THESIS

MAPPING THE LANDSCAPE OF WILDFIRE RISK MITIGATION: UNDERSTANDING THE LINKS BETWEEN EQUITY, COMMUNITY ASSETS, CAPACITIES, AND COLLABORATION

Submitted by

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ABSTRACT

MAPPING THE LANDSCAPE OF EQUITY IN WILDFIRE RISK MITIGATION: UNDERSTANDING THE LINKS BETWEEN COMMUNITY ASSETS, CAPACITIES, AND COLLABORATION

Wildfire is a natural process that has shaped landscapes for millennia, but its exclusion since Euro-American settlement has had negative effects on forest health and composition, increasing the risk of large, high-severity wildfires. Many communities are grappling with this increased risk, as more people move into the Wildland Urban Interface (WUI) and climate change exacerbates hot, dry conditions that may help wildfires spread. Actions such as prescribed burning, hand or mechanical thinning, creating defensible space around structures, and home hardening can reduce communities' risk of wildfire but often require coordination with state, local, and federal partners, as well as time and money. Here, we explore community capacity to reduce impacts of wildfire. Collaboration, time and money are just a few indicators that make up a community's capacity reduce wildfire impacts, which can affect the strategies they are able to implement (i.e., communities with low capacity may be unable to carry out many programs). Previous work has identified that these indicators along with others that constitute community capacity, while additional studies have highlighted the connection between social vulnerability and wildfire risk. However, little work has been done to understand the link between community capacity and wildfire mitigation in specific areas and contexts. To address this gap in this two-part thesis, our objectives were: 1) to access and develop various spatial datasets for indicators of community capacity to visualize capacity for wildfire mitigation across Colorado, and 2) to understand the processes that link capacity to mitigation outcomes.

For Chapter 1, we conducted a first-of-its-kind study in Colorado mapping indicators of community capacity to represent variation across the state and to identify communities where high wildfire probability co-occurred with low capacity. Our findings highlight the eastern plains, the

northwestern part of the state, and San Luis Valley as areas with lower potential capacity. Further, areas within Weld, Las Animas, and Archuleta counties are places with lowest potential capacity but the greatest potential for wildfire. These findings also suggest that different communities have a variety of ways they build capacity and highlight the important role that funding plays in helping communities increase their capacity.

In Chapter 2, we explored local nuances and processes that link capacity to mitigation negative outcomes from wildfire by conducting 11 group interviews across Colorado. Our findings suggest that several key pieces of the process can drive outcomes: inter-organizational collaboration, leveraging funds, prioritization and planning, having dedicated staff for wildfire mitigation, building community buy-in, and engaging with various stakeholders. Creative workarounds emerged as a unique way across communities to overcome common barriers to wildfire mitigation, suggesting policy and institutional processes to streamline mitigation work may have outsized benefits, particularly in communities with limited resources. Our results highlight a need to point back to the systems that make communities vulnerable in the first place.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

CHAPTER 1:
A SPATIAL TOOL TO UNDERSTAND COMMUNITY CAPACITY TO REDUCE WILDFIRE IMPACTS IN COLORADO, USA

1.1 INTRODUCTION

The American West is characterized by rapid demographic and land use change coupled with increasing high-intensity wildfires (Calkin et al. 2014, Cheng and Dale 2020). Mitigating impacts of wildfire fundamentally requires the engagement of diverse actors and institutions, from private landowners to local organizations to state and federal management authorities (Fischer and Charnley 2012, Schultz and Moseley 2019). However, understanding and supporting effective wildfire mitigation involving diverse stakeholders remains a significant challenge (Spies et al. 2014, Fischer et al. 2016).

Central to this challenge is the complexity of reducing wildfire impacts, including variability in what comprises the capacity of communities to plan and complete mitigation work (Paveglio et al. 2016, Schultz and Moseley 2019). Amidst these uncertainties and the increasing frequency of large wildfires, an understudied dimension is emerging that could amplify challenges facing western landscapes: clear disparities in wildfire mitigation capacity. While the overlap of social vulnerability and wildfire potential or impact has garnered recent attention (Wigtil et al. 2016, Davies et al. 2018, Palaiologou et al. 2019), there is limited work operationalizing capacity in order to uncover such disparities across communities (Cheng and Dale 2020). The purpose of this study is to translate conceptual understanding of capacity into a spatial model and map capacity together with wildfire risk at a policy- and management-relevant scale, across the state of Colorado, USA.

1.1.1 Community Capacity

A community's vulnerability is important and related to the negative impacts of wildfire it may face. Vulnerability is a function of exposure to environmental hazard, conditioned on sensitivity to the hazard, and moderated by capacity (Turner et al. 2003) (Figure 1.1). Capacity is discussed in many ways across disciplines, as both "adaptive capacity" and "capacity" (Williams et al. 2012, Fischer and Jasny

2017, Cinner and Barnes 2019). Exposure refers to the nature and degree to which an entity is subjected to climate hazards, like wildfires, whereas sensitivity describes how much the system will be affected by these hazards. An entity's exposure and sensitivity to climate hazards defines their adaptive capacity, or ability to cope with the impacts of the hazard (Turner et al. 2003, Garschagen and Romero-Lankao 2015).

Further, adaptation and mitigation are discussed similarly across disciplines and when we discuss mitigation here, it may align with definitions of adaptation within the hazards' literature (for further discussion see Walker et al. (2023)). For this study, we focus on capacity, although still draw upon frameworks around adaptive capacity, and adopt a synthetic definition of capacity specific to reducing the impacts of wildfire: "the combination of local social characteristics and external forces (including ecological processes or larger social forces) that influence whether and how human communities" mobilize toward a set of goals (Paveglio et al. 2015).

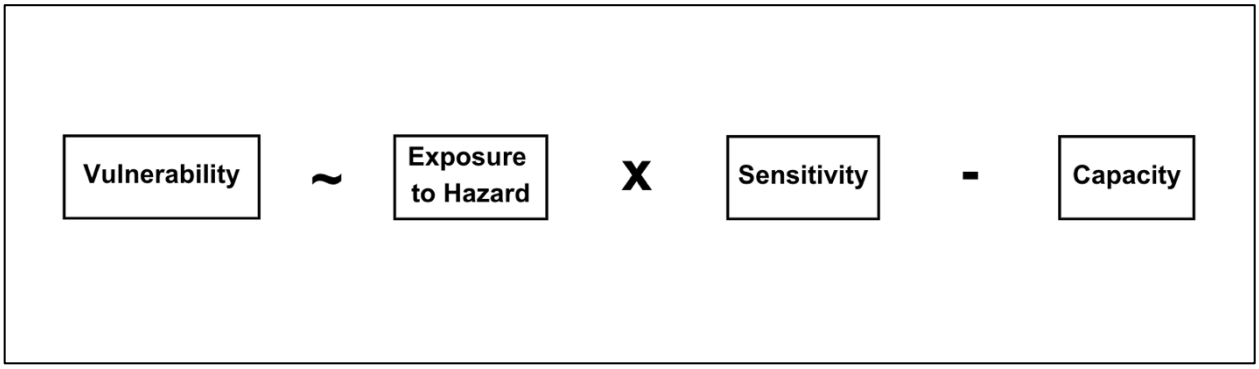


Figure 1.1. Understanding capacity related to vulnerability, exposure to hazard, and sensitivity, adapted from Turner et al. 2003.

