I. Introduction

Background

Wildfires have been increasing in severity and cost over the last several decades due to increasing fuel loading and ex-urban development in the wildland-urban interface (WUI). WUIs are where wildland uses meet urban land uses. Radeloff, Hammer, Stewert, Fried, Holcomb, and McKeefry (2005) estimated that the United States (U.S.) WUI covers 719,156 km^2 and contains 44.8 million housing units. The expansion of homes and associated commercial development in the WUI places property, assets, and human lives at risk from wildfires (Bhandary & Muller, 2009; Reams, Haines, Renner, Wascom, & Kingre, 2005). At the same time federal costs to suppress wildfires are drastically increasing; in 1985 costs were $239,943,000, and costs in 2012 were $1,902,446,000 (National Interagency Fire Center, 2013). The total Federal cost for wildfire suppression between 1985 and 2012 was $25,370,157,000 (National Interagency Fire Center, 2013). While the land use change drivers of WUI development may differ in other parts of the world, the expansion of the WUI into high-risk wildfire zones is not unique to the U.S. (Brummel, Nelson, & Jakes, 2012; Carmo, Moreira, Casimiro, & Vaz, 2011; Dondo Bühler, Curth, & Garibaldi, 2013; Harris, McGee, & McFarlane, 2011; Holland, March, Yu, & Jenkins, 2013).

Initial responses to wildfire in the United States WUI almost exclusively emphasized fire suppression (Steelman & Burke, 2007). The fire suppression policies implemented between 1905 through 1911 failed to address several key issues related to wildfire in the WUI: 1) the necessity of fire for ecosystem health; 2) the ability of fire to moderate fuel load buildup; and 3) the altering the public's perception of wildland aesthetics and processes (Busenberg, 2004; Veblen, Kitzberger, & Donnegan, 2000). Despite the failings of fire suppression policies, these policies

governed wildfire practices for almost 100 years. Initial WUI development conflicts were raised by Vaux (1982), who classified the interface of urban development and forestry as a significant area of concern and cautioned foresters to not underestimate its political and policy significance. Additionally, Bradley (1984) also spoke of the significance of the urban/forest interface, defined as two traditional land uses occurring in proximity to each other (i.e. forestry and urban development). Early views of the urban/forest interface defined the problems as resource conflicts that begin as spatial conflicts and quickly become sociopolitical, often pitting a set of values against one another (Bradely, 1984; Vaux, 1982). These early conflicts often revolved around forest managers' concern over forest resources as a commodity, such as mineral extraction and timber harvests, and urban edge residents' concern in forests as land commodity, such as aesthetic amenities, recreation, and wildlife (Bradely, 1984). However, land managers tackling these concerns failed to address the growing wildfire issues in the WUI.

Recently, U.S. wildfire management policy has shifted from fire suppression to an integrated program of fire suppression, preparedness, mitigation, and community assistance (Caban-Gonzalez, Haynes, Mccaffrey, Mercer, & Watson, 2007). This shift is recognizable in the wildfire research literature. Researchers, designers, and planners have been working to understand the increasing conflicts between WUI landowners and natural wildfire regimes by using a wider multitude of research designs, methods, and theories, in addition to continuing wildfire-modeling research (Bhandary & Muller, 2009; Brown, Agee, & Franklin, 2004; Burby & Deyle, 2000; Heyerdahl, Brubaker, & Agee, 2001; Muller & Schulte, 2011; Paveglio, Jakes, Carroll, & Williams, 2009; Reams et al., 2005). For example, research has developed best management practices for community wildfire protection planning processes (P. J. Jakes et al., 2012; Society of American Foresters, 2004), identified firewise development and land

management practices (Headwaters Economics, 2014; Moritz et al., 2014; Paterson, 2007; Winter, McCaffrey, & Vogt, 2009), identified socio-economic barriers to implementing firewise best management practices (Chuvieco, Martínez, Román, Hantson, & Pettinari, 2014; Collins, 2008; Gardner, Cortner, & Widaman, 1987; Kousky, Olmstead, & Sedjo, 2011; Poudyal, Johnson-Gaither, Goodrick, Bowker, & Gan, 2012), and created better models of wildfire risk and behavior (Ager, Vaillant, & Finney, 2011; Kramer, Collins, Kelly, & Stephens, 2014; LANDFIRE, 2010). Practitioners have attempted to implement these best practices to mediate increasing fire risk with policies limiting development in high-risk areas, requiring fire rated building materials and sprinkler systems, implementing community wildfire protection plans, creating defensible space around buildings, and reducing fuel loads (Bhandary & Muller, 2009; Muller & Schulte, 2011) with varying levels of success.

Current wildfire planning efforts are the result of The Healthy Forests Restoration Act of 2003 (HFRA). HFRA was the culmination of a decade of changing wildfire mitigation research and wildland fire policy reforms that were in response to the growth of WUI development, danger from catastrophic WUI wildfires, and decline in WUI ecosystem health (Steelman, 2008). HFRA called for communities to implement Community Wildfire Protection Plans (CWPP) (Grayzeck-souter, Nelson, Brummel, Jakes, & Williams, 2009). CWPPs are often implemented at the county or community (i.e. municipality, borough, town, city or local fire district) scale, hence the term ‘County’ or ‘Community Wildfire Protection Plan.’ Increasingly, CWPPs are also implemented at a neighborhood or subdivision scale. CWPPs are a required collaboration between local fire departments, the state agency responsible for forest management and relevant local government, in consultation with adjacent federal land management agencies and surrounding community residents (Grayzeck-souter et al., 2009).

CWPPs have several key benefits and objectives for achieving a more effective wildfire mitigation strategy. The development of CWPPs should include priority areas for fuel reduction and provide ignitability assessment throughout the community (U.S. Congress, 2003). Communities benefit from having CWPPs because it allows for a flexible and contextually defined, localized WUI boundary; localized fuel treatment prioritization; prioritization of funding; and integration into local land use policies (P. J. Jakes et al., 2011; Steelman & Burke, 2007). Robustly implemented CWPPs allow land managers to reestablish natural fire regimes while minimizing the risk to people, thus rehabilitating and restoring fire-adapted ecosystems and minimizing ongoing wildfire risks over the long-term (Steelman & Burke, 2007). Researchers have only begun to tackle CWPP effectiveness.

While research is expanding into CWPP effectiveness, there are still numerous gaps in the literature. Often CWPP and local wildfire research is not generalizable because studies have used small n or single case study examples, which make it difficult to understand specific contexts that facilitate effective CWPP processes and implementation. These same studies often focused on the social outcomes of CWPP processes, including capacity building and the interrelationships of participants, while giving little attention to the content of CWPP products, policies or the physical implementation of CWPP goals and objectives. This oversight creates a disconnect in understanding how processes lead to deliverables as well as how deliverables lead to implementation. Finally, CWPP literature has understudied the links between CWPP processes, documents, and the integration of wildfire safe policies into local zoning and land use codes. As a result, the question of how effective CWPP processes and CWPP implementation are at achieving their goals remains.

II. Literature Review

In this section, key terms are defined and a review of the necessary literature for this project is presented. First, I define the central terms to this proposal: 1) the Wildland Urban Interface (WUI), which will be split into the operationalized sub-classifications WUI interface and WUI intermix, and 2) the often-confused interrelated terms of hazard, risk, and vulnerability. Second, I discuss the evolving role of wildfire in the WUI, providing an overview of wildfire policy and risk reduction efforts. Third, I present an in-depth overview and critique of HFRA and CWPPs. Finally, I conclude this section with an overview of the CWPP process and implementation best practices, including barriers to successfully implementations.

Key Terms and Definitions

The *Wildland Urban Interface (WUI)*[1] is the interface zone between urban development and wildland vegetation. While there is no single, agreed-upon definition of the WUI across all institutions and research efforts,[2] I will be operationalizing Radeloff et al's (2005)[3] in this project. This definition was created using the Federal Register's definition of WUI, which was combined with detailed analysis of housing density data, remote sensing vegetation data, and spatial adjacencies to wildland vegetation.[4] This definition is widely used 10 years after its creation as the means to calculate WUI across large geographic areas in current research efforts (Arganaraz et al., 2017). Additionally, the Radeloff et al (2005) definition has been widely documented and supported by the USFS in HFRA initiatives, and the temporal datasets as well as source code to replicate their process has been provided.

[1] Also, referred to as Rural-Urban Interface (RUI).
[2] Refer to comprehensive paper, "Ecological Planning in the Wildland Urban Interface".
[3] Important to note is that Theobald and Romme have started to merge their definitions of WUI with Radeloff et al (2005).
[4] See Radeloff et al (2005) for specific details.

The definition of WUI that is operationalized in this research will be split into two sub-classifications: WUI intermix and WUI interface. For the purposes of this proposal, WUI intermix has no clear line of differentiation between development and wildland fuel because the wildland fuels are continuous outside and within the developed area. WUI interface is where wildland fuels border infrastructures and a clear line of differentiation exists between wildland fuels and residential, business, and public structures (hereafter referred to as development) because the wildland fuels typically do not continue into the developed area.

WUI intermix will be identified with the following characteristics: 1) areas will be greater than or equal to 6.18 houses per square kilometer, and 2) greater than or equal to 50 percent cover of wildland vegetation (Radeloff et al., 2005). *WUI interface* will be identified as 1) areas with greater than or equal to 6.18 houses per kilometer squared, and 2) greater than 50 percent vegetation cover, which is located less than 2.4 kilometers from an area that is 1) greater than 5 square kilometers in size and 2) has vegetation cover of greater than or equal to 75 percent (Radeloff et al., 2005). In calculating these areas, Radeloff et al (2005) would split a census block if it were only partially within the 2.4 kilometer distance; however, simply splitting census blocks is problematic because the distribution and locations of housing density within the census block is unknown. This is particularly problematic because these census blocks range from 0.001 square kilometers to 2,700 square kilometers. I will be using a more conservative measure and will include the entire census block.

Hazard, risk, and vulnerability are often misused interchangeably in the media. However, each term has a very distinct meaning within the literature that affects mitigation implementation prioritization and wildfire modeling efforts. *Wildfire hazard* is the potential to be exposed to a wildfire event, often measured through climate, weather, slope, and fuel loads (Ager et al., 2014;

Ager, Vaillant, Finney, & Preisler, 2012). *Wildfire risk* combines wildfire hazard with the potential impacts to community infrastructure and private property (Bryant & Westerling, 2014). Important to note is that wildfire risk assumes that all community populations have an equal ability (e.g. financially) to respond to wildfire events. *Wildfire vulnerability* broadens the concept of wildfire risk to include an individual or household's ability to anticipate, respond to, and recover from a wildfire event (Collins, 2008a).

Wildfire Policy and Risk Reduction Efforts in the WUI

For more than nine decades, the goal of US wildfire legislation was to protect natural resource commodities and human communities from wildfire damages by suppressing all wildfires. This response to wildfire failed because fire is necessary for ecosystem health and the moderation of fuel load buildup, and this has additionally created the significant obstacle of altering the public's perception of "natural" wildland aesthetics and processes (Busenberg, 2004; Veblen et al., 2000). To be fair, this fire suppression policy response was the result of the understanding of wildfire at the time. Therefore, it is important to understand the background suppression policies in order to address their effects on current development challenges in modern wildfire mitigation in the WUI.[5]

Initial westward expansion of the 1800s was driven by resource economies, such as timber, agricultural activities, and mining (Riebsame, Gosnell, & Theobald, 1996; Theobald & Romme, 2007; Travis, 2007), and wildfire was viewed as a threat to commercial timber activities and watershed protection (Fire History Society, n.d.; Headley, 1916; Muir, 1941; Silcox, 1910). The U.S. Forest Service (USFS) was established in 1905 with managerial control of national

[5] For a more detailed discussion of wildfire policy history, see the comprehensive paper "Ecological Planning in the Wildland Urban Interface".

forests (Fire History Society, n.d.; Headley, 1916; Muir, 1941; Silcox, 1910). Administrators were convinced that catastrophic fire events could only be prevented through fire suppression (Fire History Society, n.d.; Headley, 1916; Muir, 1941; Silcox, 1910). The resulting Weeks Act offered financial incentives to states for suppressing fires under the direction of the USFS, which is still in place today, (Southard, 2011) and the Civilian Conservation Corps supplied thousands of men to work building fire breaks and fighting fires (Fire History Society, n.d.).

