al.* 2009; Mockrin *et al.* 2015). The highly variable character of post-fire response makes it a fertile area for research and highlights the importance of sharing lessons learned across sites. We studied three wildfires on the Front Range of Colorado (2010–12) to assess how recovery facilitated or impeded adaptation, focusing on changes in the built environment because housing is a quantifiable and publicly available marker of adaptation and recovery (Highfield *et al.* 2014), and one of the main factors that influences future wildfire management challenges.

Study areas and fires

Colorado has experienced increasingly destructive wildfire seasons over time. The 2002 Hayman Fire destroyed 133 homes and led to nearly US$100 million in insurance losses. It was surpassed in magnitude by the 2010 Fourmile Canyon Fire, the 2012 High Park Fire, the 2012 Waldo Canyon Fire and the 2013 Black Forest Fire. Each of those fires was the most destructive in local history and, combined, they resulted in more than US$1 billion in insurance claims, the loss of four lives and the destruction of 1274 homes (Wildfire Insurance and Forest

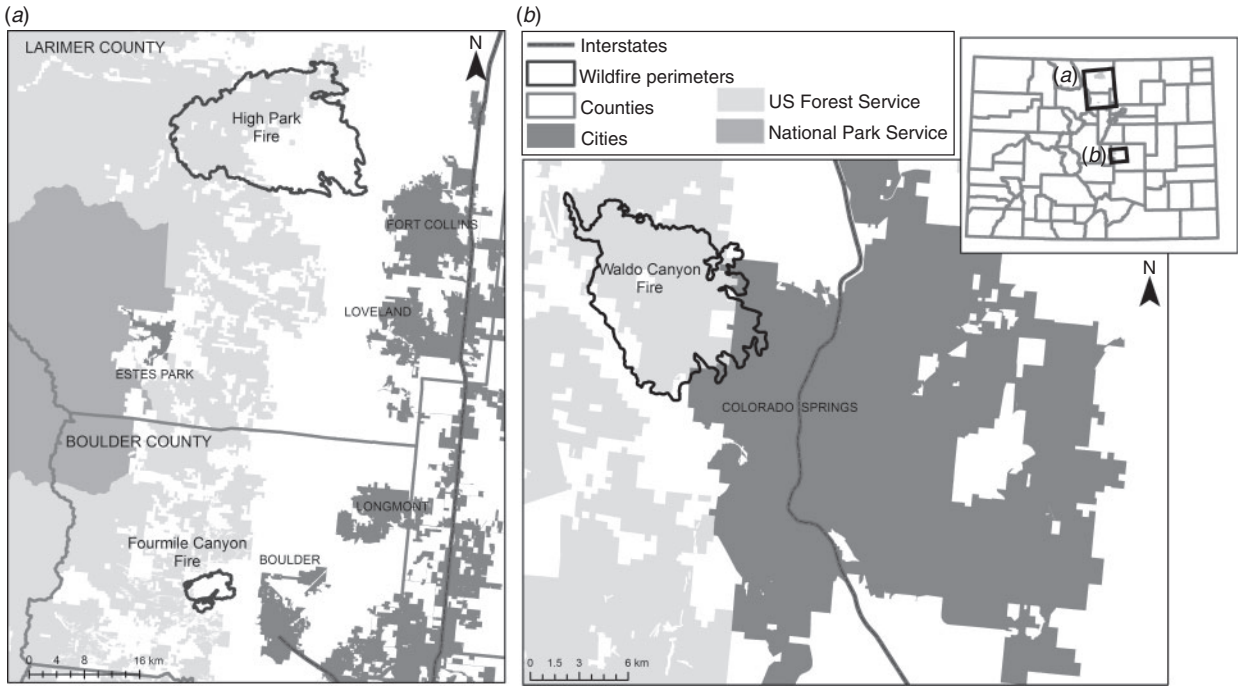

Fig. 1. Location of major wildfires 2010–12 on the Colorado Front Range: (*a*) High Park and Fourmile Canyon fires and (*b*) Waldo Canyon fires. Inset shows each region within context.

Health Task Force 2013). Despite the rising profile of wildfire hazards in the state, fire planning and management in Colorado fall primarily to the local level, with the state requiring counties to adopt Community Wildfire Protection Plans (CWPP) if fire risk exists (Colonised Revised Statutes 2011, 30–15–401.7 Determination of fire hazard area – Community wildfire protection plans – Adoption – Legislative declaration – Definitions) and authorising local governments to engage in wildfire planning and response and general land-use planning and regulation (Legislative Council Staff 2016). We studied three of these fires, the Fourmile Canyon fire, the High Park Fire and the Waldo Canyon Fire (Fig. 1) (the Black Forest Fire occurred after our fieldwork). WUI communities are diverse (Paveglio *et al.* 2015*b*), and each of the study locations had a unique mix of socioeconomic, institutional and biophysical characteristics.