Capacity is thus the pathway through which a community can reduce its vulnerability (Smit and Wandel 2006). Adaptive capacity has also been conceptualized as the combination of flexibility, organization, learning, socio-cognitive constructs, agency, and assets (Cinner and Barnes 2019). In this sense, capacity may include human capital (e.g., knowledge, skills, health, education, income, gender, age, race), economic capital (e.g., public organizational budgets, non-profit cash flow, business cash flow, technologies), natural capital (e.g., condition and productivity of land, air, water, recreation, scenic

beauty), and social capital (e.g., prior history of conflict or cooperation, trust, relationships) (Cheng and Sturtevant 2012).

Paveglio et al. (2015) expand upon wildfire risk mitigation capacity by characterizing communities into archetypes based on the capacity indicators that a community may hold. They group adaptive capacity indicators of wildfire risk mitigation into four conceptual categories: 1) access to and ability to adapt scientific or technical knowledge, 2) place-based knowledge and wildfire experience, 3) demographic and structural characteristics, and 4) interactions and relationships within the community. Within each of these categories, Paveglio et al. (2015) propose numerous indicators such as agency, past accomplishments, knowledge of fire risk, presence of local mills, and Community Wildfire Protection Plans (CWPPs). Communities can have different assemblages of these diverse indicators that make up capacity (Cheng and Sturtevant 2012).

1.1.2 Conceptual Indicators of Capacity in Communities Facing Wildfire Impacts

Community capacity to reduce the impact of wildfire exists in the context of higher order processes within social-ecological systems. In the Wildland Urban Interface (WUI), community institutions - formal and informal rules or conventions that societies use to structure interactions (Ostrom 2009, Epstein et al. 2015) – can provide guidance for reducing the impacts of wildfire and structure the interactions of various actors in the community (Abrams et al. 2015). Such institutions can provide a venue for learning and facilitate in developing the ability to respond to risk such as wildfire, thereby amounting to a form of adaptive governance (Folke et al. 2005, Abrams et al. 2015). Adaptive governance is defined as "the ability to observe and interpret essential processes and variables in ecosystem dynamics to develop the social capacity to respond to environmental feedback and change" (Folke et al. 2005, p. 445). Therefore, governance is important to the capacity of a community and can help reduce the impacts of wildfire.

Following the conceptual categories and specific examples from (Paveglio et al. 2015), we identified indicators of capacity and subsequent datasets that fit within the framework. Although the

framework provides flexibility, there is degree of uncertainty regarding which indicators may be more important in certain instances, and what combination and/or sequence of capacity indicators build upon each other. Below we will discuss the four conceptual categories from (Paveglio et al.(2015) and describe examples of indicators that fit within each.

"Access to and ability to adapt scientific or technical knowledge" is the knowledge or community interaction with experts (e.g., fuels management, fire behavior) that is accessible and usable for community members (Paveglio et al. 2009). This can be supported through various community organizations or collaborative groups/programs. For example, Homeowners Associations (HOAs) can play an important role in structuring community fire adaptation (Abrams et al. 2015, Steffey et al. 2020). Likewise, collaborative organizations (e.g., watershed coalitions) can bring individuals together and may be effective in planning and implementing risk assessments, emergency plans, fuel treatments, the often-multi-scale coordination required for mitigation, and applying to grants (Cheng and Sturtevant 2012). Further, Firewise is a national program administered by the National Fire Protection Association (NFPA) and provides a framework for communities to take action to reduce wildfire risk (Steffey et al. 2020). Finally, past fuel treatments can serve as an indicator by demonstrating a community had the technical knowledge to carry out these efforts (Paveglio et al. 2015).

"Interactions and relationships within the community" are important in building capacity because the interactions that people have locally can create a sense of belonging and support norms of trust and reciprocity needed to solve complex problems (Paveglio et al. 2009). Examples of venues for these interactions include Community Wildfire Protection Plans (CWPPs) and Fire Protection Districts. CWPPs are plans emphasized by the Healthy Forests Restoration Act with the aim to collaboratively develop and identify priority areas for hazardous fuel reduction treatments (Jakes et al. 2011). Fire Protection Districts also fall into this category because of the many interactions they have with their communities around wildfire risk mitigation (Madsen et al. 2018). Districts help to provide better service to smaller communities that are unable to support a full-time career fire department and can also provide services to unincorporated areas that do not have structured government and budgets.

"Demographic and structural characteristics" also can play a large part in the culture and function of communities, as different people can bring different kinds of knowledge and perspectives to prepare for wildfire (Paveglio et al. 2009). These include basic demographic features of an area (e.g., median household age, housing density,) as well as the institutions and other existing structures, such as forest products companies and grant writing ability of a community. Forest products companies include contractors to do mitigation work, as well as facilities to mill lumber and process slash (Paveglio et al. 2015). Grants specific to accessing mitigation funds are also important such as from the Forest Restoration and Wildfire Risk Mitigation Grant Program (FRWRM) administered by the Colorado State Forest Service (https://csfs.colostate.edu/grants/forest-restoration-wildfire-risk-mitigation/). Although such funding programs support WUI communities to create more resilient landscapes, such as by developing and implementing Community Wildfire Protection Plans (CWPPs), these programs may drive positive feedback cycles in which well-functioning, -resourced, and -connected communities gain disproportionate access to funds at the expense of less-advantaged communities, thereby widening disparities in mitigation capacity (Cheng and Dale 2020).

Demographic and structural characteristics also include social vulnerability. Social vulnerability indices (SVI), created to help officials identify communities that may need assistance before, during, or after disasters, often are comprised of census data such as socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation (Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program 2020). These indices can be important indicators that contribute to capacity and have received recent attention, such as the EJScreen Mapping Tool by the EPA (https://www.epa.gov/ejscreen), the Colorado EnviroScreen (https://cdphe.colorado.gov/enviroscreen), and the Council on Environmental Quality's Climate and Economic Justice Screening Tool (https://screeningtool.geoplatform.gov/en/#3/33.47/-97.5). Many more indices on similar topics exist, such as one created by (Wigtil et al. 2016) that combined social vulnerability with wildfire potential across the contiguous United States. These indices can be useful for policy makers and land managers to

understand social phenomena in a condensed form (Leslie et al. 2015, Hicks et al. 2016). However, the creation of these indices often relies upon secondary datasets, such as the U.S. Census, which leads to questions of validity, such as whether indicators represent what is happening on the ground in communities (Lavoie et al. 2018). U.S. Census data have also been associated with issues of inconsistent documentation, and unreliable reporting. Indicators based on these data may not reflect historical context or power relations (Lyons et al. 2016, Lavoie et al. 2018). Understanding these drawbacks, we still included SVI in this model of capacity, while acknowledging that it lacks nuance related to the local context. Colorado forest landscapes are socially diverse, and local variation in social processes likely influence disparities in wildfire risk mitigation capacity but likely is not the sole driver.

"Place-based knowledge and wildfire experience", also thought of as the intimate knowledge of the local environment, likely varies among residents within a community (Paveglio et al. 2009). It is important because local knowledge within a community can inform where wildfire risk mitigation projects are prioritized and how they should be implemented. Past wildfire experience and place-based knowledge could include locations of past wildfires, understanding of fire risk in the area, and strong relationship to place.