During the 1960s, research began to show the positive role fire played in forest ecology: restoring vegetation by releasing seeds, controlling diseases and invasive species, and managing wildfire fuel loads. As a result, the USFS instituted a let burn policy (Fire History Society, n.d.), which fell out of favor as early as the 1980s due to dangerous fire conditions in the WUI where development had increased, driven by resort development, urban expansion, low-density homeowner development (Fire History Society, n.d.; Manning, 2012).

Contemporary wildfire policy began in 2002 when President Bush established the Healthy Forest Initiative (HFI), which led to the 2003 Healthy Forest Restoration Act (HFRA), involving the preparation and implementation of hazardous fuels reduction projects on federal land and assisting rural communities, states, and land owners in restoring healthy forest and watershed conditions (United States Department of Agriculture Forest Service Missoula Technology and Development, 2016). A critical component of this legislation is the creation of the Community Wildfire Protection Plan (CWPP), to be discussed in further detail below.

Current wildfire mitigation actions have also expanded to include insurance requirements, which are critical components of legislative and administrative actions due to catastrophic[6] financial consequences of natural disasters. Due to catastrophe loading, insurance

[6] The insurance industry classifies a disaster as catastrophic when losses total more than $20 million (Miller, 2007)

underwriting, and public insurance legislation, wildfire insurance requirements alone have been unable to significantly discourage WUI development or to encourage wildfire mitigation efforts. Wildfire is traditionally underwritten using the hurricane standard of catastrophe loading, which is problematic because while hurricanes often function on yearly cycles and affect the same geographic location while wildfire events vary dramatically depending on past event history and mitigation efforts. Legislation, such as California's FAIR Plan, has been enacted to provide insurance when private insurers were unwilling to provide coverage. These efforts have unintentionally provided means to obtain insurance coverage in areas that otherwise would be deemed too risky, allowing new residents to move into known high-risk areas while obtaining publicly-subsidized insurance coverage (Headwaters Economics, 2016a; Miller, 2007; Troy, 2007).

Other legislative and administrative actions can be enacted to mitigate wildfire in the WUI. These actions can be categorized as incentives for behavioral and development change in the WUI or deterrents to current development behaviors. Incentives for behavioral change involve funding for wildfire mitigation efforts and disclosure of risk. Federal funding needs to be provided to prioritize the development of a consistent protocol for mapping fire risk as well as scheduled map updates (Basker, 2014). Financial and technical assistance need to be provided to communities to affect the pace, scale, and pattern of development in the undeveloped portion of the WUI (Basker, 2014). Funding should also be provided to acquire and maintain firebreak/buffer easements of WUI communities (Gorte, 2013).

Disclosure of risk involves the full disclosure of wildfire risk to home buyers in at-risk areas (Basker, 2014; Troy & Romm, 2007). Disclosure also involves communication about risk and mitigation behaviors. Communication efforts should include improved mapping efforts,

access route information, wildfire warning systems, real-time water availability and location data, and firefighting resource coordination (Gorte, 2013). Disclosures alone are unable to overcome the desirability of the WUI living. For example, California passed the Natural Hazard Disclosure Law (AB 1195) in 1998, and price premiums remained at the level of +3% after its enactment, except for property that was within 5 kilometers of a recent fire event (Troy & Romm, 2007). Additionally, hazard disclosure is only as good as the initial fire hazard maps. Maps are initially created by the state, for high hazard severity zones, but municipalities can change and amend them without recourse from the state, often leaving lots of high hazard areas undesignated (Troy & Romm, 2007).

Inter-governmental cooperation and public participation are the foundations of local actions in wildfire mitigation – the focus of this research proposal. Local responses to wildfire have historically favored public participation through education (Collins, 2008), but they also include federal and state-subsidized fire suppression, real-estate disclosures, high-resolution risk mapping, and support for CWPP planning and implementation.

Local planning initiatives require strong financial incentives that are typically missing in these communities. For example, many communities are understaffed and lack the technical guidance and finances to develop plans that minimize risk from wildfire (Headwaters Economics, 2014; Jakes et al., 2012). Even when planning departments are adequately funded, most local planning efforts place a higher priority on economic growth and development, which is often to the detriment of creating safe communities (Deyle & Smith, 2000).

Communities are beginning to evaluate their mitigations programs effectiveness; however, these evaluations are often overly simplified. Performance measures that are commonly used are only accounting for the number of properties mitigated, the number of

participating property owners and community groups, and the number of educational meetings and workshops conducted with a designated time period (Reams et al., 2005). These simple accounting measures do not evaluate social or spatial metrics of wildfire mitigation efforts.

Local advocates Deyle and Smith (2000) argue that tax benefit equity is a means for financing local government costs of disaster response and recovery, stating that property owners who choose to develop land in hazardous areas should share the financial responsibility of providing emergency management services and infrastructure. Likewise, they should financially support the planning, preparation, mitigation, and response and recovery conducted by local government (Deyle & Smith, 2000). However, while tax assessments based on level of hazard risk is a reasonable first step, socioeconomic status needs to be considered as well. And increasingly, risk perception research has focused on vulnerable populations, particularly regarding low socioeconomic status or income, emphasizes the differential capacity of people to anticipate, to respond, and to recover from hazard events (Collins, 2008). For example, low-income renters do not have the agency to choose where they live and additional fees stemming from hazard area tax assessments would be disproportionately burdensome. This consideration of a de facto poverty tax is essential as it is estimated that a third of the 13 million WUI residents are socioeconomically vulnerable (Collins, 2008).

Research has shown that hazard mitigation policies and ordinances are more effective if they are integrated into other local plans (Bhandary & Muller, 2009; Brody, 2003; Butsic, Kelly, & Moritz, 2015). Several land use regulations exist that can assist in reducing wildfire risk including: overlay zoning, site plan review procedures, development standards, subdivision regulations, WUI code, comprehensive plan, hazard mitigation plan, climate change plan, watershed management, and preservation of open space. Headwater Economics (2016b)

produced a report of innovative case studies that are using local ordinances to mitigate wildfire risk. A combination of each of the previously mentioned land use regulations should be evident in effective implementation of CWPPs in order to minimize wildfire risk. However, it is unknown to what degree and quality local ordinances have integrated wildfire risk mitigation efforts. Additionally, little is known in their broader contribution to affecting wildfire risk reduction in the built environment or deterring additional WUI growth. Qualifying CWPP reports and processes should extend to include the implementation of wildfire risk and mitigation into local ordinances because they have been effective in other types of hazard mitigation (Bhandary & Muller, 2009; Brody, 2003; Butsic et al., 2015). Each local ordinance and their potential contribution to minimizing wildfire risk are described below.

Overlay zoning provides a set of standards that apply to properties within a specific geographic area, superseding the underlying base standards of a given zoning district. This is an instrumental tool in avoiding potential conflicts between resource protection or other zoning requirements and forest thinning or defensible space requirements. Wildfire mitigation can also be incorporated into site plan review processes to ensure safe development in the WUI allowing for the enforcement of the following: pre-development mitigation measures, adequate water supply, and multiple ingress and egress options. These requirements are articulated in both development standards and subdivision regulations. Development standards are land use regulations that determine the quality of development, which for wildfire include: adequate water supply, defensible space, resource protection, and ongoing maintenance. Subdivision regulations determine how lots are created and divided, including layout standards for new subdivision developments. For wildfire these include: adequate water access, water supply, and mitigation

requirements. Some WUI communities are also implementing WUI specific codes that enforce describe required building, landscape, and lot development codes.

Very few comprehensive laws, statutes, or building codes exist that address combustion-resistant building materials (Stephens & Collins, 2007) even though using combustion-resistant building materials is key in the survival of structures during wildfires. Possibly due to enhanced public perception and increasingly stringent building codes, the construction industry and homeowners are adapting fire-resistant materials (Collins, 2008). Fire-resistant building materials and practices include fire-rated roofing, siding, and decking; closed eaves and soffits; and protecting vents and windows (Brzuszek & Walker, 2008; Meldrum et al., 2015; Reams et al., 2005). An effective wildfire mitigation response should include all of these elements within local building codes. However, while fire-resistant material is being required in new construction, these efforts do not address the thousands of existing non-fire-resistant homes. Currently, homes without appropriate fire-resistant construction materials are not required to be brought up to code. Accurately accounting for how many homes that are not fire resistant is difficult because collecting the data requires in the field assessments and to-date cannot be done remotely. Fire-resistant construction does not justify continued development in the WUI and does not address the subsequent suppression costs (Headwaters Economics, 2014).

In addition to building material construction, local initiatives regarding wildfire fuel loads are paramount in the WUI. The wildlands and WUI, due to past fire suppression policies, have historically high levels of fuels. Actions that thin the vegetation include prescribed fire, mechanical thinning, mastication, plowing with a bulldozer, applying herbicide (Gorte, 2013; Bar-Massada, Radeloff, & Stewart, 2014). This vegetation modification serves to reduce the fuel load within wildland vegetation for potential wildfires and in defensible space around dwellings.

Headwaters argues that prescribed fires should be used more extensively in mitigating wildfire (Gorte, 2013). It is estimated that 230 million acres of non-WUI Forest Service and Department of Interior lands are in need of treatment because they are at risk from ecological damage from wildfire (Headwaters Economics, 2014). However, less than three million acres are treated per year (Headwaters Economics, 2014), which is insufficient to reduce wildfire risk. It is unlikely there will be a dramatically increased acreage receiving fuel treatments in the near future due to budgetary and political constraints. Another concern is that prescribed fires in areas already populated could present a threat to human lives, which can be addressed through best practice research outlined by Headwaters. Unfortunately, many fuel reduction treatments in the WUI do not address the millions of acres of private property.

Defensible space creation, related to the thinning of forests and fuel reduction, is a perimeter around buildings and structures with modified vegetation cover to reduce fuel for potential wildfires. It also provides firefighters a clear environment in which to maneuver to protect structures. Implementations of defensible space are various and inconsistent; however, the National Fire Protection Association (NFPA) is promoting a set of Firewise community defensible space standards, defining defensible space in the home ignition zone – the area within 200 feet of the house (National Fire Protection Association, 2016).

The home ignition zone is generally subdivided into three zones. Zone 1 is within 30 feet of a structure vegetation should be carefully spaced, low-growing and free of resins, oils and waxes that burn easily. Zone 2 is from 30 to 100 feet of the structure, plants in this zone should be low-growing, well irrigated and less flammable. Zone 3 is from 100 to 200 feet, vegetation in this zone should be thinned. Each zone has specific vegetation spacing and composition requirements (Table 1). It is important to note that the zone measurements are for flat ground

only, and zone distances should increase on steeper slopes – but there is no direction on calculating these increases. Any zone of defensible space can be truncated at a private landowner's property line, which importantly ties wildfire mitigation to individual homeowner concerns about privacy, desired natural aesthetics, wildlife and recreational values, physical and economic capacity, and their personal knowledge (Brzuszek & Walker, 2008; Winter et al., 2009).

Defensible space zone	Distance	Vegetation, fuel thinning, and reduction requirements
Zone 1	0-30'	• Plants should be carefully spaced, low-growing and free of resins, oils and waxes. • Lawns should be mown regularly. • Trees should not overhang structures, be pruned up six to ten feet off the ground, and conifers should be spaced 30 feet between tree crowns. • Create 'fire-free' area within five feet of the home, using non-flammable landscaping • materials and/or high-moisture-content annuals and perennials. • Remove dead vegetation from under deck and within 10 feet of house. • Water plants, trees and mulch regularly. • Consider xeriscaping if you are affected by water-use restrictions.
Zone 2	30-100'	• Leave 30 feet between clusters of two to three trees, or 20 feet between individual trees, and prune trees up six to ten feet off the ground. • Use a mixture of deciduous and coniferous trees. • Create 'fuel breaks', like driveways, gravel walkways and lawns.
Zone 3	100-200'	• Thin this area, reducing the density of tree canopy. • Remove smaller conifers that are growing between taller trees. • Remove heavy accumulation of woody debris.