Fourmile Canyon Fire – unincorporated Boulder County

The Fourmile Canyon Fire started on 6 September 2010 in the foothills 9.66 km (6 mi) west of Boulder, and burned over 90% of a 25 km^2 fire area within the first 10 h (Graham *et al.* 2012), destroying more than a third of the homes within the fire perimeter (165 out of 474). Vegetation is ponderosa pine–juniper and Douglas-fir–ponderosa pine, depending on elevation (Graham *et al.* 2012). This unincorporated area is a bedroom community in the foothills west of the city of Boulder and its residents value their independence and WUI environments (Mockrin *et al.* 2015). Housing stock affected included modest, older homes from the 1960s and 1970s as well as more affluent and recently developed areas with expensive homes. Housing is dispersed and served by steep, narrow roads. House-to-house fire spread was not a major factor in structure loss. Property values within the city of Boulder and nearby areas are high (Castle 2015).

Boulder County residents are generally politically progressive and county government has long been active in land-use planning and wildfire mitigation. After 44 homes were lost in 1989 to the Black Tiger Fire, the county adopted WUI regulations for new homes in designated wildfire zones. Since 1990, all new roofs had to be Class A fire retardant (Boulder County 2011*a*), and since 1993, building permit approval has required a vegetation mitigation plan (Boulder County 2015). Land-use and building codes mandate best site location on the property, vegetation mitigation, access, water supply and fire-resistant materials (Boulder County 2013, 2015). From the early- to mid-1990s, the county assessed risk to individual homes (although funding precluded regular updates) (Boulder County 2011*a*), provided mitigation education and supported homeowner vegetation mitigation through reimbursement and community facilities for vegetation disposal (Boulder County 2011*a*). A county-wide CWPP was completed in 2011 (Boulder County 2011*a*).

High Park Fire – unincorporated Larimer County

From 9 June 2012 until containment on 1 July 2012, the High Park Fire burned over 352 km^2 on a mixture of Forest Service and private land, in the foothills 32.19 km (20 mi) west of Fort Collins, destroying 259 structures and causing one fatality. Housing included primary residences and seasonal homes (cabins), some clustered in small unincorporated communities, many of them modest, older structures. Residents value WUI amenities and lifestyle (Brenkert-Smith *et al.* 2006). Roads are steep and narrow, and housing is low-density, so house-to-house fire spread was not a major factor in losses. Vegetation is

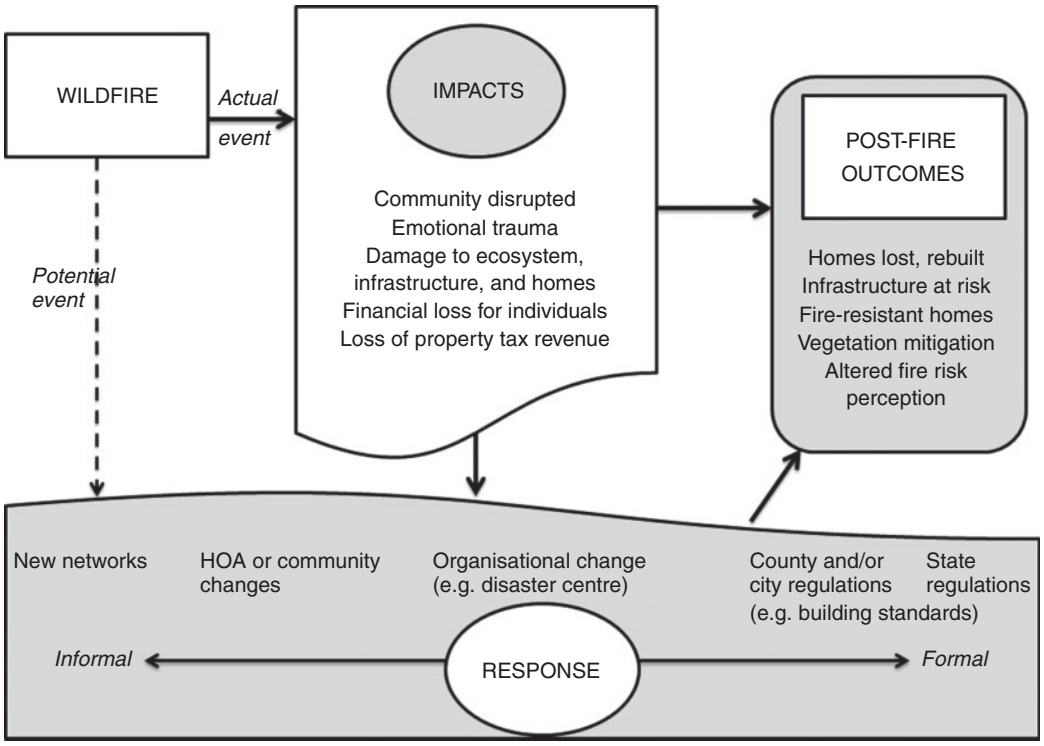

Fig. 2. Wildfire impacts, policy responses and resultant outcomes after wildfire, adapted from Birkmann (2010). HOA, homeowners' association.

predominantly mature lodgepole pine with mixed-conifer forests at lower elevations (Forest Service BAER Program 2012).