All the indicators described can make up the capacity to reduce impacts of wildfire, but not all are required for having capacity. For example, a community may have many new residents who lack wildfire experience, but have the financial resources to devote to mitigation work. Another community might have an engaged fire protection district but lack collaborative organizations, yet they are still able to implement mitigation projects. Our aim is to understand spatial variation in indicators of capacity in the context of wildfire planning in Colorado.

1.2 METHODS

1.2.1 Study Area: Colorado, USA

Colorado is characteristic of much of the recent wildfire increase in the western US, which has been associated with increased temperatures and earlier snowmelt in the spring (Stephens et al. 2020).

Additionally, about 65% of the state's forests are managed by federal agencies, with the USFS managing the majority at 47% (Colorado State Forest Service, https://csfs.colostate.edu/colorado-forests/colorado-land-ownership/, accessed 28 February 2023).

Historical fire suppression strategies have resulted in dense, continuous forests, which increases the risk of large, high-intensity crown fires (Keane et al. 2022). Additionally, Colorado has seen rapid population growth in the last 10 years, rising by 14.8% (United States Census Bureau 2021), with disproportionate growth in the wildland-urban interface. High fire risk plus more people in the WUI means larger risk for communities.

Colorado has a generally dry climate as a landlocked state and sits at an average elevation of 2072 meters (Doesken et al. 2003). Precipitation varies greatly across the state, but average annual precipitation is 43 cm with increased precipitation in the mountains (Doesken et al. 2003). Vegetation type also varies greatly across the state, from dry grasslands and shrublands to mixed conifer stands. There have been several devastating wildfires in recent years, including the Cameron Peak Fire in 2020, which was the largest in Colorado recorded history at over 200,000 acres (see Figure 1.2 for a visualization of vegetation features and past fire locations across the state).

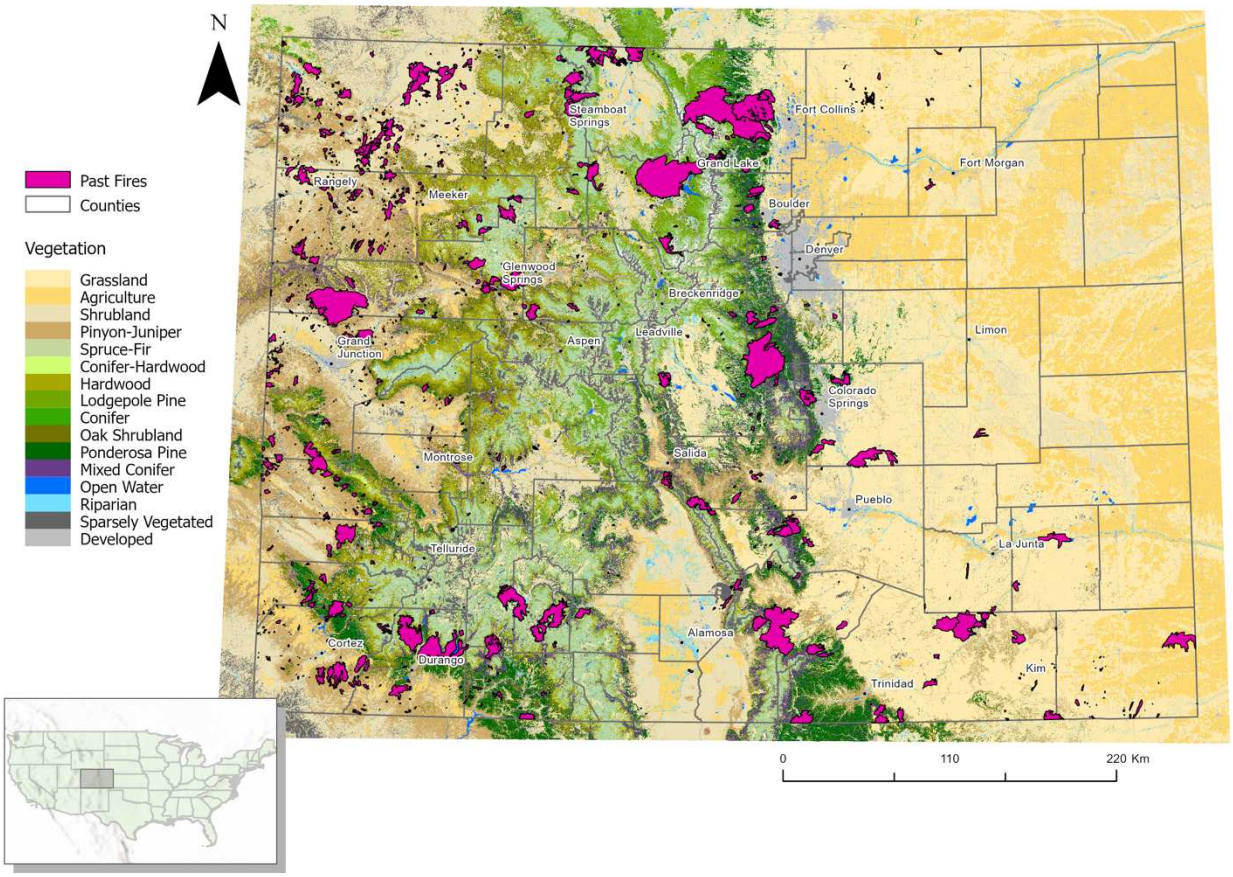


Figure 1.2. Study area map of the state of Colorado, USA with county boundaries and vegetation cover data from COWRA (2022). Wildfire data from National Interagency Fire Center (1990-2021).

1.2.2 Construction of Capacity Maps

1.2.2.1 Data Sources

Paveglio et al. (2015) proposed a framework of adaptive capacity in the context of wildfire risk mitigation and management. Here, we adapted their work by operationalizing capacity indicators using available or derived data resolved to the spatial extent of the State of Colorado (Table 1.1). The datasets fit largely within three of the four categories suggested by Paveglio et al. (2015): 1) access to and ability to adapt scientific or technical knowledge, 2) demographic and structural characteristics, and 3) interactions and relationships within the community. The last category, "place-based knowledge and wildfire experience" is primarily qualitative and nuanced. Due to the scale at which we were working, no

current datasets exit. Exclusion of this category represents a clear limitation of our approach, and future efforts should work to spatialize indicators of place-based knowledge and experiences.

Table 1.1. All data sources included in the spatialization of community capacity to mitigate for wildfire in Colorado, USA.