Table 1: NFPA Firewise Community Recommended Defensible Space Requirements (National Fire Protection Association, n.d., 2016).

Healthy Forest Restoration Act and Community Wildfire Protection Plans

The Healthy Forest Restoration Act (HFRA), passed in 2003, is the result of wildland fire policy reforms that were designed to improve the capacities of land-management agencies to protect communities, watersheds and, other at-risk lands from catastrophic wildland fires (Jakes et al., 2011). The legislation provisions are to expedite the preparation and implementation of the reduction of hazardous fuels on federal lands and assisting rural communities, states, and landowners in restoring healthy forest and watershed conditions. HFRA—without providing uniform guidelines or standards—encourages communities to collaboratively develop Community Wildfire Protection Plans (Jakes et al, 2011).

The components and process of the *Community Wildfire Protection Plan (CWPP)* is structured loosely by HFRA. Within that structure is built the flexibility of local communities to, ideally, create a CWPP that reflects community values and area-specific environmental conditions in order to effectively mitigate wildfire in the WUI. CWPP guidelines are designed to be flexible to address local contexts, though each plan must have the following required components: prioritized fuel reduction, treatment of structural ignitability, and collaboration, (Society of American Foresters, 2004). Hazardous fuel reduction area treatments must be identified and prioritized, and the methods of fuel reduction treatments must also be recommended (Jakes et al., 2011, 2012; Resource Innovations Institute for a Sustainable Environment, 2008; Society of American Foresters, 2004; Steelman & Burke, 2007).

These CWPPs are required to identify at least two zones of defensible space surrounding building structures. These plans are required to be collaboratively developed by local, state, and federal stakeholders, and the local government (e.g. counties or cities); local fire department(s); and state entity responsible for forest management must agree on the final contents (Society of

American Foresters, 2004). HFRA also requires that at least three entities must agree to the final CWPP: applicable local governments (i.e. counties or cities); local fire department(s); and state entity responsible for forest management (Society of American Foresters, 2004). While not required, HFRA does outline and recommend an eight-step process for CWPP development. The outline is as follows: convene decision-makers; involve federal agencies; engage interested parties; establish a community base map; develop a community risk assessment; establish community priorities and recommendations; develop an action plan and assessment strategy; and finalize community wildfire protection plan.

HFRA provides the authorization to expedite environmental assessment, administrative appeals, and legal review for hazardous fuels projects on federal land (Society of American Foresters, 2004). HFRA also emphasizes the need for federal agencies to collaborate with communities in developing hazardous fuel reduction projects by placing priority on treatment areas identified by CWPPs (Society of American Foresters, 2004). It also distributes financial resources across federal and non-federal projects according to CWPP objectives. The HFRA also disincentives the absence of a CWPP through the financial policy of requiring at least 50 percent of all funds to be used within the WUI. Without a CWPP, the WUI is defined within ½ mile of a community's boundary or within 1 ½ miles when mitigating circumstances exists, e.g. steep slopes – less than most locally developed CWPP definitions.

HFRA is a step in the right direction, but it does present several issues. HFRA's biggest flaw is that it does not address continued development in the WUI. The spirit of individualism and the resentment of government intervention in private property rights hinder such legislative actions surrounding wildfire risk and mitigation (Collins, 2007), which explains why only half of state legislatures address land use planning and only 11 of these encourage local governments to

plan for hazard mitigation (Burby & Deyle, 2000). The result of continued WUI growth is that wildfire funds are continually allocated suppress fires in order to protect homes rather than towards risk reduction efforts. Exacerbating the issue is that forest mitigation work – such as Healthy Forest initiatives – has been consistently underfunded (Steelman & Burke, 2007; Trego, 2014).

Healthy WUI forests and WUI development (HF) includes the observable implementation of fire resistant building materials, defensible space, and overall fuel loads within the WUI. While HF are theoretically important to evaluating the effectiveness of CWPP implementation, they are currently not able to be evaluated across large, disparate geographies. HF measures are currently not feasible for this study because datasets do not exist or would require expensive high resolution remote sensing multi-spectral imagery. Additionally, such datasets are time intensive on the ground assessments. As such, the current study will not include HF, but future studies should work to address this issue.

CWPP Process and Implementation Best Management Practices

Required by the HRFA, CWPPs must contain and use the following: prioritized fuel reduction, treatment of structural ignitability, and collaboration, (Society of American Foresters, 2004). Hazardous fuel reduction area treatments must be identified and prioritized, and the methods of fuel reduction treatments must also be recommended (Jakes et al., 2011, 2012; Resource Innovations Institute for a Sustainable Environment, 2008; Society of American Foresters, 2004; Steelman & Burke, 2007). Additionally, these plans are required to identify at least two zones of defensible space surrounding building structures, as previously defined.

The CWPP process is required to be collaboratively developed by local, state, and federal stakeholders, the local government (e.g. counties or cities), the local fire department(s) and the

state entity responsible for forest management (Society of American Foresters, 2004). HFRA also requires that three entities must agree to the final CWPP: applicable local governments (i.e. counties or cities); local fire department(s); and state entity responsible for forest management (Society of American Foresters, 2004).

Researchers and practitioners have identified eight critical steps for CWPP process: 1) convene decision-makers; 2) involve federal agencies; 3) engage interested parties; 4) establish a community base map; 5) develop a community risk assessment; 6) establish community priorities and recommendations; 7) develop an action plan and assessment strategy; and 8) finalize community wildfire protection plan (Jakes et al., 2007; Jakes et al., 2012; Society of American Foresters, 2004). Decision-makers form the operating group with representation from the local government, local fire authorities, and the state agency responsible for forest management. They will be responsible for creating the CWPP and mutually agreeing on the final contents. Where there are multiple local governments and fire authorities, it is recommended that they select a single representative to participate as a core team member. Once convened, the core team should engage local representatives of the USFS and Bureau of Land Management (BLM) for support, perspectives, and priorities.

The success of the CWPP will hinge on the core team effectively engaging a broad range of stakeholders. Substantive input from a diversity of interests ensures the final document reflects the highest priorities of the community and helps to facilitate the implementation of recommended projects. Identifying leaders, within or outside the community, who can help mobilize others will help to expand the creation of core CWPP member and community participants (Jakes et al, 2012). These leaders can also serve as catalysts for action and recruit others to the CWPP process. Stakeholders can include, but is not limited to: forest management

groups, city council members, resource advisory committees, HOAs, Division of Wildfire/Fish and Game, Department of Transportation, local and state emergency management agencies, water districts, utilities, recreation organizations, environmental organizations, forest products interests, local chambers of commerce, and watershed councils. To solicit additional input, the core team may choose to hold public meetings.

The core team, agencies, and stakeholders should collaboratively develop a community base map that includes: 1) inhabited areas at potential risk to wildland fire; 2) areas containing critical infrastructure that are at risk to fire disturbance events, e.g. escape routes, municipal water supply structures, and major power or communication lines; and 3) a preliminary designation of the community's WUI zone. This map will be used to facilitate a community risk assessment, which helps the core team and community members to prioritize areas for treatment and to identify the highest priority uses for available financial and human resources. A successful and meaningful community assessment should be co-developed considering the following risk factors: fuel hazards; risk of wildfire occurrence; homes, businesses, and essential infrastructure at risk; other community values at risk; and local preparedness and firefighting capacity. Ranking systems typically consist of adjective rating systems, e.g. high, medium, and low. The key objective of these discussions is to develop the community's prioritized recommendations for fuel treatment projects on federal and nonfederal lands in the WUI, including preferred treatment methods for each project. These decisions result in the action plan (identifies the roles and responsibilities, funding needs, and timetables for carrying out the highest priority projects) and the assessment strategy (ensures that the document maintains long-term relevance and effectiveness).

To complete the CWPP process, the core team agrees on the location of the wildland-urban interface, the fuels treatment priorities, preferred methods for fuels treatment projects, structural ignitability recommendations, and other information to be contained in the final document. Results should then be communicated to the broader stakeholder group, community members, and key land management partners. The University of Oregon's Resource Innovations Institute for a Sustainable Environment created a CWPP monitoring and evaluation guide to help communities ensure the quality of implementing the previously discussed steps, details are provided in Table 2.

CWPP Goal	Monitoring and Evaluation Questions
Partnerships and Collaboration	Who has been involved with CWPP development and implementation?
	How did the fire-planning process influence CWPP implementation?
	How has the collaborative process assisted in implementing the CWPP and building capacity for the community to reduce wildfire risk?
	Have social service agencies (or groups that might assist low-income and vulnerable populations) been partners in CWPP efforts? If so, how?
	Have partners involved in the planning process remained engaged in the plan's implementation?
	Has CWPP collaboration made a difference or had a positive impact on local organizations, neighborhoods, and/or actions?
Risk Assessment	How has the community changed over time (demographics, residential and commercial development, etc.)?
	If this is a multi-jurisdictional plan, what is the number and percent of communities at risk with a CWPP in the area?
	Are there new or updated data sources that may change the risk assessment and influence fuels priorities?
	How is the risk assessment being used to make decisions about fuels priorities or the designation of the wildfire/urban interface boundary?
	Has the community enacted a wildfire-related ordinance? If so, is it a county, state, or local ordinance?
	What percent of communities at risk also have low-income, vulnerable populations? Are these communities engaged in reducing wildfire risk?
Reducing Hazardous Fuels	How many acres have been treated for hazardous fuels reduction on public and private land that had been identified as high priority projects in the CWPP?
	How many fuels reduction projects have spanned ownership boundaries to include public and private land?
	What is the number and percent of residents who have participated in projects and completed defensible space on their land?
	Has economic development resulted from fuels reduction?
	How many local jobs have resulted because of fuels reduction or restoration activities?
	How many hazardous fuels reduction projects (or acres treated) have been implemented in connection with a forest restoration project (including a stewardship contract?)
Reducing Structural Ignitability	What kind of resource losses have occurred from wildfires in the year being reported on?
	Are the current codes and regulations for wildfire hazard adequate?
	Has the public knowledge and understanding about structural ignitability been increased by strategies adopted in the CWPP?
	How many Firewise Communities have been recognized?
	How has the availability and capacity of local fire agencies to respond to wildland and structural fires improved or changed since the CWPP was developed?
Education and Outreach	What kind of public involvement has the CWPP fostered?
	What kind of change in public awareness about wildfire has resulted from the plan?
	What kinds of activities have citizens taken to reduce wildfire risk?
Emergency Management	Is the CWPP integrated into the county or municipal Emergency Operations Plan?
	Does the CWPP include an evacuation plan? If yes, has it been tested or implemented since the adoption of the CWPP?
	Is the CWPP aligned with other hazard mitigation plans or efforts?

Table 2: Indicator Framework for Monitoring and Evaluating a Community Wildfire Protection Plan (Resource Innovations Institute for a Sustainable Environment, 2008).

While the previously described eight steps are integral to a successful CWPP and the assessment protocol developed at the University of Oregon provides framework and resource to evaluate CWPPs, neither completely addresses all the components of a successful planning process or hazard mitigation plan such as broad public participation, evaluation of implementation, and understanding local context (Brody, 2003; Brummel et al., 2012; Fleeger & Becker, 2010; Goldstein & Butler, 2012; Horney et al., 2017; Jakes et al., 2012). The research of Jakes et al (2012) fills these gaps by outlining additional criteria for a successful CWPP process. Jakes et al (2012) outlines five components to community context: 1) remind community members of how they handled past challenges, such as a wildfire or environmental disaster in order to help the community understand how it is vulnerable and create a sense of urgency for developing a CWPP; 2) study previous collaborative efforts in the community, whether wildfire planning or other projects, to identify how they were successful and use lessons from those experiences to lay the groundwork for doing a CWPP; 3) identify people who were involved in earlier collaborative or wildfire planning efforts and bring their experience to developing a CWPP; 4) find ways to overcome the challenge of inexperienced communities in collaboration or wildfire planning; and 5) address disagreements within a community early, related to wildlife or not, that could threaten the CWPP process.

Tapping into resources that help CWPP participants successfully work together is paramount because effectively functioning collaborative groups can overcome financial and resource obstacles. The key benefits of this include building community capacity to be used during the CWPP process and other activities beyond wildfire planning. While the expansion of the network can provide more people, technology, and funding to the CWPP process, additional conflicts about CWPP goals can arise.