Larimer County has had wildfire-related regulations since 1990, starting with a roofing materials ordinance. In 1998, the county identified a wildland fire hazard area where all new construction must meet WUI standards (vegetation, materials) (Larimer County 2014*b*, 2014*a*) and created a county wildland fire safety program to provide education, hazard assessments and vegetation disposal assistance, and conduct vegetation thinning (Larimer County 2009). In 2002, the county completed a county-wide subdivision wildfire hazard assessment (Larimer County 2009). The county has had a County Fire Plan since 2003, last updated in 2009 (Larimer County 2009).

Waldo Canyon Fire – City of Colorado Springs

The Waldo Canyon Fire affected densely clustered single-family homes in suburban Colorado Springs. The fire started on 23 June 2012, required the evacuation of 30 000 people, destroyed 347 homes (out of 1928), burned 74 km^2, killed two residents and took firefighters 18 days to fully contain (Quarles *et al.* 2013). Lots were small and homes were often only 3.66 to 6.10 m (12 to 20 ft) apart, so many were destroyed owing to house-to-house fire spread (Maranghides *et al.* 2015). Homes were modest primary residences, constructed mostly in the 1980s, and served by municipal utilities, housing middle-class residents. Vegetation includes Gambel oak, ponderosa pine, mixed-conifer and pinyon–juniper communities (Maranghides *et al.* 2015).

Colorado Springs has an active wildfire mitigation and preparation program. WUI regulations (structures and vegetation) apply to homes in a designated Hillside Overlay Zone. First passed in 1993 to preserve natural resources and reduce geologic hazards, wildfire standards were added in 2003, starting with roofing requirements (City of Colorado Springs 2006; City of Colorado Springs Fire Department 2013). Wildfire education began in the early 2000s, and the city created a wildfire mitigation plan in 2001, and a CWPP in 2011 (City of Colorado Springs 2011). The wildfire mitigation program serves over 36 000 households, provides individual risk assessments and includes an active vegetation management program (disposal assistance, fuel treatments in open space) (City of Colorado Springs 2011). The city is politically conservative (Tausanovitch and Warshaw 2014), and strongly influenced by military, business and evangelical Christian groups.

Methods

We characterised recovery policy and outcomes using Birkmann's (2010) framework (Fig. 2). Formal responses are local government policies, whereas informal responses are changes made by non-state actors, including non-profit organisations and homeowners' associations (HOAs). In addition to local governments', we also present state-level response to the fires and changes in the availability of federal resources: the State of Colorado re-evaluated WUI fire management after the 2012 fire season, and catastrophic flooding occurred on the Front

Range in 2013,[1] further elevating the importance of hazard mitigation and recovery. Policy responses, combined with fire impacts, result in post-fire outcomes (Birkmann 2010) including changes in the built environment. In order to assess how recovery after wildfire contributes to, or forestalls, becoming a fire-adapted community, we used Smit and Wandel's (2006) definition of adaptive responses as those that reduce future vulnerability. Specifically, we considered the number of homes in the area, use of fire-resistant materials and vegetation mitigation practices, and lesser or equivalent home size and value when rebuilding to be adaptive responses. Rebuilding larger and more valuable homes increases potential economic losses and, if house-to-house fire spread is an issue, larger homes increase future risk (Collins and Bolin 2009).

We used a mixed-methods case study design to investigate policy responses and outcomes after wildfire, reviewing government documents, interviewing local officials and community leaders, and collecting background information from newspaper articles. Documents gathered included WUI and land-use regulations, reports on the wildfires and recovery, CWPPs, communications specific to fire response (websites, pamphlets, press releases) and state legislation. To assess recovery policy, we surveyed documents for a standard set of information: who created policy and gave guidance; incentives or restrictions to guide rebuilding, including fees and home size restrictions; time allowed for rebuilding; and time between the fire and policy issuance. For WUI regulations, we identified standards for materials and vegetation. Augmenting document review with interviews is common in hazards research, to better understand policy intent, adoption and perceived efficacy (e.g. Olshansky 2001; Harris *et al.* 2011). We used interviews to describe motivations for and development of government response, allocation of government resources, perceptions of how standards in WUI regulations performed during the fire, the process by which any changes in WUI regulations occurred, and information on the actors involved in recovery and rebuilding. Interviews also provided insights about homeowners' logistical challenges and factors that influenced rebuilding, including homeowners' risk perception and interest in mitigation.