CATEGORIES	SOURCE	DATA TYPE & HOW IT WAS USED
CWPP	CSFS, 2020	Polygon data. Separated into 3 different layers; community-level CWPPs, Fire Protection District level CWPPs, and County level CWPPs. Binary, yes or no.
Collaboratives	CSU Center for Collaborative Conservation, 2021	Point data. Performed a distance accumulation. The closer to a collaborative, the higher the raster classification.
Fire protection districts	Colorado State Government, US Fire Administration, 2021	Polygon data. Staff composition (career, mostly career, mostly volunteer, volunteer) determined raster classification
Firewise community	CSFS, 2018	Polygon data. Binary, yes or no.
Social Vulnerability	Center for Disease Control Social Vulnerability Index RPL_Themes, 2020	Raster data. SVI score determined raster classification.
FRWRM grant	CSFS FRWRM, 2017-2022	Point data aggregated to Fireshed scale based on total amount ($) funded. Amount funded determined raster classification.
Forest product companies	CSFS, current 2023	Point data. Performed a distance accumulation. The closer to a forest product company, the higher the raster classification.
HOAs	Colorado DORA DRE, 2023	Point data. Buffered to 30 meters. Binary, yes or no.
Past fuel treatments	Colorado Forest Restoration Institute, 2003-2020	Polygon data. Binary, yes or no.
Burn probability	Colorado All Lands (COAL) 2022	Raster data, utilized for looking at capacity against wildfire probability
Conditional wildfire intensity	Colorado All Lands (COAL) 2022	Raster data, utilized for looking at capacity against wildfire probability

1.2.2.2 Variable Weighting

No current literature describes which indicators are the "most important" to determining community capacity to reduce wildfire impacts. To address this uncertainty, we surveyed wildfire researchers and wildfire practitioners using an opportunistic sampling approach at two academic and professional conferences. We purposefully sampled academic and practitioner audiences at both conferences to solicit feedback about indicators of capacity. The survey was deployed following presentations on wildfire risk mitigation capacity in a special session on wildfire risk for an academic audience at the American Association of Geographers Conference in Denver, Colorado on March 24,

2023. The survey was also distributed at the Colorado Wildland Fire Conference, a practitioner conference, in Fort Collins, Colorado on April 13, 2023. While recognizing limitations of this sampling strategy, we feel we capture relevant perspectives in the field.

We surveyed participants, asking them to rank indicators of capacity specific to their experiences in a particular study system or community (Supplementary Material 1.1). Participants were presented with 14 indicators of wildfire mitigation capacity operationalized from (Paveglio et al. 2015). They were asked to specify how important each indicator was for wildfire mitigation capacity in their area on a scale of 0 to 10, with 0 being "not at all important" and 10 being "extremely important". Following the presentations, participants were presented with a QR code to access the survey; all participants gave informed consent (IRB#: 3466).

The survey produced 86 responses from which weights were determined. To calculate the weights based on the average score (Table 1.2), we used the following equation:

Weight = (100/sum(averages)) * average

Table 1.2. The indicators of wildfire mitigation capacity utilized based on (Paveglio et al. 2015). Average is the average score given to each indicator based on 86 responses to a simple survey and the Weight is the final calculated weight of each indicator in the weighted version (rounded to the nearest whole number) of the wildfire mitigation capacity map of Colorado, USA.

	INDICATOR	AVERAGE	STANDARD ERROR	WEIGHTS
1	HOAs	4.943	0.265	7
2	Firewise	5.029	0.281	7
3	Presence of contractors	5.129	0.325	7
4	SVI	4.900	0.250	7
5	Past fuel treatments	6.643	0.214	9
6	CWPP Comm	7.057	0.259	10
7	CWPP FPRD	7.057	0.259	10
8	CWPP County	7.057	0.259	10
9	FPRD	7.286	0.261	10
10	Collaborative orgs	8.000	0.222	11
11	Grants	8.800	0.192	12

None of the indicators had an average weight of less than five out of ten, suggesting that we had a good selection of indicators to use in the model.

1.2.2.3 Weighted Overlay

The capacity map was created by using ESRI Arc Pro's Weighted Overlay Tool from the Spatial Analyst Toolbox (Esri Inc. 2020), a commonly used tool for indexing (Hoque et al. 2019, Jabbar et al. 2019, Mahmood and Hamayon 2021). Each data layer, if point data, was first buffered to match the true extent of that data. Distance accumulation was performed for forest product and collaboratives point data to account for proximity to the source organization. All data were then converted to raster layers with a cell size of 30m, reclassified to 5 bins (0, 25, 50, 75, 100), and then added as inputs into the Weighted Overlay Tool. The final raster output was then aggregated at the fireshed (Evers et al. n.d.) level using the Zonal Statistics Tool (Esri Inc. 2020). Finally, that output was laid over (by setting the transparency to 50%) with the combined Burn Probability and Fire Intensity for Colorado to show where the highest wildfire likelihood overlaps with lowest capacity in the state.

1.2.3 Wildfire Data

Current wildfire data were used to represent capacity and fire risk together visually. Burn Probability and Conditional Wildfire Intensity (or Conditional Flame Length) from COAL 2022 were utilized. Burn Probability is the simulation of ignition and spread of a large number of fires on a landscape (Finney 2005) and therefore provides a robust estimation of fire likelihood (Parisien et al. 2019). While Conditional Wildfire Intensity is the measure of the average flame length and is a measure of wildfire hazard, or the potential for losses given that a fire occurs (Ager et al. 2013). Previous research has shown that examining both Burn Probability and Conditional Wildfire Intensity together can characterize potential wildfire behavior (Ager et al. 2013). We wanted to combine the two for visualization purposes, and reclassified each raster to 5 bins (1, 2, 3, 4, 5), then performed a weighted overlay with each dataset contributing 50% to the model. The output was then averaged to the fireshed using Zonal Statistics in ArcPro. While other data exists describing Burn Probability and Conditional Wildfire Intensity (e.g., wildfire risk, USDA), we chose these datasets because they were higher resolution, the most recent, and optimized at the state level.

These wildfire data were overlaid with the fireshed-scale capacity layer to visualize variation in capacity together with wildfire risk. We present both the weighted and unweighted capacity layers.

1.3 RESULTS

1.3.1 Capacity Model and Wildfire Potential

Potential capacity to reduce wildfire impacts varied greatly across the state of Colorado. In the unweighted model, the greatest potential capacity (indicated in dark green) was in the northern Front Range, specifically in Boulder, Larimer, Jefferson, and Douglas counties. Lowest potential capacity (indicated in red) was across the eastern plains where there is little forest (Figure 1.3a). The respondent-weighted model shifted estimated capacity in many areas (Figure 1.3b, darker green), highlighting the variable importance respondents identified in certain indicators (e.g., increased relative weight assigned to grants, collaboratives organizations, and fire protection districts. Some areas that fell in high potential capacity in the weighted model included Gunnison, Park, and Route counties. However, the weighting process suggests diminished capacity in some areas, such as Grand, Archuleta and Alamosa counties (Figure 1.3b). In comparison, the unweighted model categorized more of the state as low capacity, specifically the eastern plains, with the highest capacity concentrated in areas near the Front Range (e.g., Larimer, Boulder, Jefferson Counties; see Figure 1.3a).

Overlaying capacity with wildfire burn probability and conditional intensity identified communities that are at the highest risk but with the lowest potential capacity. In the unweighted model, areas with high capacity and lower risk included places in Grand, Jackson, Park, Chaffee, and Delta counties (Figure 1.3c, white). Areas with high wildfire risk but the lowest potential capacity, included only Weld and Las Animas counties (Figure 1.3c, dark purple). Areas with low capacity and medium wildfire risk included large areas across the eastern plains as well as places in Rio Blanco, Moffat, and Mesa counties (Figure 1.3c, dark gray/blue).