For ensuring long-term success of the CWPP, Jakes et al (2012) suggest four strategies: 1) incorporate projects into the CWPP that can be accomplished quickly to foster homeowner buy-in and broaden long-term support; 2) nest local CWPPs within broader plans to augment resources, support, and implementation; 3) incorporate CWPP into formal government structure and processes; and 4) quickly identify changes that affect the CWPP and adapt accordingly. These incorporate a number of above-mentioned wildfire mitigation strategies, such as legislative and administrative actions, inter-governmental cooperation, and acknowledging the important role of individualism and private property rights.

The issue of the appropriate geographic scale of the CWPP is neglected by the HFRA and the Resource Innovations Institute for a Sustainable Environment's guidelines. Scale choice should be driven by the motivations and goals articulated in the CWPP. For example, CWPPs should be developed at a small scale, e.g. neighborhood or community level, if the goals are to motivate homeowners to reduce hazards on their properties. However, CWPPs should be developed at a larger scale, e.g. counties, municipalities, and fire districts if the goals are to reduce regional landscape wildfire risk.

Evaluation of CWPP implementation involves the degree of which fuels treatments and structure ignitibility objectives have been put into place. However, currently there is limited ability to efficiently measure either across large areas using freely available remote sensing datasets. Evaluating physical implementation requires very expensive high resolution multi-spectral imagery and on the ground and time-intensive house and lot assessments (Platt, 2014; Price & Gordon, 2016; Skowronski et al., 2016). Additionally, evaluation of CWPP implementation should also include the degree to which a CWPP is integrated into local governance, and this aspect of evaluation is often ignored (Jakes et al, (2012). This integration

should be evident in the local ordinances, including relevant CWPP information and directing new and infill development away from moderate to high risk areas. Therefore, the overall status of CWPP evaluation is: while best management practices for process and implementation have been reported in the literature, little research has evaluated their effectiveness in linking process to implementation, nor has evaluation of CWPP processes extended beyond a small number of purposefully selected qualitative case studies.

III. Research Aims, Questions, and Significance

The purpose of this research is to evaluate CWPP effectiveness, which requires an understanding of the process that created the CWPP as well as CWPP implementation. For the purposes of this project, effectiveness means that 1) the process of developing the CWPP is inclusive of the diverse stakeholders in the area, involving participatory actions of those stakeholders; 2) the CWPP clearly articulates and documents the extent of the wildfire hazard; 3) the CWPP plans created at the community and neighborhood level adhere to principles of defensible space and other evidence-based wildfire mitigation best practices, stating implementable and measurable goals; and 4) the implementation of the CWPP goals result in observable physical environment changes. In order evaluate CWPP planning in terms of effectiveness, indices will be created to examine the CWPP process and the resulting documents as well as the CWPP implementation. These indices will include community contextual variables, such as socio-economic and demographic variables, as these variables are known to impact other planning programs and their implementation.

Specifically, my research objectives/questions are:

- Create an index that defines the level of effectiveness of CWPP process (inputs);
- Create an index that defines the level of effectiveness of CWPP implementation (outputs); and
- What social, economic, demographic and geographic factors predict the level of effectiveness of CWPP inputs and outputs?

Addressing these research objectives/questions is important to researchers for four main reasons. First, little research has been conducted to evaluate the effectiveness of CWPP processes and on evaluating the effectiveness of CWPPs on implementing wildfire mitigation strategies. Second, this study will methodologically broaden the scope of wildfire research through a larger *n* sample, which allows for greater generalizability, enables the pinpointing of outliers more easily, and creates the potential for a better margin of error. These are not possible with the current small *n* or case study wildfire research. Third, this study introduces the spatial analysis of the implementation of CWPP mitigation objectives, such as limiting WUI expansion into known wildfire hazard areas, which is paramount in assessing CWPP effectiveness. Fourth, this study will empirically evaluate the socio-economic, demographic, and biophysical conditions that lead to or inhibit effective CWPP processes and implementation.

For this study, the CWPP process includes both the actual process meetings as understood through meeting minutes and the approved CWPP plan. CWPP implementation is a composite of both policy and biophysical interventions. CWPP policy implementation are the integration of wildfire policies into building and zoning codes; comprehensive plans; subdivision ordinances, and HOA guidelines. The biophysical components of CWPP implementation include no net change in WUI expansion, densification, and health WUI forests and development.

Details on each index and measurement protocols are discussed at length in the research design section of the proposal.

The wildfire and hazard planning literature has identified a number of socio-economic and demographic variables that can influence CWPP processes and implementation, including age, length of homeowner tenure, full-time/part-time residency, and income. Survey research has shown that these four variables can play a statistically significant role in effective public participation processes, and CWPP implementation (Collins, 2008; Crow et al., 2015; Roper, 2015; Smith, Leahy, Anderson, & Davenport, 2013; Wolters, Steel, Weston, & Brunson, 2017). Other variables considered were: educational attainment, owner occupied housing, retirement status, slope, percent WUI, percent wildland cover, aspect, proximity to recent fire, hazard exposure, and single egress points; however, these have proved statistically insignificant or less significant in previous studies (Collins, 2008; Crow et al., 2015; Roper, 2015; Smith et al., 2013; Wolters et al., 2017).

The purpose of indices, in general, is to allow comparisons across time and space (Ebert & Welsch, 2004). The proposed process index and implementation index are critical to wildfire mitigation in the CWPP process because they aid in decision-making surrounding the prioritization of planning processes and implementation strategies. This is significant in the daily practices of wildfire mitigation and the CWPP process for both the decision-makers and the community members. In regards to decision-makers, an effective process index is important for the following reasons: 1) to validate localized best practices of community engagement, 2) to prioritize the utilization of staff-time and resources, and 3) to facilitate community participation without overburdening community members. For community members, there are two main benefit of a process index: 1) the promotion of more meaningful engagement in the planning

process; by focusing community participation in areas where community members can actively contribute, the community members will not be fatigued and frustrated by diluting their participation across too many initiatives and 2) legitimizes the CWPP planning process by providing sustained appraisals on planning products, procedures and results.

An effective implementation index also benefits decision-makers and community members during the CWPP process. To decision-makers, an effective implementation index facilitates 1) the validation of localized best practices of defensible space, zone sizing, forest thinning practices, and so forth; 2) the prioritization of implementation strategies in regards to economic restraints and location throughout the community; 3) the utilization of incentives for implementation, particularly on private property; and 4) the application of implementation policy mechanisms, including fines for unmitigated WUI development and requirements of disclosure of guidelines during property transfer. For community members, an implementation index has two benefits: 1) knowing and understanding the levels of wildfire safety in their community as well as the progress being made to reach the community safety goals, and 2) receiving targeted guidance in how to best reduce risk on their private property.

Understanding what social, economic, demographic and geographic factors predict CWPP effectiveness is paramount to how decision-makers engage community members. These underlying structural contexts of the community members' ability to participate in wildfire mitigation efforts regardless of how much wildfire mitigation education has been presented. For example, members of a community in abject poverty may understand the importance of wildfire mitigation but may also need to choose between landscape alteration and food. Furthermore, these same community members may not be able to attend community participation events because they work multiple jobs to provide for themselves and/or their family. Therefore, the use

of these predictive factors by decision-makers is 1) to gauge whether the lack of environmental outcomes (i.e. wildfire safe communities) is due to these community factors or due to the CWPP process and/or implementation, 2) to identify and allocate necessary resources and time to address other community issues, such as poverty or language barriers, in order to produce more effective processes and implementation, and 3) to understand the limit of a community's capacity to participate in various implementation processes and strategies.

IV. Research Design

The intent of this section is to describe the methodology that is proposed for such a research effort. Included in this section will be a description of the ethical implications, a description of the study the setting, and the proposed research design – which includes a pilot study, study sample, data collection methods, procedures, and analysis efforts.

Research Permissions and Ethical Considerations

Ethical issues will be considered and addressed at each phase of the study. This research study falls under the classification of non-human subject research because this research uses secondary, publicly available data and records: census, satellite remote sensed data, and open access GIS data. However, final determination of the research study classification lies with the Colorado Multiple Institutional Review Board (COMIRB). Prior to the study a Request for Review form will be completed and submitted for review.

Study Area

The study area covers all of Colorado and is 104,094 mi^2 (269,837 km^2). Colorado's physical geography is diverse and contains both rugged mountainous terrain, vast plains, desert lands, canyons, and mesas. The mean elevation of Colorado is 6,811' (2,076 m) with a high point of 14,440' (4,401 m) and a low point of 3,317' (1,011 m). Colorado contains approximately 550

peaks that exceed 13,123’ (4,000 m). Colorado's location, physical geography, and elevation characteristics create extreme weather changes, but the state mostly consists of a dry climate with tiny pockets of more humid weather that increase with altitude. While higher elevations typically receive moisture from winter snowfall, Colorado only averages 17” (430 mm) of rain per year statewide and rarely experiences a time when a portion of the state is not in some degree of drought: conditions that exacerbate wildfire risk.

Colorado has a long history of addressing wildfire, which is of growing concern because the total acres burned in Colorado wildfires has increased nearly twelve-fold since 1960. The two most destructive fires in state history occurred in the years 2012 – the Waldo Canyon Fire – and in 2013 – the Black Forest Fire. Combined, these fires resulted in four deaths, burned over 30,000 acres, destroyed 850 homes, and resulted in $750 million in insurance claims. Currently, all 62 Colorado counties contain some level of wildfire risk, covering 87,258 mi^2 (225,997 km^2), potentially exposing approximately 977,146 people wildfire (Data Transfer Solutions, 2013). Colorado is currently experiencing rapid population growth, and as Colorado continues to grow, its urban areas are rapidly expanding into fire-prone lands in the WUI. Theobald and Romme (2007) projects Colorado’s WUI will increase from 715,000 acres in 2000 to 2,161,400 acres by 2030. In response to growing wildfire risk, 53 counties have implemented CWPPs. In fact, many counties have implemented multiple CWPPS totaling 240 CWPPs in Colorado (Colorado State Forest Service, 2017).

Research Design

This study’s research design consists of plan evaluation and a quasi-experimental evaluation. Plan evaluation and changes in WUI and forest health will be used to create the CWPP process index and the CWPP implementation effectiveness index. The quasi-

experimental aspect of the research design will document the pre- and post-CWPP implementation changes in physical geographic variables while correlating and regressing against several independent variables.

Pilot Study

Boulder County, Colorado will be used for the pilot study. Boulder County contains 13 CWPPs, and the pilot study will implement the full data collection and analysis process in order to understand any potential for uncertainty and error in addition to completing an index instrument validation[7]. Validation of the instrument for the CWPP process index consists of two researchers reading all CWPP process document data and assigning appropriate scores – 0 or 1 – based on the CWPP process index instrument, which is detailed in Appendix A. For example, while reading each individual CWPP, each researcher will assign a 0 for no or a 1 for yes if the particular CWPP addresses a particular question in the instrument. If scoring discrepancies are found – the researchers disagree on whether the CWPP addresses a particular aspect – the researchers will discuss the discrepancy to identify a potential human error and/or the instrument will be modified for clarity. This will continue until the scoring is within an acceptable Cohen's Kappa (Gwet, 2014; Stevens, Lyles, & Berke, 2014).

The validation of the instrument for the CWPP implementation index consists of two phases: document analysis and geospatial analysis. The validation of the document analysis portion of the implementation index will follow the same protocols as the CWPP process instrument validation, including multiple researcher scoring and addressing discrepancies. The implementation index instrument details are in Appendix B. All geospatial data and analysis will

[7] Detailed discussion of the creation of the instrument and analysis of instrument results in creating indices is discussed in the Data Analysis section.

undergo Crosetto and Tarantola's (2001) uncertainty and sensitivity analyses (Fig 1). Any necessary refinements will be resolved and reported prior to the full studies implementation. It is anticipated that the pilot study will be completed in two months.