We interviewed 27 people, including eight government employees (recovery programs, wildfire mitigation, building department, land-use department, utilities), seven non-profit employees, four fire department leaders (volunteer and government departments), five community or neighbourhood leaders serving as representatives to government or non-profit organisations, two home builders (in Colorado Springs) and one regional insurance industry representative. Interviews were conducted individually or in pairs, with one six-person group discussion at a Colorado Springs non-profit organisation. In total, we spoke to six people in Boulder, eight in Larimer and twelve in Colorado Springs. We identified interviewees from online research, and key interviewees recommended others to contact. M. Mockrin conducted interviews in person when possible (three over the phone) within 1 to 2 years after wildfires, using the same set of open-ended, semi-structured questions. After professional transcription, we used open coding to organise concepts into initial categories, then focused coding to organise material into themes (Corbin and Strauss 2015).

Results

Recovery programs and policy

In each of the three fires, local government created recovery programs and redirected resources to recovery (Table 1). Boulder and Larimer counties hired recovery coordinators, whereas in Colorado Springs, recovery was run by a non-profit organisation, Colorado Springs Together (CST), which only existed for 1 year after the fire, at the behest of the mayor. In each location, rebuilding was a key part of recovery; local governments invested substantial resources in promoting and facilitating rebuilding (Table 1). Boulder County expedited site-plan review and each homeowner had a case manager in the land-use department (Boulder County 2014). Larimer County reduced building permit fees for those who were under- and uninsured (Larimer County Board of Commissioners 2012*b*). Colorado Springs simplified site-plan review by allowing the use of previous plans and master plans (City of Colorado Springs 2012), and reduced fees for site-plan review and utility reconnection (City of Colorado Springs 2012; City of Colorado Springs 2012).

Recovery program leaders and local governments described their efforts as supporting homeowners and encouraging rebuilding, with rebuilding critical to ensuring community recovery:

> Larimer County is anxious to be supportive of citizens impacted by the fires while being fair and responsible with County resources. Insurance policies should cover building permit fees in many cases while today's approval addresses a process for those owners who are not insured or are underinsured. A reduction of building permit fees also provides an incentive for rebuilding, which will provide economic and community support in fire areas. (Larimer County Board of Commissioners 2012*a*)

> For members of our community who have been impacted by the fire, we are deeply committed to helping you with your recovery efforts. Please let us know if there is anything we can do to assist you as you continue to rebuild your lives and homes. (Boulder County Commissioners; Boulder County 2011*b*)

> CST's mission:
>
> to serve as the primary community organisation to bring the community spirit and substantial resources of the businesses and citizens of the Pikes Peak Region to restore the lives, homes, and neighborhoods impacted by the Waldo Canyon Fire. We will restore these quickly and effectively. (Colorado Springs Together 2016)

In all locations, the design for recovery programs (county coordinator, CST) emerged within days of fire containment, and recovery policies were established quickly (Table 1). Recovery programs used resources from the Federal Emergency

[1]Flooding along the Front Range is not uncommon, but this event was unusually severe. Heavy and widespread rainfall affected 14 counties, killing 10 people, destroying 2000 homes and damaging 26 000 homes (Hines *et al.* 2014).

Table 1. Rebuilding programs in Boulder, Larimer and Colorado Springs
WUI, wildland–urban interface; HOA, homeowners' association

Boulder	Larimer		Colorado Springs
Recovery policy created by	County commissioners	County commissioners	City government, including Development Review Enterprise and Pikes Peak Regional Building Department
Resources available from	County recovery coordinator, county land-use department	County recovery coordinator, county planning and building services	Colorado Springs Together (CST)
Recovery policy issued	5 weeks post-fire	4 weeks post-fire	4 weeks post-fire
Recovery program duration	Recovery coordinator for 2 years, stayed after 2013 floods	Recovery coordinator for 1 year, stayed after 2013 floods until summer 2015	CST open for 1 year
Rebuilding timeline	2 years with a 1-year extension for building permit. Extended to 3.5 years	3 years for debris removal and building permit	2 months for debris removal; building permit within 4 years. After 5 years, charges for utility hook-up return to normal
WUI regulations changed	No	No	Yes, strengthened
Building/land-use codes changed	No. Did allow trailers, considered non-conforming uses and structures,[A] helped those who did not obtain a permit when house was first built	No. Did allow trailers, considered non-conforming uses and structures,[A] helped those who did not obtain a permit when house was first built	Some lessened. Could be built to earlier codes but not life and safety standards, including fire. Site review standards for geohazards waived; homeowners advised to consult with an engineer or geologist
Size of home	Restricted by expedited site-plan review: requires same size or up to 49.24 m^2 (530 ft^2) bigger.[B] Additional approvals needed for wastewater if number of bedrooms increases	Not restricted, other than standard height, setback requirements. Additional approvals for wastewater if size increases	Not restricted, other than standard coverage, height, setback requirements. Some HOAs had minimum size (approval needed to build smaller)
Permit and utility hook-up fees	Building permit unchanged. No charge to reconnect septic	For under- or uninsured reduction US $1000 in building permit/property (any structure). Funded for 60% of those who lost structures[C]	Building permit unchanged. Substantially reduced review fee (charged non-Hillside). Utility reconnection reduced for 5 years

[A]With full site-plan review, home must be within 25% of neighbourhood median size.
[B]Uses and structures that were legal when built but not allowed under current zoning and codes.
[C]Also included Woodland Heights fire (2012), Estes Park, 25 homes lost.