The respondent-weighted model differed slightly from the unweighted model. Areas with high capacity and lower risk were similar, but did not include Jackson or Grand County and less of Chaffee

County. This model instead included Elbert, San Miguel and Hinsdale counties, as well as more of Gunnison county (Figure 1.3d, white). Areas with high wildfire risk but the lowest potential capacity for the weighted model were the same as the unweighted model but included an area in Archuleta County (Figure 1.3d), dark purple). Lowest potential capacity with medium wildfire risk for the weighted model was more spread out than the unweighted model with fewer large areas on the eastern plains. Instead, this model highlighted areas in Saguache, Costilla, Archuleta, Garfield, and Moffat counties (Figure 1.3d, dark gray/blue). To view Burn Probability and Conditional Wildfire Intensity separately, see Supplementary Figures 1.1 and 1.2 respectively.

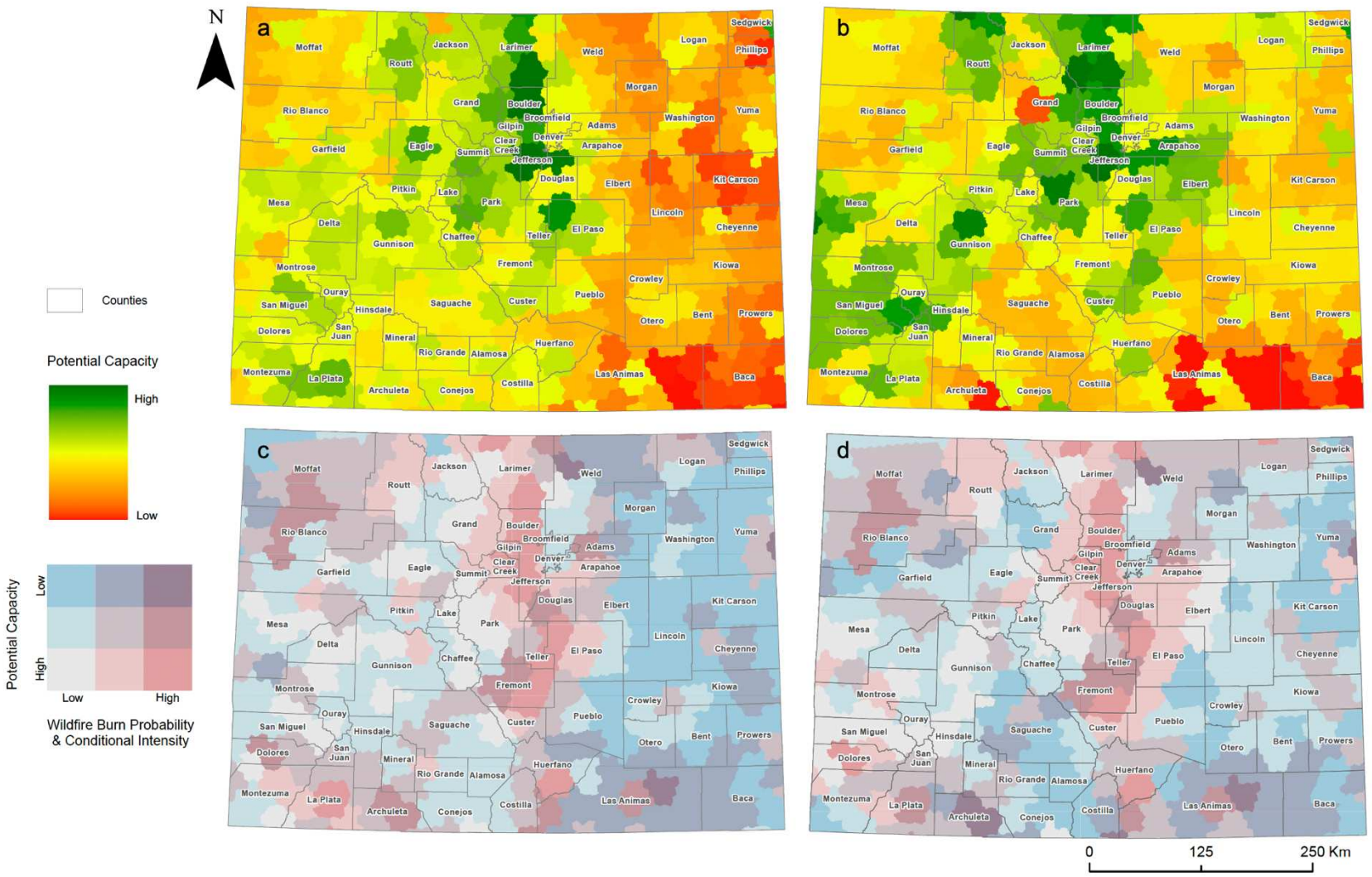


Figure 1.3. Potential capacity for wildfire risk mitigation across Colorado, USA using 11 different indicators and aggregated to the fireshed scale where a) unweighted model of potential capacity, b) weighted model of potential capacity, c) unweighted model of capacity against wildfire burn probability and conditional wildfire intensity, and d) weighted model of capacity against wildfire burn probability and conditional wildfire intensity. Wildfire data from Colorado All Lands (COAL) 2022. Potential capacity is depicted on a scale from red (lowest) to dark green (highest). Looking at potential capacity against wildfire probability and intensity is depicted on a matrix from light blue to dark blue, light pink to dark pink, with the darkest purple representing the lowest potential capacity with the highest burn probability and conditional intensity.

1.3.2 Different Ways to Support Capacity

When we aggregated indicators of capacity, we found the visualization masked variation in the composition represented in certain communities (Figure 1.4). This is particularly evident in moderately low to moderately high capacity firesheds. In Figure 1.4 below, we illustrate an example of this variation in capacity indicators among four different firesehds that were all classified as “moderate-to-high capacity”. Thus, our results suggest the tradeoffs inherent in aggregating multiple indicators of capacity, but also that communities may represent similar levels of capacity supported through different pathways.