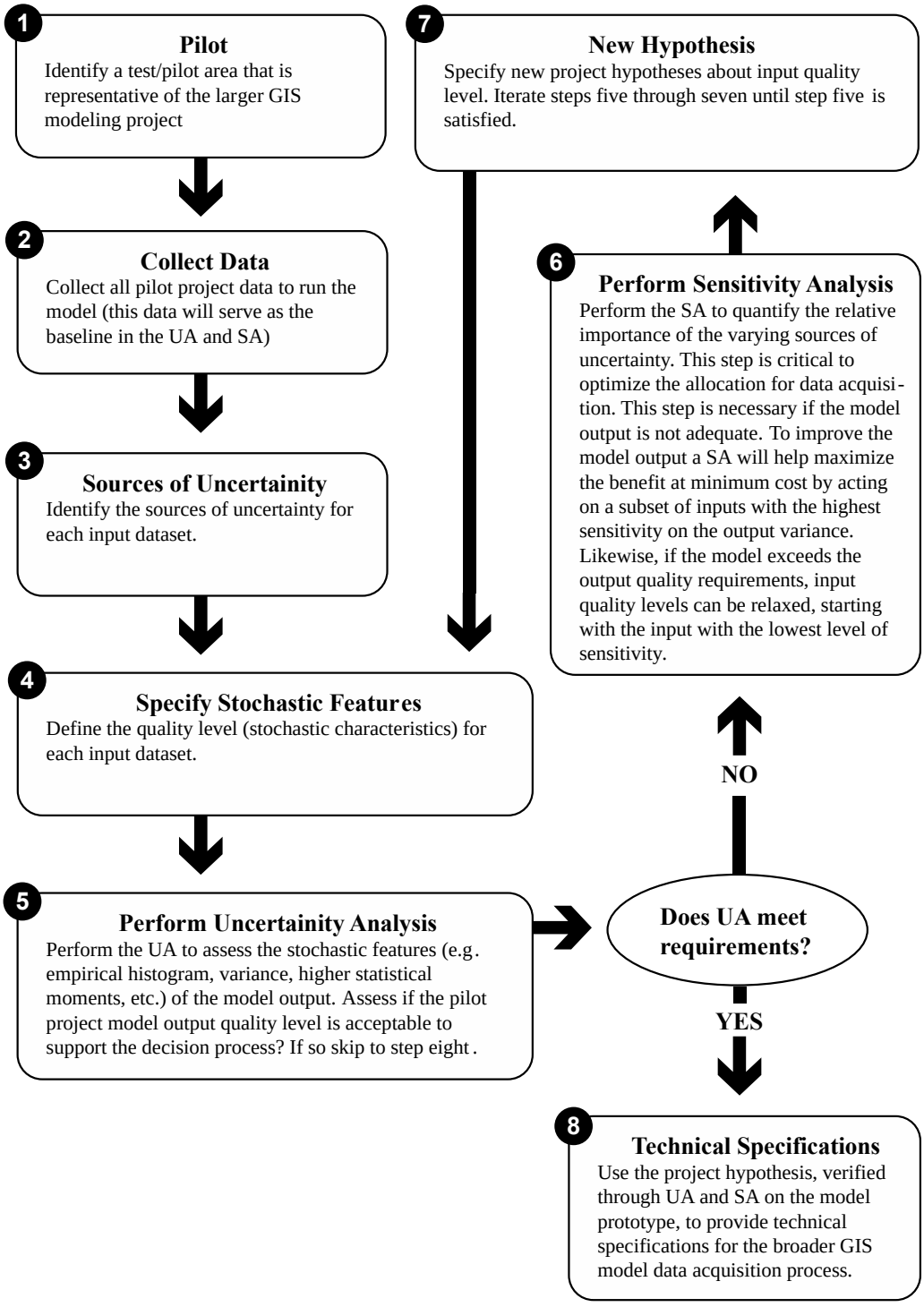

Figure 1. Crosetto and Tarantola's (2001) integrated UA and SA process for the optimization of resources allocation in the GIS based model implementation.

Study Sample

In order to understand the effectiveness of CWPPs as well as the socio-demographic and biophysical relationships in the CWPP process and implementation, this study intends to select a representative sample of 1) economic status of Colorado's population, 2) WUI coverage, and 3) CWPP type. Obtaining a representative sample is difficult given the size and heterogeneity of Colorado. In order to accomplish this goal of representation, a two-tiered cluster sampling methodology will be utilized involving 1) a stratified sample of counties based on median household income levels and percent of WUI (e.g. interface and intermix), and 2) a stratified sample of CWPPs based on the geographic extent of the CWPP: county-wide or localized. The next two subsections discuss the protocols of these two stratifications.

First Tier Stratification: Median Household Income

In order to stratify counties according to median household income, the first step is to compile county boundary map layers that will be used to obtain a representative sample of counties. County boundary files will be obtained from the US Census TIGER data set. The 2010 U.S. Wildland Urban Interface data set (Radeloff et al., 2005) will be used to mask non-WUI counties from the sample population of counties and to calculate the percentage of county area designated as WUI. To mask non-WUI counties, the WUI dataset will be reclassified into dummy variables. WUI interface and intermix will be reclassified as WUI (1), while all other variables will be considered non-WUI (0). Next, the county socio-economic census variables will be joined to the existing county layer database file. The 2010 median household income and percentage of WUI coverage will be used to stratify each county into four strata using natural breaks. All counties from each stratum will be sampled.

Second Tier Sampling: CWPP

In order to sample according to the presence of CWPP for the second tier, first, the CWPP boundaries for each selected county will be compiled using a combination of census, state, county, fire district, and municipality GIS files. Then, the presence of CWPP information will be collected from state, fire district, county, and municipality websites. CWPPs will be sorted into two categories: 1) CWPPs that cover the whole extent of the county and 2) CWPPs that cover localized regions of the county rather than the entire county – often multiple local CWPPs are present in these counties without county-wide CWPPs. A simple random sample will be used to select 128 CWPPs. There will be an oversampling of county-wide CWPPs because they are rarer than the more local CWPPs.

Data Collection Procedures

In the proposed study, the two instrument results will be employed to create two indices: the CWPP process index and the CWPP implementation index. These indices will be the dependent variables. This study will evaluate whether independent variables – age, length of homeowner tenure, full-time/part-time residency, and income – are predictive of the CWPP process index score and the CWPP implementation index score.

Data Gathering Plans

The data for this study consists of two types of data: documents and geospatial. Both types of data are publically available for download on the internet or by contacting county or municipal planning departments. Indexing CWPP processes requires the following document data: completed CWPP reports and CWPP process meeting minutes. Indexing CWPP implementation is twofold: policy and physical environment interventions. The policy interventions require document data in the form of: local building and zoning codes, HOA guidelines, and comprehensive plans. The physical intervention data will be evaluated by change

in landcover using Landsat 7 imagery from 2000 (pre-HFRA) and 2016. The independent variable data consists of US Census data attributes at the block group level for the 2000 (pre-HFRA) and 2010 census. All data will be downloaded, catalogued, and geospatial data will be re-projected into a single coordinate system. If documents or Landsat imagery are unavailable for a sampled CWPP, then the random sampling will continue until the appropriate sample is reached. It is anticipated that data collection efforts should be completed in one to two months.

Data Analysis

Four types of data analysis are proposed for this study. The first is to create indices for both CWPP process and implementation using the instruments introduced in the earlier discussion of the Boulder pilot study. The use of these instruments to create the CWPP process index and the CWPP implementation index is described in greater detail in the following two subsections. Second, descriptive statistics and delta changes for each independent variable – age, length of homeowner tenure, full-time/part-time residency, and income – will be provided at each time period. The observational unit for the independent variables is the geographic extent of each CWPP. For each independent variable the min, max, and average will be calculated for 2000 and 2010. The delta – or change – for the min, max, and average of each independent variable will also be calculated for each CWPP extent. Third, relationships between the independent and dependent variables will be determined using Pearson product moment correlation coefficients. Fourth, in order to identify associations between the independent variables and each dependent variable – individually and as a composite index of overall CWPP effectiveness – inferential statistics will consist of weighted multiple regression because: 1) all variables are ratios; 2) one dependent and several independent variables; and 3) varying sample rates in stratified cluster sampling. All assumptions will be tested and met before statistical

analysis. GIS data tables will be exported and imported into SPSS. SPSS will be used for both the descriptive and inferential statistics. It is anticipated that data analysis will be completed in four to six months.

CWPP Process Index

To systematically and quantitatively evaluate CWPP processes, I will employ a protocol designed specifically for evaluation of wildfire in the WUI. The evaluation protocol builds on the best management practice literature published by Society of American Foresters (2004), Jakes et al (2007), Resource Innovations Institute for a Sustainable Environment University of Oregon (2008), Rodman and Stram (2008), and Jakes et al (2012). This study also builds on protocols previously developed for the evaluation of flood, hurricanes, tsunamis, and earthquake mitigation in comprehensive plans and planning processes (Andersson-sko, 2016; Berke et al., 2015; Brody, 2003; Frazier, Walker, Kumari, & Thompson, 2013; Horney et al., 2017; Johansen, Horney, & Tien, 2017; Lyles, Berke, & Smith, 2014; Stevens & Shoubridge, 2015). This protocol is based on the assumption that plans and meeting minutes identify local hazards, specify hazard mitigation goals and objectives, and promote the use of best CWPP process and implementation practices (Andersson-sko, 2016; Lyles & Stevens, 2014; Srivastava & Laurian, 2006).

This study – following published research literature – evaluates CWPPs on the identification of local wildfire hazard; the inclusion of consistent goals and objectives to mitigate the hazard; and the adoption of policies or strategies to promote the use of best management practices and achieve hazard mitigation goals. The evaluation protocol relies on 56 indicators, organized into 11 themes: context, goals and objectives, community capacity, partnerships and collaboration, base map, risk assessment, hazardous fuels reduction, reducing structural ignitability, education and outreach, emergency management capacity, and long-term success

(see Appendix A). The context of the planning process is evaluated through five indicators. Plan goals and objectives are evaluated through eight indicators: vulnerability reduction goals, environmental quality goals, and goals related to the protection of public interest. Community capacity is evaluated through two indicators. Public participation is evaluated through the theme of partnerships and collaboration; it includes 11 indicators. The factual basis of plan is evaluated through two themes: base map and risk assessment, containing one and nine indicators, respectively. Wildfire hazard mitigation strategies are evaluated through three themes: hazardous fuels reduction, reducing structural ignitability, and education and outreach, containing one, five, and four indicators, respectively. Emergency management capacity contains six indicators and long-term success contains four indicators. The full evaluation protocol instrument can be found in Appendix A.

Plans will be coded using the protocol to assess the presence or absence of each of the 56 indicators. Each indicator will be coded as "1" if each indicator definition is present in the plan, and "0" if the indicator is absent. Meeting minutes[8] will be utilized to understand the context in which the CWPPs were developed to further understand the perceptions of the quality of plans, necessary gaps and improvements, and potential barriers to CWPP implementation.

Because there are 56 indicators spread unevenly across 11 themes, each indicator will be normalized in order to proportionally weight them. A sensitivity analysis will be used to determine if a theme, or indicator within a theme, impacts the final results. Future models can use the sensitivity analysis to place more importance on those indicators and themes that are statistically more important than others.

[8] Meeting minutes themselves will not be scored according to the instruments.

CWPP Implementation Index

Successful CWPP implementation requires both policy and biophysical interventions, thus a CWPP implementation index is a composite score of policy and observable interventions. Policy interventions include: wildfire risk reduction best management practices integrated into building and zoning codes; comprehensive plans; subdivision ordinances, and HOA guidelines. To systematically and quantitatively evaluate CWPP implementation into local governance structure, same protocol instrument that will be used for CWPP process evaluation will also be used to code the policy interventions: which contains the following four categories: comprehensive plan; zoning codes, development standards, subdivision design guidelines, and HOA ordinances; building codes; and plan review and inspection procedures. There is a total of 17 total indicators. For further description of the analysis process, see above. The full proposed evaluation protocol instrument can be found in Appendix B.