Management Agency (FEMA) and other communities experienced with wildfire. For example, Boulder's decisions to place limits on the size of rebuilt homes and not waive building permit fees resulted from discussions with governments in California and Colorado (Hayman Fire). Larimer County's response was modelled in part on Boulder's. CST used resources from FEMA, and the Colorado Springs building department's response was shaped by employee experience with other disasters (outside CO). Interviewees in all locations also asserted that such resources were limited and that their situations were unique, requiring them to improvise and 'learn on the job'.

WUI regulations

Before the fire, each jurisdiction had WUI regulations, and Boulder and Larimer counties did not lessen requirements, whereas Colorado Springs strengthened them (City of Colorado Springs 2013; City of Colorado Springs Fire Department 2013) (Table S1, available as online supplementary material).[2] None of the locations required changes to homes that survived fires, and none made changes to broader land-use regulations such as zoning or land subdivision regulations. Boulder County devoted the most consideration to combining rebuilding with other land-use goals (e.g. home location changes within parcels were encouraged if they reduced fire hazard, improved access or lessened land-use impacts) (Boulder County 2014).

Comparing WUI regulations, all locations now specify roofing and siding materials; Boulder County and Colorado Springs have additional requirements (e.g. gutters, decks, soffits, windows, sprinklers and mesh screening on openings), many of them newly adopted in Colorado Springs (Table S1). The vegetation requirements for foothills locations (Larimer and Boulder) both followed the Colorado State Forest Service (CSFS) recommendations, which are tailored for large lots and exurban settings, whereas Colorado Springs' standards reflect

[2]Boulder and Larimer County did later make some changes to building material standards in the 2015 code amendments, applicable to permits issued in 2016 (Table S1).

their smaller lots (Table S1). Major changes in vegetation requirements in Colorado Springs included increased clearance around the house and stricter requirements for removing tree limbs, and design standards now include more guidance on plants and maintaining vegetation (City of Colorado Springs 2006; City of Colorado Springs Fire Department 2013).

These fires presented interviewees a rare opportunity to consider whether building materials and vegetation mitigation improved likelihood of home survival. In all locations, interviewees deemed vegetation mitigation and structural changes helpful, but not a guarantee that a home would survive fire because of the 'extreme' natures of these fires. In Larimer County, one fire expert thought the number of homes lost demonstrated the limitations of these standards. Boulder County officials were more optimistic about the regulations, because newer homes, built to stricter regulations, experienced higher survival rates (Wildfire Insurance and Forest Health Task Force 2013). In Colorado Springs, a fire department investigation deemed older standards insufficient, resulting in new regulations. These were quickly enacted after a series of public hearings with homeowners, insurance companies and builders. Those involved emphasised the collaborative nature of reforms and close links between government and the building community. Builders and architects estimated the costs of new standards, improving community support. Interviewees discussed objections to guidelines applying to only new construction, which some of those rebuilding thought targeted them. However, making regulations retroactive was not politically feasible.

Informal policy response

Interviewees in each location detailed the critical role of non-profit organisations in recovery, coordinating social services such as mental health assistance and providing help with rebuilding. In Larimer County, the NoCo Rebuilding Network formed after a 2010 fire destroyed 13 homes to promote rebuilding sustainably in a fire-adapted manner (resources also available for those relocating to a non-WUI area). In Boulder and Larimer County, United Policyholders, a non-profit organisation formed after the 1991 Oakland Hills fire (CA), provided information about insurance. CST worked with the Rocky Mountain Insurance Information Association, a regional organisation of insurance companies (Handy 2013).

The importance of HOAs varied: none of the homes lost in Boulder County were in HOAs, some were in Larimer County and all were in Colorado Springs (32 HOAs in Colorado Springs, B. Cutter, pers. comm.). In Colorado Springs, interviewees mentioned several instances where HOAs required or encouraged rebuilding (e.g. approval required to rebuild a smaller home, vacant lots not allowed by covenant). Where HOAs were present, they facilitated the restoration of communal infrastructure but the magnitude of damage was challenging. In Colorado Springs, neighbourhoods needed expensive repairs (drainage, irrigation) that required raising HOA fees despite the loss of homes. Some HOAs had not been active, governing documents were destroyed in the fire, or covenants and architectural standards were outdated. The building department began sharing permits online so that HOAs could review rebuilds. Lastly, although HOAs could be effective at information-sharing within their boundaries, they could also hinder broader communication by each contacting the city separately.