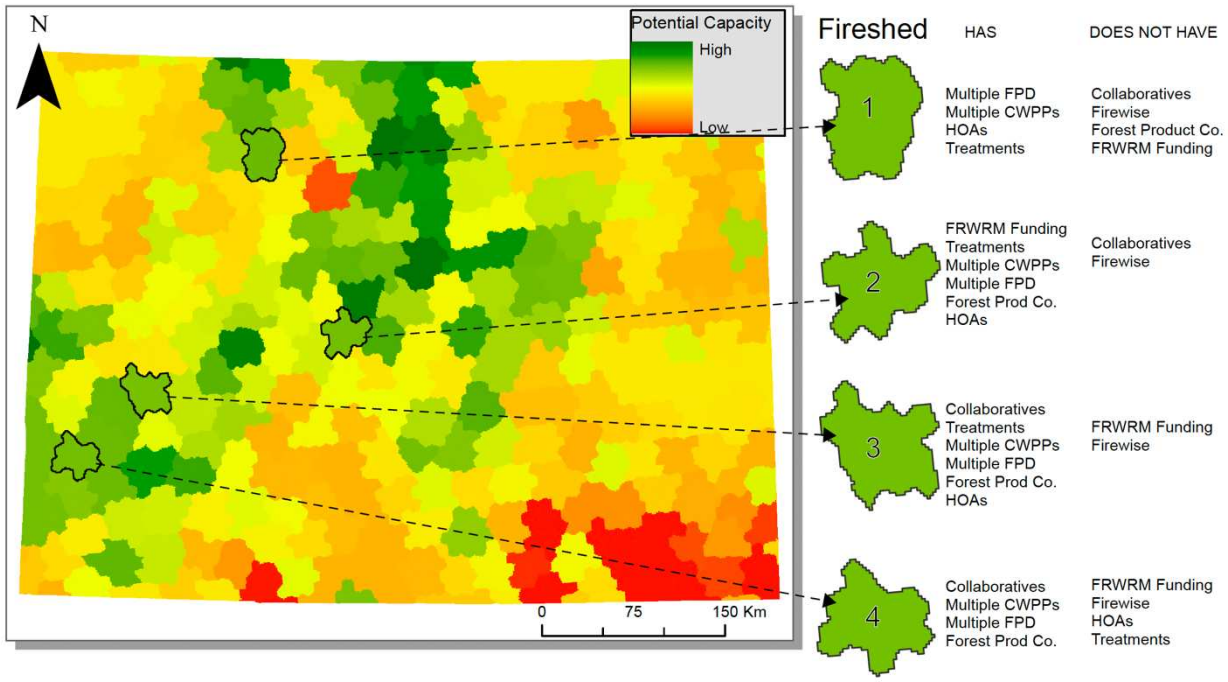


Figure 1.4. Potential capacity for wildfire mitigation across Colorado, USA using 11 different indicators, aggregated to the fireshed scale, and weighted based on a survey of experts in the field. Four different firesheds of the same color and potential capacity were pulled out to examine various ways a community could build capacity.

1.3.3 The Critical Role of Community Funding

Weighted rankings by survey respondents highlighted the importance of grant funding in capacity to reduce the impacts of wildfire. The main mechanism for community- or fireshed-scale funding in Colorado is the FRWRM grant program, though other programs exist that communities could access to

fund mitigation work. To explore the alignment of grant programs with capacity needs, we re-ran our original model with funding removed and weighted all remaining ten variables equally (10%) (Figure 1.5). We explored this capacity (less funding) base map overlaid with the actual level of funding received (Figure 1.5a). Much of the FRWRM funding has gone to the Front Range (Figure 1.5a). Of particular interest are areas that have applied for funding but never received it, depicted as a black outline without the gray fill, as well as communities that have never applied (Figure 1.5b).

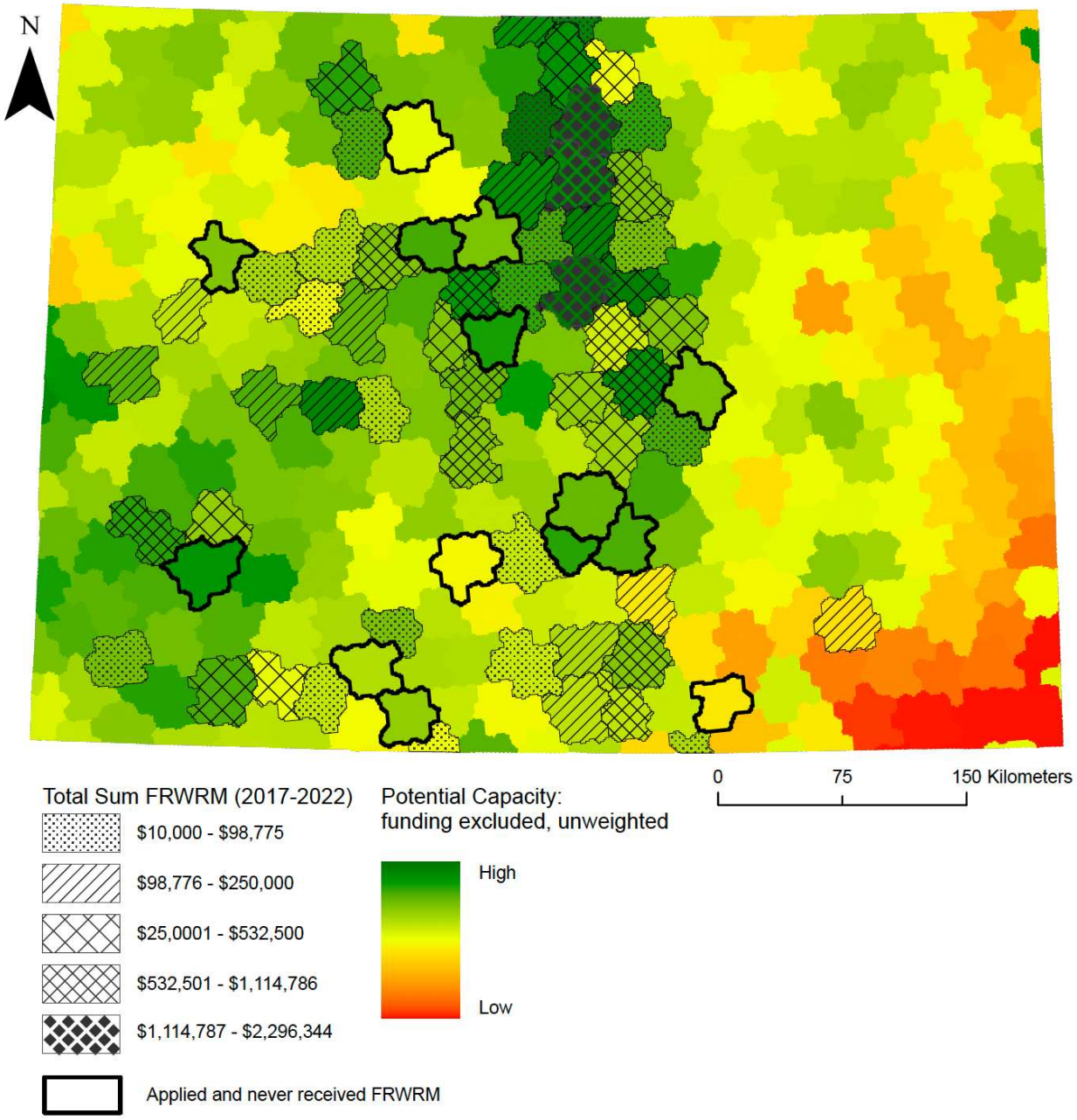


Figure 1.5. Potential capacity for reducing impacts of wildfire across Colorado, USA using 10 different indicators (excluding FRWRM funding from the model), aggregated to the fireshed scale and unweighted. Sum of FRWRM funding received (from 2017 to 2023) per fireshed on a scale from $10,000 to $2,296,344. Firesheds outlined with just a black border indicates that area applied to FRWRM but has never received funding.

1.4 DISCUSSION

1.4.1 Interpreting the Spatial Tool for Understanding Community Capacity

We found that potential capacity varies greatly across the state, with large areas along the Front Range exhibiting the highest potential capacity. Areas in the southeastern and northwestern parts of the state, as well as the San Luis Valley fell within the lower end of potential capacity when looking at the weighted model. By operationalizing a conceptual model of capacity (Paveglio et al. 2015), we highlight the spatial distribution of capacity, including geographic disparities with respect to wildfire probability. Our results support the findings of earlier research by Cheng and Dale (2020) into the distribution of funds from the FRWRM grant program. They found that already high-capacity communities were enhanced by this program and low-capacity communities were left with fewer resources (Cheng and Dale 2020). Our findings are consistent with this positive feedback loop, highlighting an aggregation of funding resources in the Front Range where the majority of the population and wealth of the state are concentrated.