Biophysical changes are the quantified aggregate of WUI expansion, densification, and healthy WUI forests and development. WUI boundaries will be calculated using a modified version of Radeloff et al.'s (2005) WUI work, as outlined in "Key Terms and Definitions" section of the literature review. WUI boundaries in Colorado will be calculated for the years 2000 and 2010. Percent change in the WUI's geographic extent will be calculated for each sampled CWPP's geographic boundary using the following: ((WUI Year 2-WUI Year 1)/WUI Year 1), calculations will be completed using QGIS. WUI densification will be calculated using population data for each CWPP geographic region, which will be compiled using census blocks for the 2000 and 2010 US Census in QGIS. Percent change will be computed by: ((Population Year 2-Population Year 1)/Population Year 1). If CWPP and local ordinances promoting wildfire wise land use practices should eliminate or reduce WUI expansion and densification in high risk

wildfire zones. The composite index for CWPP implementation is calculated using the following formula: ((WUI Year 2-WUI Year 1)/WUI Year 1) + ((Population Year 2-Population Year 1)/Population Year 1).

V. Study Outline

This dissertation will be organized into six chapters. Chapter one will be an introduction to the dissertation, which situates the study within the context of WUI and wildfire research followed by theoretical and methodological issues. Additionally, this chapter will demonstrate the need to empirically evaluate the effectiveness of CWPP process and implementation in addition to the socio-economic, demographic, and biophysical variables that predict effective CWPP processes and implementation. Chapter one will also include the organization of each subsequent chapter.

Chapter two will introduce the study area and provide the background for this study. This chapter will begin with a contextualization of the threat of wildfires in the west, particularly Colorado, followed by a discussion of WUI development and the limitation of land use planning in WUIs. This chapter will then provide the historical context and details of wildfire policy and policy changes followed by a broad summary of CWPPs and wildfire mitigation strategies. This chapter will conclude with the rationale for this study.

Chapter three will be a literature review, starting with an overview of hazard policy literature, specifically related to wildfire. Then it will discuss policy process including outcomes, citing several definitions of effective policy measures. CWPP and process documents, remote sensing and GIS data will be the data sources. This chapter will discuss the application and importance of document analysis, high-resolution remote sensing, and GIS data. It will conclude with the conceptual framework and study variables.

Chapter four will discuss the research design. It will first review various research methods relevant to this research project. Then it will outline the sampling protocol, data, data acquisition process, and data analysis.

Chapter five presents the analysis and findings of the research divided into four parts: document analysis, remote sensing findings, descriptive analysis results, and regression analysis. This chapter will conclude with an interpretation of the document and regression analysis results.

Chapter six will discuss the theoretical and policy implications of the research findings. This chapter will be comprised of three sections: 1) summary of research findings, 2) summary of the theoretical and policy implications, and 3) direction of future research.

VI. Study Dissemination

This research will be published in *Landscape Journal*, *Environment and Planning B: Planning and Design*, and *Journal of Urban and Regional Planning* or *The International Journal of Wildfire*, as well as presented at the *Association Collegiate Schools of Planning* conference. Additionally, a white paper will be published and shared with the wildfire planning practice community via social media, email, and my personal website.

VI. Bibliography

Ager, A. A., Day, M. A., McHugh, C. W., Short, K., Gilbertson-Day, J., Finney, M. A., & Calkin, D. E. (2014). Wildfire exposure and fuel management on western US national forests. *Journal of Environmental Management*, *145*, 54–70. https://doi.org/10.1016/j.jenvman.2014.05.035

Ager, A. A., Vaillant, N. M., & Finney, M. A. (2011). Integrating fire behavior models and geospatial analysis for wildland fire risk assessment and fuel management planning. *Journal of Combustion*, *2011*. https://doi.org/10.1155/2011/572452

Ager, A. A., Vaillant, N. M., Finney, M. A., & Preisler, H. K. (2012). Analyzing wildfire exposure and source-sink relationships on a fire prone forest landscape. *Forest Ecology and Management*, *267*, 271–283. https://doi.org/10.1016/j.foreco.2011.11.021

Andersson-sko, Y. (2016). Effective and sustainable flood and landslide risk reduction measures: an investigation of two assessment frameworks. *International Journal of Disaster Risk Reduction*, *7*, 374–392. https://doi.org/10.1007/s13753-016-0106-5

Arganaraz, J. P., Radeloff, V. C., Bar-Massada, A., Gavier-Pizarro, G. I., Scavuzzo, C. M., & Bellis, L. M. (2017). Assessing wildfire exposure in the wildland-urban interface area of the mountains of central Argentina. *Journal of Environmental Management*, *196*, 499–510. https://doi.org/10.1016/j.jenvman.2017.03.058

Bar-Massada, A., Radeloff, V. C., & Stewart, S. I. (2014). Biotic and abiotic effects of human settlements in the wildland-urban interface. *BioScience*, *64*(5), 429–437. https://doi.org/10.1093/biosci/biu039

Berke, P., Newman, G., Lee, J., Combs, T., Kolosna, C., Berke, P., … Salvesen, D. (2015). Evaluation of Networks of Plans and Vulnerability to Hazards and Climate Change: A Resilience Scorecard. *Journal of American Planning Association*, *81*(4), 287–302. https://doi.org/10.1080/01944363.2015.1093954

Bhandary, U., & Muller, B. (2009). Land use planning and wildfire risk mitigation: an analysis of wildfire-burned subdivisions using high-resolution remote sensing imagery and GIS data. *Journal of Environmental Planning and Management*, *52*(7), 939–955. https://doi.org/10.1080/09640560903181147

Bradely, G. (1984). The urban/forest interface. In G. Bradley (Ed.), *Land use and forest resources in a changing environment: the urban/forest interface* (pp. 3–16). Seattle, WA:

University of Washington Press.

Brody, S. D. (2003). Are we learning to make better plans? A longitudinal analysis of plan quality associated with natural hazards. *Journal of Planning Education and Research*, *23*, 191–201. https://doi.org/10.1177/0739456X03258635

Brown, R. T., Agee, J. K., & Franklin, J. F. (2004). Forest restoration and fire: principles in the context of place. *Conservation Biology*, *18*(4), 903–912. https://doi.org/10.1111/j.1523-1739.2004.521_1.x

Brummel, R. F., Nelson, K. C., & Jakes, P. J. (2012). Burning through organizational boundaries? Examining inter-organizational communication networks in policy-mandated collaborative bushfire planning groups. *Global Environmental Change*, *22*(2), 516–528. https://doi.org/10.1016/j.gloenvcha.2011.12.004

Bryant, B. P., & Westerling, A. L. (2014). Scenarios for future wildfire risk in California: links between changing demography, land use, climate, and wildfire. *Environmetrics*, *25*(6), 454–471. https://doi.org/10.1002/env.2280

Brzuszek, R. F., & Walker, J. B. (2008). Trends in community fire ordinances and their effects on landscape architecture practice. *Landscape Journal*, *27*, 142–153. https://doi.org/10.3368/lj.27.1.142

Burby, R., & Deyle, R. (2000). Creating hazard resilient communities through land-use planning. *Natural Hazards Review*, *1*(2), 99–106. https://doi.org/10.1061/(ASCE)1527-6988(2000)1:2(99)

Busenberg, G. (2004). Wildfire management in the United States: the evolution of a policy failure. *Review of Policy Research*, *21*(2), 145–156. https://doi.org/10.1111/j.1541-1338.2004.00066.x

Butsic, V., Kelly, M., & Moritz, M. (2015). Land use and wildfire: a review of local interactions and teleconnections. *Land*, *4*(1), 140–156. https://doi.org/10.3390/land4010140

Caban-Gonzalez, A., Haynes, R., Mccaffrey, S., Mercer, D. E., & Watson, A. (2007). *Fire social science research – selected highlights*. *General Technical Report PNW-GTR-736*. Portland, OR.

Carmo, M., Moreira, F., Casimiro, P., & Vaz, P. (2011). Land use and topography influences on wildfire occurrence in northern Portugal. *Landscape and Urban Planning*, *100*(1–2), 169–176. https://doi.org/10.1016/j.landurbplan.2010.11.017

Chuvieco, E., Martínez, S., Román, M. V., Hantson, S., & Pettinari, M. L. (2014). Integration of ecological and socio-economic factors to assess global vulnerability to wildfire. *Global Ecology and Biogeography*, *23*(2), 245–258. https://doi.org/10.1111/geb.12095

Collins, T. W. (2008). What influences hazard mitigation? Household decision making about wildfire risks in Arizona's White Mountains. *The Professional Geographer*, *60*(4), 508–526. https://doi.org/10.1080/00330120802211737

Colorado State Forest Service. (2017). Colorado community wildfire protection plans. Retrieved January 1, 2017, from http://csfs.colostate.edu/wildfire-mitigation/colorado-community-wildfire-protection-plans/

Crosetto, M., & Tarantola, S. (2001). Uncertainty and sensitivity analysis: tools for GIS-based model implementation. *International Journal of Geographical Information Science*, *15*(5), 415–437. https://doi.org/10.1080/13658810110053125

Crow, D. A., Lawhon, L. A., Koebele, E., Kroepsch, A., Schild, R., & Huda, J. (2015). Information, resources, and management priorities: agency outreach and mitigation of wildfire risk in the western United States. *Risk, Hazards & Crisis in Public Policy*, *6*(1), 69–90. https://doi.org/10.1002/rhc3.12073

Data Transfer Solutions. (2013). *Colorado wildfire risk assessment project: final report*. Fort Collins, CO.

Deyle, R. E., & Smith, R. A. (2000). Risk-based taxation of hazardous land development. *Journal of the American Planning Association*, *66*(4), 421–434. https://doi.org/10.1080/01944360008976125

Dondo Bühler, M., Curth, M. de T., & Garibaldi, L. A. (2013). Demography and socioeconomic vulnerability influence fire occurrence in Bariloche (Argentina). *Landscape and Urban Planning*, *110*, 64–73. https://doi.org/10.1016/j.landurbplan.2012.10.006

Fire History Society. (n.d.). U.S. Forest Service History Fire Suppression. Retrieved January 1, 2016, from http://www.foresthistory.org/ASPNET/Policy/Fire/Suppression/Suppression.aspx

Fleeger, W. E., & Becker, M. L. (2010). Decision processes for multijurisdictional planning and management: community wildfire protection planning in Oregon. *Society & Natural Resources*, *23*(4), 351–365. https://doi.org/10.1080/08941920802120067

Frazier, T. G., Walker, M. H., Kumari, A., & Thompson, C. M. (2013). Opportunities and

constraints to hazard mitigation planning. *Applied Geography*, *40*, 52–60. https://doi.org/10.1016/j.apgeog.2013.01.008

Gardner, P. D., Cortner, H. J., & Widaman, K. (1987). The risk perceptions and policy response toward wildland fire hazards by urban home-owners. *Landscape and Urban Planning*, *14*, 163–172. https://doi.org/10.1016/0169-2046(87)90021-1

Goldstein, B. E., & Butler, W. H. (2012). Collaborating for transformative resilience: shared identity in the U.S. Fire Learning Network. In B. E. Goldstein (Ed.), *Collaborative Resilience: Moving Through Crisis to Opportunity* (pp. 339–358). Boston, MA: MIT Press.

Grayzeck-souter, S. A., Nelson, K. C., Brummel, R. F., Jakes, P., & Williams, D. R. (2009). Interpreting federal policy at the local level: the wildland–urban interface concept in wildfire protection planning in the eastern United States. *International Journal of Wildland Fire*, *18*, 278–289.

Gwet, K. L. (2014). *Handbook of inter-rater reliability: the definitive guide to measuring the extent of agreement among raters* (4th ed.). Gaithersburg, MD: Advanced Analytics, LLC.

Harris, L. M., McGee, T. K., & McFarlane, B. L. (2011). Implementation of wildfire risk management by local governments in Alberta, Canada. *Journal of Environmental Planning and Management*, *54*(4), 457–475. https://doi.org/10.1080/09640568.2010.515881

Headley, R. (1916). *Fire Suppression, District 5. U.S. Forest Service*. Washington, DC.

Headwaters Economics. (2014). *Reducing wildfire risks to communities: solutions for controlling the pace, scale, and pattern of future development in the wildland-urban interface*. Bozeman, MT.

Headwaters Economics. (2016a). *Do insurance policies and rates influence home development on fire-prone lands?* Bozeman, MT.