In all locations, there were common benefits and challenges to the community after the fires. Interviewees spoke of stronger community ties and of new, stronger and more resilient networks emerging, especially for communication and aid, but the stress and challenges of losing homes and rebuilding led to negative interactions as well. Residents valued rebuilding: both Boulder County and Colorado Springs gave homeowners gift baskets after reconstruction.

State and federal policy response and resources

At the state level, Governor Hickenlooper (Democrat) convened a WUI Task Force in response to these wildfires, to identify and support state and local activities to promote forest health and reduce losses from wildland fires (State of Colorado 2013). Although the task force recommended a state-level model ordinance for WUI regulations and prohibition of inconsistent community building or land-use requirements such as HOA mandates to use materials that increase fire risk, they declined to recommend mandatory state-level standards as 'one-size-fits-all solutions are not appropriate in a state like Colorado with diverse ecosystems and communities. Local solutions are more likely to enhance community buy-in, creating the necessary conditions for meaningful change' (Wildfire Insurance and Forest Health Task Force 2013). To date, no model ordinance is in place nor are inconsistent policies prohibited, but new legislation on insurance and vegetation mitigation was enacted. The Homeowner's Insurance Reform Act (House Bill 13–1225 2013) clarified responsibilities, required more coverage be made available for homeowners and set new methods for estimating replacement costs. The Wildfire Risk Reduction Grant Program (Senate Bill 13–269 2013) funds vegetation projects on non-federal lands through the Colorado Department of Natural Resources (Colorado Department of Natural Resources 2015).

Federal resources were initially limited: only Larimer and Colorado Springs fires were declared Major Disasters (28 June 2012), providing FEMA funds for counselling and unemployment assistance and loans from the Small Business Administration. However, homeowners affected by the 2013 floods received individual assistance for housing damages through (among other sources) Housing and Urban Development Community Development Block Grants (CDBG), and the 2012 fires in Colorado Springs and Larimer County were retroactively declared eligible for these CDBG funds in 2015. At the state and local level, federal funds post flooding created a new source of support for long-term disaster and recovery planning, including wildfire (Colorado Department of Local Affairs 2015).

Outcomes

Rebuilding rates varied substantially among the three fires. Within 2 years, 75% of all homes lost to fire in Colorado Springs had been replaced or had permits approved, but only 30 and 34% in Larimer and Boulder Counties were being rebuilt or had permits to rebuild. As of January 2016, 3.5 years after the Colorado Springs and Larimer fires and 5.5 years after the Boulder fire, 88% in Colorado Springs, 31% in Larimer County and 52% in Boulder County were rebuilt or had permits to rebuild.

All rebuilt homes met current WUI standards. Although no changes were required for surviving homes, each location saw initial increased interest in mitigation, especially vegetation mitigation. In all locations, some residents remained uninterested in undertaking vegetation mitigation or structural modifications. In some cases, interviewees thought homeowners were less motivated to choose fire-resistant materials because they believed loss of vegetation lowered their future risk of wildfire. Interviewees expected interest in voluntary efforts to diminish over time.

Colorado Springs experienced the most active real estate market after the fire, including sales of now-vacant lots, and assessed home values returned to pre-fire levels within 2 years (Handy 2014). Home builders purchased multiple lots for future development, modest 'starter' homes lost to fire were replaced by more upscale houses, and assessor's data indicated that rebuilt homes were 13% bigger than those lost, on average (Handy 2014). In foothills locations (Larimer and Boulder), interviewees reported few lot sales and declining housing values, due to the national housing crisis and the fires. By 2015, however, foothills real estate hit new peaks, partially driven by land costs in the cities of Boulder and Fort Collins (Ferrier 2015; Castle 2015), and housing values in Boulder city and the surrounding area remain some of the highest on the Front Range. In Boulder, rebuilt homes were similar in size to those that were destroyed (because of the rebuilding regulations), but it is unclear how home sizes changed in Larimer County. Although home site changes were encouraged if they enhanced safety in Boulder County, existing access and topography made it challenging to change locations (Mockrin *et al.* 2015). In all study areas, these locations are prised for their views and amenities, and opportunities for future development are constrained (area is 'built out'), especially in Boulder and Colorado Springs.

Factors that influenced rebuilding

Interviewees identified multiple factors common across fires that shaped rebuilding decisions: finances, emotional trauma, attachment to the neighbourhood or setting, age or lifecycle concerns, pre-existing motivations for moving, and challenges of working with insurance companies. Opinions about future risk of fire were similar across locations: interviewees thought fire was likely to occur again and that fuels remained, but heightened risk perception did not consistently discourage rebuilding. Many thought that future risk of damage to homes was lower because there was less vegetation, and rebuilt homes were constructed to better standards. Interviewees blamed extreme weather for the large numbers of homes lost, expecting that future fires would be less destructive. Fire officials consistently expressed more concern about future risk than other interviewees.