1.4.1.1 Different Pathways to Capacity

Our results corroborate previous literature in the wildfire space in identifying that capacity is complex (Cheng and Sturtevant 2012, Paveglio et al. 2015, Schultz and Moseley 2019). Here, we have added nuance to the archetypes that Paveglio et al. (2015) suggested. Our findings suggest a more flexible approach to understanding capacity, recognizing that each community has different needs and starting points based on its location, geography, history, social context, and political standing regardless of whether it is urban or rural (Brooks et al. 2012). While we acknowledge that categorizations can be helpful, especially distinctions between urban and rural communities, we seek to highlight the nuanced variation. Indeed, recent wildfire experiences across the west can be characterized by population, and it has been noted that both rural and urban communities can have highly vulnerable (and low capacity) populations (Modaresi Rad et al. 2023).

Community capacity and what a community chooses to focus on can also vary by time and location across the state. Some communities may focus on building collaborative organizations while others may rely more heavily on fire protection districts, but both may have the same overall capacity. Alternatively, communities may focus on applying for grants, while others may work to build relationships and congregate collective risk mitigation at the neighborhood scale, such as through HOAs or wildfire safety certification. Our approach complements the Stages of Collaborative Readiness (Huayhuaca et al. 2023) largely in that the combination and/or sequence of capacity indicators build upon each other in concert, much like the Stages of Collaborative Readiness that also build upon each other.

1.4.1.2 The Role of Funding

Funding is an important piece of capacity, as illustrated by our survey of professionals working in the field of forestry/wildland fire research and practice. We recognize that the FRWRM program is only one of several grant programs funding mitigation work in Colorado, but existing research suggest this program serves as a good example of funding practices in the state (Cheng and Dale 2020). We also understand that some of the results may be counter-intuitive at first glance, such as 1) the small number of firesheds that have applied for funding, and 2) lack of success some wealthy areas appear to have experienced in securing funding, with several that applied and never received funding.

The first finding is likely the result from the temporal extent of the data we were able to collect. Our data span 2017-2023, so it is not the entire history of the program, which started off under a different name; Colorado Risk Reduction Grant Program and began in 2013 (WRRG; Senate Bill 13-269; https://leg.colorado.gov/sites/default/files/ digest2013.pdf). It is possible that including data from the other four years of the program would highlight additional firesheds. Past research on the program has shown that more than half of the total funding went to either local governments (municipal and county-level), or non-governmental organizations (NGOs), with the rest of the funding going to HOAs, Fire Protection Districts and other unclassifiable entities (Cheng and Dale 2020). Several studies have also shown that wildfire mitigation grants tend to go to more affluent (and often urban) communities, rather

than less-wealthy rural communities (Ojerio et al. 2011, Cheng and Dale 2020, Seong et al. 2022). Drawing on these findings, we can surmise that most of the firesheds highlighted as having applied are places with larger local governments and locations where there are more NGOs.

We have several speculations for the second point of why wealthy areas appear to have applied and never received funding. Wealthier areas may have alternative funding sources and may not need to rely as heavily on state grants to fund their mitigation work. It is possible that these areas are utilizing federal funding, which often requires a higher match than state funding, which less wealthy communities may be unable to acquire (Kodis et al. 2021). Funding can also play a role in maintaining disparities. No studies found to date have looked at social vulnerability and funding rates for wildfire risk mitigation work, which could be an important topic for future research. However, one study identified inequitable funding distribution by FEMA for disaster relief (Domingue and Emrich 2019). It is also possible that funders could break feedback loops by funding more vulnerable communities. For example, communities that have never received funding previously might suddenly be set on a new trajectory with funds (Cheng and Dale 2020).

1.4.2 Limitations: Data and Analytical Decisions

Some of the data we utilized were developed and collected by other partners, thus more tailored to their needs and not completely matching the years of other datasets we used. We were unable to gain access to a more recent spatial dataset of Firewise communities, and thus we used data complete up until 2018. Similarly, the past fuel treatment data goes back twenty years in time but is only current to 2020. We have reason to believe that this dataset is currently being updated, but the data release was not within the timeframe of this project. Future work could create an updated model with more recent spatial data.

Another issue we encountered was that some datasets were point data only and would be more accurate in polygon format. Specifically, the locations of collaborative organizations would be better suited for this model if there were polygons depicting their jurisdictional boundaries. We worked around this by doing a distance accumulation from the points. Additionally, we understand that collaborative

organizations all have varying levels of capacity themselves, but we could not capture this nuance with any existing datasets for Colorado. Future work could explore what collaborative capacity looks like, how collaboratives are networked with other organizations, and how that may influence capacity. The HOA data was also point data, although we obtained data on the number of units in each HOA, which factored into the analysis. This was slightly problematic because some HOAs are much larger than others and, would again be more accurate as polygon data.

Finally, another important limitation is that we were unable to include data on several social components that are integral to building and leveraging local capacity, such as information sharing among residents, relationships to place, trust in government, presence of local champions, and additional aspects of community capacity (Paveglio et al. 2015). Future work could explore approaches to collect that type of capacity data, but it would be difficult given the scale. We also understand that this spatialized map of potential capacity negates local nuance that may more accurately represent a place's capacity to reduce impacts of wildfire. We want to be clear that this exercise overall was a model and is not intended to put any communities into boxes especially because the model ignores within-fireshed variation in capacity indicators and variation over time, such as would exist in specific communities. This was an exploratory exercise in further understanding capacity and we could see future studies addressing complexity and nuance more fully by looking at changes in capacity over time and by interviewing communities across the state as others have called for (Jacobs 2019).

1.4.3 Policy Recommendations & Future Impacts

Having local organizations (e.g., Fire Protection Districts, collaborative organizations, HOAs) involved in the governing of wildfire risk mitigation can increase communities' ability to socially organize and learn, as compared to top-down federal-level governance of wildfire preparedness (Abrams et al. 2015). All the indicators included in our model are known to influence community capacity, and we created a spatial visualization for the state of Colorado. CWPPs are one way to convene collaborations and to plan out priority areas for treatment, while grants are a way for communities to fund these

treatments and planning processes. Having local contractors in the area and a history of past fuel treatments may further enable future mitigation efforts. Firewise communities are evidence of community buy-in, and social vulnerability adds in local context such as socio-economic status.

This model can be helpful to community managers and higher-level policymakers alike. For communities, the visualizations provide a way to better understand what is happening in the area, what resources may be available, and highlight key indicators that may be missing from a place. Future iterations of this model could include specific names of entities to better aid community members in finding resources and contacts to connect with. This model could also assist managers in each community to understand how other communities may be approaching wildfire mitigation strategies. Managers could also use this model to self-assess and reflect on where they may be in the Stages of Readiness (Huayhuaca et al. 2023) and what they need to prioritize next. Finally, this model could be useful to higher-level policymakers in providing information on places that lack funding but have wildfire risk and a need for funds to implement projects.

REFERENCES

Abrams, J., M. Knapp, T. B. Paveglio, A. Ellison, C. Moseley, M. Nielsen-Pincus, and M. S. Carroll. 2015. Re-envisioning community-wildfire relations in the U.S. West as adaptive governance. *Ecology and Society* 20(3):34.

Ager, A. A., M. Buonopane, A. Reger, and M. A. Finney. 2013. Wildfire Exposure Analysis on the National Forests in the Pacific Northwest, USA. *Risk Analysis* 33(6):1000–1020.