Headwaters Economics. (2016b). *Land use planning to reduce wildfire risk: lessons from five western cities*. Bozeman, MT.

Heyerdahl, E. K., Brubaker, L. B., & Agee, J. K. (2001). Spatial controls of historical fire regimes: a multiscale example from the interior west, USA. *Ecology*, *82*(3), 660–678. https://doi.org/10.1890/0012-9658(2001)082[0660:SCOHFR]2.0.CO;2

Holland, M., March, A., Yu, J., & Jenkins, A. (2013). Land use planning and bushfire risk: CFA referrals and the February 2009 Victorian fire area. *Urban Policy and Research*, *31*(1), 41–54. https://doi.org/10.1080/08111146.2012.736255

Horney, J., Nguyen, M., Salvesen, D., Dwyer, C., Cooper, J., & Berke, P. (2017). Assessing the quality of rural hazard mitigation plans in the southeastern United States. *Journal of Planning Education and Research*, *37*(1), 56–65. https://doi.org/10.1177/0739456X16628605

Jakes, P., Burns, S., Cheng, A., Saeli, E., Nelson, K., Brummel, R., & Grayzeck, S. (2007). Critical elements in the development and implementation of community wildfire protection plans (CWPPs). In B. W. Butler & W. Cook (Eds.), *The fire environment— innovations, management, and policy; conference proceedings RMRS-P-46CD* (pp. 613–624). Destin, FL: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Jakes, P. J., Esposito, C., Burns, S., Nelson, K. C., Cheng, A. S., Sturtevant, V. E., & Williams, D. R. (2012). *Best management practices for creating a community wildfire protection plan*. Newton Square, PA.

Jakes, P. J., Nelson, K. C., Enzler, S. a., Burns, S., Cheng, A. S., Sturtevant, V., … Staychock, E. (2011). Community wildfire protection planning: is the Healthy Forests Restoration Act's vagueness genius? *International Journal of Wildland Fire*, *20*(3), 350–363. https://doi.org/10.1071/WF10038

Johansen, C., Horney, J., & Tien, I. (2017). Metrics for evaluating and improving community resilience. *Journal of Infrastructure Systems*, *23*(2), 1–11. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000329.

Kousky, C., Olmstead, S., & Sedjo, R. (2011). In harm's way: homeowner behavior and wildland fire policy. In K. M. Bradshaw & D. Lueck (Eds.), *Wildfire Policy: Law and Economics Perspectives* (pp. 178–199). New York, NY: Taylor & Francis for RFF Press.

Kramer, H. a., Collins, B. M., Kelly, M., & Stephens, S. L. (2014). Quantifying ladder fuels: a new approach using LiDAR. *Forests*, *5*(6), 1432–1453. https://doi.org/10.3390/f5061432

LANDFIRE. (2010). *The LANDFIRE Project: supporting fire and land management across the nation*. https://doi.org/10.1017/CBO9781107415324.004

Lyles, W., Berke, P., & Smith, G. (2014). A comparison of local hazard mitigation plan quality in six states , USA. *Landscape and Urban Planning*, *122*, 89–99. https://doi.org/10.1016/j.landurbplan.2013.11.010

Lyles, W., & Stevens, M. (2014). Plan quality evaluation 1994–2012: growth and contributions, limitations, and new directions. *Journal of Planning Education and Research*, *3*(4), 433–

450. https://doi.org/10.1177/0739456X14549752

Manning, R. (2012, August). In a major policy reversal, the Forest Service is fighting every fire this year -- but at what cost? *OnEarth Magazine*, 4–7.

Meldrum, J. R., Barth, C. M., Falk, L. C., Brenkert-Smith, H., Warziniack, T., & Champ, P. A. (2015). *Living with wildfire in Delta County, Colorado: cross-community comparisons*. Fort Collins, CO.

Miller, C. (2007). Wildfire underwriting in California: an industry perspective. In A. Troy & R. G. Kennedy (Eds.), *Living on the edge: economic, institutional and management perspectives on wildfire hazard in the urban interface* (pp. 121–125). Bingley, U.K.: Emerald Group Publishing Limited.

Moritz, M. A., Batllori, E., Bradstock, R. A., Gill, A. M., Handmer, J., Hessburg, P. F., … Syphard, A. D. (2014, November). Learning to coexist with wildfire. *Nature*, *515*, 58–66. https://doi.org/10.1038/nature13946

Muir, W. D. (1941). *Forest fire control in the United States of America*. New Haven, CT.

Muller, B., & Schulte, S. (2011). Governing wildfire risks: what shapes county hazard mitigation programs? *Journal of Planning Education and Research*, *31*(1), 60–73. https://doi.org/10.1177/0739456X10395895

National Fire Protection Association. (n.d.). *Firewise guide to landscape and construction*. *FWC-200-08-PH*.

National Fire Protection Association. (2016). The Basics of defensible space and the "home ignition zone." Retrieved January 1, 2017, from http://www.firewise.org/wildfire-preparedness/be-firewise/home-and-landscape/defensible-space.aspx

National Interagency Fire Center. (2013). Federal fire fighting costs (suppression only). Retrieved May 4, 2013, from http://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf

Paterson, R. G. (2007). Wildfire hazard mitigation as "safe" smart growth. In A. R. Troy & R. G. Kennedy (Eds.), *Living on the edge: economic, institutiona and management perspectives on wildfire hazard in the urban interface* (Vol. 6, pp. 43–71). Oxford, UK: Elsevier Ltd. https://doi.org/10.1016/S1569-3740(06)06004-4

Paveglio, T. B., Jakes, P. J., Carroll, M. S., & Williams, D. R. (2009). Understanding social complexity within the wildland-urban interface: a new species of human habitation?

Environmental Management, *43*(6), 1085–95. https://doi.org/10.1007/s00267-009-9282-z

Platt, R. V. (2014). Wildfire hazard in the home ignition zone: an object-oriented analysis integrating LiDAR and VHR satellite imagery. *Applied Geography*, *51*, 108–117. https://doi.org/http://dx.doi.org/10.1016/j.apgeog.2014.03.011

Poudyal, N. C., Johnson-Gaither, C., Goodrick, S., Bowker, J. M., & Gan, J. (2012). Locating spatial variation in the association between wildland fire risk and social vulnerability across six southern states. *Environmental Management*, *49*(3), 623–635. https://doi.org/10.1007/s00267-011-9796-z

Price, O. F., & Gordon, C. E. (2016). The potential for LiDAR technology to map fire fuel hazard over large areas of Australian forest. *Journal of Environmental Management*, *181*, 663–673. https://doi.org/http://dx.doi.org/10.1016/j.jenvman.2016.08.042

Radeloff, V. C., Hammer, R. B., Stewart, S. I., Fried, J. S., Holcomb, S. S., & McKeefry, J. F. (2005). The wildland-urban interface in the United States. *Ecological Applications*, *15*(3), 799–805. https://doi.org/10.1890/04-1413

Reams, M. A., Haines, T. K. T., Renner, C. R., Wascom, M. W., & Kingre, H. (2005). Goals, obstacles and effective strategies of wildfire mitigation programs in the wildland–urban interface. *Forest Policy and Economics*, *7*(5), 818–826. https://doi.org/10.1016/j.forpol.2005.03.006

Resource Innovations Institute for a Sustainable Environment. (2008). *Community wildfire protection plan evaluation guide*. Eugene, OR.

Riebsame, W. E., Gosnell, H., & Theobald, D. M. (1996). Land use and landscape change in the Colorado mountains I: theory, scale, and pattern. *Mountain Research and Development*, *16*(4), 395–405. https://doi.org/10.2307/3673989

Rodman, S., & Stram, J. (2008). *Community guide to preparing and implementing a community wildfire protection plan*. *A supplemental resource guide to preparing a community wildfire protection plan: a handbook for wildland–urban interface communities, March 2004*. Eugene, OR.

Roper, D. (2015). *Understanding wildfire mitigation behavior in central Oregon homeowners*. Oregon State University.

Silcox, F. A. (1910). *Fire prevention and control on the national forests*. *Yearbook of Department of Agriculture*. Washington, DC.

Skowronski, N. S., Haag, S., Trimble, J., Clark, K. L., Gallagher, M. R., & Lathrop, R. G. (2016). Structure-level fuel load assessment in the wildland–urban interface: a fusion of airborne laser scanning and spectral remote-sensing methodologies. *International Journal of Wildland Fire*, *25*(5), 547–557.

Smith, J. W., Leahy, J. E., Anderson, D. H., & Davenport, M. A. (2013). Community/Agency Trust and Public Involvement in Resource Planning. *Society & Natural Resources*, *26*(4), 452–471. https://doi.org/10.1080/08941920.2012.678465

Society of American Foresters. (2004). *Preparing a community wildfire protection plan: a handbook for wildland-urban interface communities*. Bethesda, MD.

Southard, L. F. (2011). The history of cooperative forest fire control and the Weeks Act. *Forest History Today, Spring/Fal*, 17–20.

Srivastava, R., & Laurian, L. (2006). Natural hazard mitigation in local comprehensive plans: the case of flood, wildfire and drought planning in Arizona. *Disaster Prevention and Management*, *15*(3), 461–483. https://doi.org/10.1108/09653560610669936

Steelman, T. A. (2008). Communities and wildfire policy. In E. M. Donoghue & V. E. Sturtevant (Eds.), *Forest communities connections: implications for research, management, and governance* (pp. 109–126). Washington, DC: Resources for the Future Press.

Steelman, T. A., & Burke, C. A. (2007). Is wildfire policy in the United States sustainable? What is the wildfire problem? *Journal of Forestry*, (March), 67–72.

Stephens, S. L., & Collins, B. M. (2007). Fire policy in the urban-wildland interface in the United States: what are the issues and possible solutions? In A. R. Troy & R. G. Kennedy (Eds.), *Living on the edge: economic, institutiona and management perspectives on wildfire hazard in the urban interface* (Vol. 6, pp. 33–42). Oxford, UK: Elsevier Ltd. https://doi.org/10.1016/S1569-3740(06)06003-2

Stevens, M. R., Lyles, W., & Berke, P. R. (2014). Measuring and reporting intercoder realiability in plan quality evaluation research. *Journal of Planning Education and Research*, *34*(1), 77–93. https://doi.org/10.1177/0739456X13513614

Stevens, M. R., & Shoubridge, J. (2015). Municipal hazard mitigation planning: a comparison of plans in British Columbia and the United States. *Journal of Environmental Planning and Management*, *58*(11), 1988–2014. https://doi.org/10.1080/09640568.2014.973479

Theobald, D. M., & Romme, W. H. (2007). Expansion of the US wildland–urban interface.

Landscape and Urban Planning, *83*(4), 340–354. https://doi.org/10.1016/j.landurbplan.2007.06.002

Travis, W. R. (2007). *New geographies of the American West: land use and the changing patterns of place* (2nd ed.). Washington, D.C.: Island Press.

Trego, G. D. (2014). We didn't start the fire...and we won't pay to stop it: financing wildfire management in America's wildland-urban interface. *William and Mary Environmental Law and Policy Review*, *36*, 595–634. https://doi.org/10.1525/sp.2007.54.1.23.

Troy, A. R. (2007). A tale of two policies: California programs that unintentionally promote development in wildland fire hazard zones. In A. Troy & R. G. Kennedy (Eds.), *Living on the edge: economic, institutional and management perspectives on wildfire hazard in the urban interface* (pp. 127–140). Bingley, U.K.: Emerald Group Publishing Limited.

Troy, A. R., & Romm, J. (2007). The effects of wildfire disclosure and occurance on property markets in California. In A. Troy & R. G. Kennedy (Eds.), *Living on the edge: economic, institutional and management perspectives on wildfire hazard in the urban interface* (pp. 101–119). Bingley, U.K.: Emerald Group Publishing Limited.

U.S. Congress. Healthy forests restoration act of 2003. (2003). Washington D.C.: 108th Congress.

United States Department of Agriculture Forest Service Missoula Technology and Development. (2016). The healthy forests initiative and Healthy Forests Restoraton Act interim field guide. Retrieved November 11, 2016, from http://www.fs.fed.us/projects/hfi/field-guide/web/page03.php

Vaux, H. J. (1982). Forestry's hotseat: the urban/forest interface. *American Forestry*, *88*(5), 37, 44–46.