Both the foothills and urban locations faced logistical challenges with rebuilding and recovery. In the foothills (Boulder, Larimer), damage to vegetation required substantial restoration on private land, private roads needed costly repairs, and there was an increased risk of flooding from normal rainfall. In Colorado Springs, small private lots made vegetation restoration less of a concern, but high housing density and repairs to city utilities complicated rebuilding. However, the foothills communities faced several unique challenges. Insurance was often lacking or insufficient to rebuild homes, in part because building costs were high owing to the unusual sites and remote locations. Costs and confusion surrounding insurance complicated rebuilding; some interviewees speculated that rebuilt homes could not be resold for a profit while markets remained depressed and others wondered if insurance companies would facilitate payment to those rebuilding (there should be no difference in payout, although the timing will vary) (Mockrin *et al.* 2015). These areas were also affected by widespread flooding in 2013. Residents in foothills areas were not pressured to rebuild quickly; they could keep the land for recreation purposes or build a second home, options not available to residents of the urban area in Colorado Springs. Lastly, interviewees said that some foothills residents expressed a desire for a more suburban or urban lifestyle.

Discussion

Costs and challenges of wildfire management in the USA have increased dramatically over the past 40 years, and are only expected to intensify in the future as a result of climate change, residential development, the legacy of fire exclusion. However, we know little about recovery and adaptation after wildfire. Colorado suffered unprecedented losses from the Front Range wildfires of 2010–12. Approximately 5 years after these fires, this is an opportune time to examine recovery and rebuilding.

Wildfire impacts and responses were similar across the Front Range and a diversity of WUI communities. Each location experienced similar disruptions for homeowners and communities and despite wildfires being smaller events, formal responses to wildfire were similar to other disasters. Government support for recovery was prominent, rebuilding was a fundamental part of recovery, and all programs were quickly designed and implemented. However, at present, rebuilding rates vary from 31 to 88%, similar to variability seen in other studies (e.g. Alexandre *et al.* 2015). We suggest that rebuilding rates reflect the diversity of the WUI: urban areas were all primary homes, individuals had more financial resources and fewer logistical challenges, the real estate market was active, and HOAs encouraged rebuilding. Government recovery programs alone did not ensure fast or widespread rebuilding.

Following Smit and Wandel's (2006) definition of adaptive responses as those that reduce vulnerability to wildfire, we see evidence that fires promoted adaptation as well as reinvestment in hazard-prone environments. Based on the strength of local real estate markets and the lack of land-use reforms, we suggest that the number and configuration of homes will eventually return to pre-fire conditions. Rebuilding has been slower in the foothills, but if strong real estate markets are sustained, we expect homes to be rebuilt over time, especially in the Boulder areas with higher property values. In Colorado Springs, fire led to what Pais and Elliott (2008) dubbed the 'recovery machine', where governments, markets and homeowner resources encourage redevelopment. In each location, rebuilding puts more assets at risk, given an influx of brand-new and, in some cases, larger homes. In Colorado Springs, size increases also raise concern about house-to-house fire spread.

Although housing is returning to fire-prone areas, new homes are more likely to withstand wildfire, because they were built to

current WUI standards, often replacing older homes that were built before wildfire was a concern. Homeowners may not have made similar choices without regulations, as financial constraints, decline in perceived risk and doubts about WUI standards' performance observed here can discourage mitigation (cf. Arvai *et al.* 2006; McGee *et al.* 2009; Mockrin *et al.* 2015). Ultimately, it is unclear how required and voluntary changes will change housing (materials and vegetation). Typically, more homes survive than are lost to fires, and successful risk-reduction long term will require continued vegetation mitigation. Although some of those with surviving homes were more interested in mitigation after fire, interviewees also thought interest would diminish over time, a belief supported by research (e.g. Carroll *et al.* 2005).

Despite evidence that disaster can lead to substantial policy change (Solecki and Michaels 1994; Birkland 2006), we found only modest policy changes in the wake of the fires. Local governments did not revise land-use regulations, the statewide task force declined to recommend statewide WUI regulations, and only one jurisdiction changed its WUI regulations. The extent and pattern of residential development on the landscape greatly affects the risk of wildfire loss (Buxton *et al.* 2011; Syphard *et al.* 2012; Alexandre *et al.* 2016), but in Colorado, these three major fires did not sufficiently raise the salience of land-use controls or restrictions on rebuilding. In this way, fire is similar to other disasters where land-use and planning efforts rarely change after disaster (Berke and Campanella 2006) despite their potential role in hazard mitigation (Frazier *et al.* 2013). In our study areas, much of the land has already been developed and is at risk of fire, potentially limiting the efficacy of land-use controls to reduce future fire risk (Highfield *et al.* 2014).