Veblen, T. T., Kitzberger, T., & Donnegan, J. (2000). Climatic and human influences on fire regimes in ponderosa pine forests in the Colorado front range. *Ecological Applications*, *10*(4), 1178–1195. https://doi.org/10.1890/1051-0761(2000)010[1178:CAHIOF]2.0.CO;2

Winter, G., McCaffrey, S., & Vogt, C. a. (2009). The role of community policies in defensible space compliance. *Forest Policy and Economics*, *11*(8), 570–578. https://doi.org/10.1016/j.forpol.2009.07.004

Wolters, E. A., Steel, B. S., Weston, D., & Brunson, M. (2017). Determinants of residential firewise behaviors in central Oregon. *The Social Science Journal*, *54*(2), 168–178.

https://doi.org/http://dx.doi.org/10.1016/j.soscij.2016.12.004

VII. Appendices

Appendix A: CWPP Process and Plan Evaluation Instrument

This evaluation instrument is intended to provide an overall quality score of the CWPP process and plan. Note, the evaluation targets what is deemed most important, as defined by the literature, to complete a successful CWPP process, and plan.

CWPP Title: **CWPP Location:** **Coder Name:** **Date:** **List of Pertinent Documents:**		
	Yes (Yes = 1)	**No** (No = 0)
CWPP Process and Plan		
1. Context		
• Does the CWPP plan or meeting minutes remind community members of how they handled past challenges, such as a wildfire or environmental disaster; to help the community understand how it is vulnerable and create a sense of urgency for developing a CWPP?		
• Does the CWPP plan or meeting minutes show that previous collaborative efforts in the community, whether wildfire planning or other projects were studied, to identify how they were successful and use lessons from those experiences to lay the groundwork for doing a CWPP?		
• Does the CWPP plan or meeting minutes identify people who were involved in earlier collaborative or wildfire planning efforts and bring their experience to developing a CWPP?		
• Does the CWPP plan or meeting minutes acknowledge the community has little or no experience with collaboration or wildfire planning, and document how they overcame this inexperience?		
• Does the CWPP plan or meeting minutes identify previous disagreements within a community, related to wildlife or not, that threaten the CWPP process, and document how they were addressed early in the process to prevent them from becoming barriers?		
2. Goals and Objectives		
• Does the CWPP plan clearly articulate and define the CWPPs goals and objectives.		
• Does the CWPP's goals and objectives include a WUI definition goal and objective?		

• Does the CWPP's goals and objectives include a structure ignitibility goal and objective?		
• Does the CWPP's goals and objectives include a forest thinning goal and objective?		
• Does the CWPP's goals and objectives include a defensible space goal and objective?		
• Are the CWPP's goals and objectives framed to contain multiple frames – e.g. forest health, saving lives, water protection?		
• Does the CWPP's goals and objectives also contain local values and interests?		
• Is the CWPP's geographic scale compatible with its goals and objectives – e.g. a smaller scale CWPP, at the neighborhood or community level, if the stated goals are to motivate homeowners to reduce hazards on their properties while a larger scale plan, such as at the county level, should be used if the goal is to reduce wildfire risk across the landscape?		
3. Community Capacity		
• Does the CWPP plan or meeting minutes document resources that can help CWPP participants work together?		
• Does the CWPP plan or meeting minutes document capacity issues – e.g. funding, economic, political agendas – and suggest ways to overcome them?		
4. Partnerships and Collaboration		
• Does the CWPP plan identify the core team?		
• Does the CWPP plan identify other local, state, and federal partners (may also be part of the core team)?		
• Does the CWPP plan or meeting minutes articulate the process by which additional stakeholders – e.g. forest management groups, city council members, resource advisory committees, HOAs, Division of Wildfire/Fish and Game, Department of Transportation, local and state emergency management agencies, water districts, utilities, recreation organizations, environmental organizations, forest products interests, local chambers of commerce, and watershed councils – and the community at large was solicited for inclusion in the process and use multiple methods to do so – e.g. radio ads, bus ads, emails?		
• Does the CWPP plan articulate the role each of the afore mentioned groups play, including their responsibilities?		
• Does the CWPP plan identify the process for setting priorities?		
• Does the CWPP plan identify dates and timelines for implementation?		

• Does the CWPP plan identify how often the CWPP will be evaluated and fall within a five to ten year time frame?		
• Does the CWPP plan identify social vulnerabilities and how to overcome them – e.g. assistance to low-income and underserved residence, social service organizational support, and diversity of populations served?		
• Does the CWPP plan and meeting minutes reflect continued and sustained engagement throughout the CWPP process?		
• Does the CWPP plan or meeting minutes identify leaders, from within the community or drawn from outside it, who can mobilize others and serve as catalysts for action, and recruit them for your CWPP process?		
• Does the CWPP plan or meeting minutes articulate the involvement of people in the CWPP process who have access to multiple social networks and can serve as intermediaries between the networks?		
5. Base Map		
• Does the CWPP plan contain a base map that identifies the following: inhabited areas; critical community infrastructure – e.g. hospitals, nursing homes, fire stations, emergency shelters, water availability and supplies, and evacuation routes; and a preliminary WUI designation zone?		
6. Risk Assessment		
• Does the CWPP plan articulate how the WUI boundary is defined?		
• Does the CWPP plan document how the community has changed over time, this should include all of the following: population; age; percentage of youth; percentage of elderly; number of housing units; percent of owner and renter occupied housing units; percentage of people in the labor force; percentage of families below the federal poverty line; unemployment rate; length of homeowner tenure; full-time/part-time residency status; and income?		
• Does the CWPP plan document and describe the differing jurisdictional boundaries – e.g. USFS, Parks, and other private and public land owners and managers?		
• Does the CWPP plan identify where the priority fuels projects are located in each community?		
• Does the CWPP plan identify data sources used in the risk assessment process, including new or updated data that may change the risk assessment and influence fuel priorities – e.g. hazards, risks, protection and response capabilities, structural vulnerabilities, community values and resources, low-income and vulnerable populations?		

• Does the CWPP plan outline the key factors, definitions and process used to assign risk that minimally includes three categories of risk, which were developed on the following minimum criteria: slope, aspect, and fuels?		
• Does the CWPP plan outline evaluation criteria and processes to measure changing risk overtime?		
• Does the CWPP plan identify the percent of vulnerability populations at risk and how they are going to be engaged in risk reduction?		
• Does the CWPP plan acknowledge and provide a course of action for monitoring and addressing long-term climate change driven changes in wildfire risk?		
7. Hazardous Fuels Reduction		
• Does the CWPP plan identify hazardous fuels reduction on public and private land? This should include prioritization and approximate acres needing treatment and the strategies to do so – e.g. defensible space, forest thinning techniques that include: prescribed fire, mechanical thinning, mastication, plowing with a bulldozer, and applying herbicide. This information should also include the number and percentage of homes needing defensible space treatments and number and percentage of homes needing treatment in vulnerable communities.		
8. Reducing Structural Ignitability		
• Does the CWPP plan describe past resource losses – e.g. number of human caused fires, number of lightening caused fires, and number homes lost to fires, suppression costs, and economic losses?		
• Does the CWPP plan describe past resources saved – e.g. number of homes and economic savings?		
• Does the CWPP plan outline wildfire codes and regulations – e.g. building materials, roof types, windows – and where they are applicable, including recommend updates to local governance?		
• Does the CWPP plan document the past trends of WUI expansion and outline a process for continuing to monitor and report WUI expansion?		
• Does the CWPP plan document and outline local governance measures for best control WUI growth and directing it away from moderate to high risk areas?		
9. Education and Outreach		
• Does the CWPP plan discuss how the public was and will be engaged, this should include multiple avenues – e.g. public meetings field trips, demonstration projects, household visits, youth engagement, and community events?		

• Does the CWPP plan discuss the role of fire insurance and evacuation plans, including templates/examples of evacuation plans?		
• Does the CWPP plan document changing attitudes and awareness of wildfire – e.g. change in human-caused wildfires, increased participation in local fuel reduction programs and woody debris disposal?		
• Does the CWPP plan and meeting minutes reflect attempts to provide translations of all relevant materials to non-English speakers living in the WUI?		
10. Emergency Management Capacity		
• Does the CWPP plan document the number and percentage of homes in each fire district?		
• Does the CWPP plan document the capacity of emergency management – e.g. number and percent of trained and/or certified fire fighters and crews; fire suppression equipment; and response times?		
• Does the CWPP plan address incident command training?		
• Does the CWPP plan address animal and livestock preparedness and evacuation plans?		
• Does the CWPP plan include or link to a community evacuation plan and scheduled times to test it, this should include: local neighborhood evacuation plans; safety zones; residential and vulnerable population evacuation plans; community and fire personal communication systems; and resource lists?		
• Does the CWPP plan or meeting minutes reflect the coordination of CWPPs with other hazard mitigation plans – e.g. meet FEMA requirements for natural hazard mitigation plans?		
11. Long-term Success		
• Does the CWPP plan outline the incorporation of projects into the CWPP that can be accomplished quickly to foster homeowner buy-in and broaden support for the longer term effort?		
• Does the CWPP plan discuss other related plans or link to other types of plans and process to augment resources, broaden support, and enhance implementation?		
• Does the CWPP plan discuss how the CWPP will be implemented into formal governance structure?		
• Does the CWPP plan document the existence of or encourage the participation in the Firewise community program or have a Fire Safe Council?		

Appendix B: CWPP Implementation: Local Governance Evaluation Instrument

This evaluation instrument is intended to provide an overall quality score of the implementation of CWPPs. Note, the evaluation targets what is deemed most important, as defined by the literature, to complete a successful implementation CWPPs.

CWPP Title: **CWPP Location:** **Coder Name:** **Date:** **List of Pertinent Documents:**		
	Yes (Yes = 1)	**No** (No = 0)
CWPP Implementation: Local Governance		
1. Comprehensive Plan		
• Does the comprehensive plan acknowledge and document the integration of the CWPP, WUI, and wildfire risk into the planning process?		
• Is there clear evidence that the comprehensive plan responds to wildfire risk – e.g. directing or limiting development and critical infrastructure away from moderate to high risk areas; and protection of resources?		
• Does the comprehensive plan document and strategize ways to use open space preservation, conservation, watershed management, or climate change planning to buffer existing and future development from wildfire risk or how to leverage these processes to further reduce wildfire risk?		
2. Zoning Codes, Development Standards, Subdivision Design Guidelines, and HOA Ordinances		
• Are there WUI and wildfire risk reduction specific zoning codes – e.g. WUI or risk zone overlay districts or WUI codes?		
• Does the zoning code, development standards, subdivision design guidelines or HOA ordinances include or link to forest thinning and defensible space location priorities and requirements?		
• Does the zoning code, development standards, subdivision design guidelines or HOA ordinances set or link to water supply standards defensible space requirements, resource protection requirements, and responsibilities of ongoing maintenance?		
• Does the zoning code, development standards, subdivision design guidelines or HOA ordinances outline penalties for lack of compliance?		

• Does the zoning code, development standards, subdivision design guidelines or HOA ordinances restrict development within high wildfire-risk areas?		
• Does the zoning code, development standards, subdivision design guidelines or HOA ordinances contain documented incentives for developers to plan and implement open space and trails to act as fuel breaks?		
• Does the zoning code, development standards, subdivision design guidelines or HOA ordinances set adequate minimum road widths?		
3. Building Codes		
• Are there local building codes that address fire-resistant building codes that cover the following topics: fire-rated roofing, siding, and decking; closed eaves and soffits; and how to protect windows and vents?		
• Does the local building codes meet or exceed the current International WUI Building Code requirements for ignition resistant construction?		
4. Plan Review and Inspection Procedures		
• Do the plan review or inspection procedures include water tests and inspections to ensure adequate water supply requirements?		
• Are there inspection procedures to monitor mitigation implementation and maintenance and proper wildfire building code implementation for new construction?		
• Do the plan review or inspection procedures require developers or occupants to have fire insurance?		
• Does the plan review process or inspection procedures require pre-development mitigation work?		
• Does the plan review or inspection procedures ensure multiple ingress and egress options for developments?		