Without broader land-use change, rebuilding to mitigate future hazard is the remaining alternative (Highfield *et al.* 2014), and the key form of adaptation we observed. Post-fire WUI regulation changes in Colorado Springs were a rare example of timely and effective policy reform: government undertook a damage assessment, concluded that change was needed and acted before too many people started rebuilding, despite substantial pressure to 'return to normal' and rapid rebuilding. Tight links between the building and business communities and local government, Pais and Elliott's (2008) 'recovery machine,' seem to have facilitated policy reform. Among our study areas, these WUI regulations were also the oldest, and the least restrictive, so arguably the most able to benefit from updating. As a suburban community managed by both HOAs and a city government – what Paveglio *et al.* (2015*b*) term a 'formalised suburban WUI community', residents may be more accepting of government regulations and restrictions on homes. WUI regulations in our other two locations were not revised until building code updates in 2015, applicable to homes built in 2016 or later. In Boulder, the Black Tiger Fire was described as the fire that stimulated major policy change. However, in Larimer County, standards are now less stringent than other locations (including 2015 code updates), and if losses from wildfire did not spur extensive revisions, it is unclear if or when the community will undertake such updates. We note that all of our study sites have extensive work on WUI issues, dedicated staff, and that Colorado, particularly the Front Range, has experienced decades of high housing growth (Wildfire Insurance and Forest Health Task Force 2013). Wildfire may lead to different policy responses in other settings.

The state response – discussion without action – supports the notion that although hazards are 'focusing events' that raise the importance of hazards on the policy agenda, they may not lead to change (Birkland 2006). It is at odds with fire-specific research suggesting that repeated losses to fire expand the state's role in wildfire hazard reduction (Muller and Schulte 2011), which in turn facilitates successful local mitigation programs and protects local governments from political fallout (Davis 2001; Harris *et al.* 2011). More research is needed to understand the origins and effects of the state-level policies in response to wildfire, and how county and city regulations arise. California, Oregon, Utah and Nevada each have distinct approaches (Burton 2013), some of which may be more acceptable in Colorado.

We focused on local governmental actions because they affect housing and development, but also observed that, as in other disasters, non-profit organisations emerged to fill gaps in governmental response (Welsh and Esnard 2009), including a non-profit organisation dedicated to wildfire-resistant and sustainable rebuilding in Larimer County. The statewide WUI task force and interviewees highlighted the importance of HOAs; similarly to other studies, this additional level of governance can encourage or require mitigation (Stidham *et al.* 2014) or hinder adaptation (Abrams *et al.* 2015). Although initial rebuilding expenses fell primarily to individual homeowners, the 2013 floods resulted in direct federal assistance to fire-affected homeowners through CDBG grants and may signal a growing federal role in wildfire recovery. Focusing on the built environment, we did not consider other components of fire-adapted communities that can be altered by wildfire (planning, voluntary mitigation,[3] emergency preparation, suppression). Additional research can explore recovery mechanisms, post-fire social learning and civic engagement, and a broader suite of community adaptations (Goldstein 2008; Jakes and Sturtevant 2013). Studies of homeowners can further explore individual rebuilding and mitigation decisions, and how recovery varies with social and economic status, as the socially vulnerable (e.g. renters, minorities, lower-income households) are often slower to recover after disasters (Pais and Elliott 2008; Peacock *et al.* 2014).

In our analysis of the recovery after these fires, we found several commonalities. Wildfire response has much in common with other disasters across settings, suggesting governments can learn from other hazards and communities. Policy-makers should expect immediate pressure to 'return to normal', and can plan for recovery before disaster strikes to maximise adaptive change during their limited policy window (Berke and Campanella 2006). Tools considered in recovery planning for other hazards include: temporary moratoria on building permits, provisions for change in land-use regulations and damage thresholds for changes in building standards (Schwab 2014). Boulder and Larimer County experiences demonstrate

[3]For example, Boulder County launched a new voluntary mitigation program for homeowners in 2014, Wildfire Partners, http://www.wildfirepartners.org/ (accessed 9 August 2016).

that there can be long-term needs for rebuilding assistance and education. People who have not experienced wildfire may erroneously assume that recovery will be quick, especially in comparison with larger disasters (Newman *et al.* 2014).

Conclusions

We found only modest policy changes after wildfires in WUI settings on the Colorado Front Range, and limited adaptation through better-mitigated homes and stronger building and vegetation mitigation standards. Reinvestment in these hazard-prone environments was extensive, and we expect the number and location of homes to eventually be the same as were present before the fire. Planning for recovery before disaster occurs and drawing on experience with other hazards can allow local communities to use wildfires as opportunities for policy evaluation and reform.

Acknowledgements

This work was supported by the Rocky Mountain Research Station and Northern Research Station of the USDA Forest Service. We thank Garry Sanfaçon of Boulder County for his guidance and feedback throughout this study. We also thank all those interviewees who participated in this research.

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