Armitage, D. R., editor. 2010. *Adaptive capacity and environmental governance*. Springer, New York.

Bayham, J., J. K. Yoder, P. A. Champ, and D. E. Calkin. 2022. The Economics of Wildfire in the United States. *Annual Review of Resource Economics* 14(1):379–401.

Berke, P., and D. Godschalk. 2009. Searching for the Good Plan: A Meta-Analysis of Plan Quality Studies. *Journal of Planning Literature* 23(3):227–240.

Berkes, F. 2009. Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management* 90(5):1692–1702.

Berkes, F. 2010. Devolution of environment and resources governance: trends and future. *Environmental Conservation* 37(4):489–500.

Braun, V., and V. Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3(2):77–101.

Brody, S. D., J. E. Kang, and S. Bernhardt. 2010. Identifying factors influencing flood mitigation at the local level in Texas and Florida: the role of organizational capacity. *Natural Hazards* 52(1):167–184.

Brooks, J. S., K. A. Waylen, and M. Borgerhoff Mulder. 2012. How national context, project design, and local community characteristics influence success in community-based conservation projects. *Proceedings of the National Academy of Sciences* 109(52):21265–21270.

Brummel, R. F., K. C. Nelson, S. G. Souter, P. J. Jakes, and D. R. Williams. 2010. Social learning in a policy-mandated collaboration: community wildfire protection planning in the eastern United States. *Journal of Environmental Planning and Management* 53(6):681–699.

Calkin, D. E., J. D. Cohen, M. A. Finney, and M. P. Thompson. 2014. How risk management can prevent future wildfire disasters in the wildland-urban interface. *Proceedings of the National Academy of Sciences* 111(2):746–751.

Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program. 2020. CDC/ATSDR SVI CDC/ATSDR Social Vulnerability Index Database Colorado. https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html.

Chaffin, B. C., H. Gosnell, and B. A. Cosens. 2014. A decade of adaptive governance scholarship: synthesis and future directions. *Ecology and Society* 19(3):art56.

Champ, J. G., J. J. Brooks, and D. R. Williams. 2012. Stakeholder Understandings of Wildfire Mitigation: A Case of Shared and Contested Meanings. *Environmental Management* 50(4):581–597.

Chapman, S. K., J. A. Langley, S. C. Hart, and G. W. Koch. 2006. Plants actively control nitrogen cycling: uncorking the microbial bottleneck. *New Phytologist* 169(1):27–34.

Cheng, A. S., and L. Dale. 2020. Achieving Adaptive Governance of Forest Wildfire Risk Using Competitive Grants: Insights From the Colorado Wildfire Risk Reduction Grant Program. *Review of Policy Research* 37(5):657–686.

Cheng, A. S., and V. E. Sturtevant. 2012. A Framework for Assessing Collaborative Capacity in Community-Based Public Forest Management. *Environmental Management* 49(3):675–689.

Cinner, J. E., and M. L. Barnes. 2019. Social Dimensions of Resilience in Social-Ecological Systems. *One Earth* 1(1):51–56.

David, E., and E. P. Enarson, editors. 2012. *The women of Katrina: how gender, race, and class matter in an American disaster*. Vanderbilt University Press, Nashville.

Davies, I. P., R. D. Haugo, J. C. Robertson, and P. S. Levin. 2018. The unequal vulnerability of communities of color to wildfire. *PLOS ONE* 13(11):e0205825.

Doesken, N. J., R. A. Pielke, and O. A. P. Bliss. 2003. *Climate of Colorado*. Colorado Climate Center, Atmospheric Science Department, Colorado State University, Fort Collins, CO.

Domingue, S. J., and C. T. Emrich. 2019. Social Vulnerability and Procedural Equity: Exploring the Distribution of Disaster Aid Across Counties in the United States. *The American Review of Public Administration* 49(8):897–913.

Dunn, C. J., C. D. O'Connor, J. Abrams, M. P. Thompson, D. E. Calkin, J. D. Johnston, R. Stratton, and J. Gilbertson-Day. 2020. Wildfire risk science facilitates adaptation of fire-prone social-ecological systems to the new fire reality. *Environmental Research Letters* 15(2):025001.

Epstein, G., J. Pittman, S. M. Alexander, S. Berdej, T. Dyck, U. Kreitmair, K. J. Rathwell, S. Villamayor-Tomas, J. Vogt, and D. Armitage. 2015. Institutional fit and the sustainability of social–ecological systems. *Current Opinion in Environmental Sustainability* 14:34–40.

Eriksen, C., and G. Simon. 2017. The Affluence–Vulnerability Interface: Intersecting scales of risk, privilege and disaster. *Environment and Planning A: Economy and Space* 49(2):293–313.

Esri Inc. 2020. ArcGIS Pro. Esri Inc.

Evans, A., S. Auerbach, L. W. Miller, R. Wood, K. Nystrom, J. Loevner, A. Aragon, M. Piccarello, and E. Krasilovsky. 2015. Evaluating the effectiveness of wildfire mitigation activities in the wildland-urban interface. Forest Stewards Guild.

Evers, C. R., C. D. Ringo, A. A. Ager, M. A. Day, F. J. Alcasena Urdíroz, and K. Bunzel. (n.d.). The Fireshed Registry: Fireshed and project area boundaries for the continental United States.

Finney, M. A. 2005. The challenge of quantitative risk analysis for wildland fire. *Forest Ecology and Management* 211(1–2):97–108.

Fischer, A. P., and S. Charnley. 2012. Risk and Cooperation: Managing Hazardous Fuel in Mixed Ownership Landscapes. *Environmental Management* 49(6):1192–1207.

Fischer, A. P., and L. Jasny. 2017. Capacity to adapt to environmental change: evidence from a network of organizations concerned with increasing wildfire risk. *Ecology and Society* 22(1):art23.

Fischer, A. P., T. A. Spies, T. A. Steelman, C. Moseley, B. R. Johnson, J. D. Bailey, A. A. Ager, P. Bourgeron, S. Charnley, B. M. Collins, J. D. Kline, J. E. Leahy, J. S. Littell, J. D. Millington, M. Nielsen-Pincus, C. S. Olsen, T. B. Paveglio, C. I. Roos, M. M. Steen-Adams, F. R. Stevens, J. Vukomanovic, E. M. White, and D. M. Bowman. 2016. Wildfire risk as a socioecological pathology. *Frontiers in Ecology and the Environment* 14(5):276–284.

Fleeger, W. E. 2008. Collaborating for success: Community Wildfire Protection Planning in the Arizona White Mountains. *Journal of Forestry* 106(2):78–82.

Fleming, C. J., E. B. McCartha, and T. A. Steelman. 2015. Conflict and Collaboration in Wildfire Management: The Role of Mission Alignment. *Public Administration Review* 75(3):445–454.

Folke, C., T. Hahn, P. Olsson, and J. Norberg. 2005. ADAPTIVE GOVERNANCE OF SOCIAL-ECOLOGICAL SYSTEMS. *Annual Review of Environment and Resources* 30(1):441–473.

Fusch, P. I., and L. R. Ness. 2015. *Are We There Yet? Data Saturation in Qualitative Research*. Pages 1408–1416. Walden University, Walden Faculty and Staff Publications.

Garschagen, M., and P. Romero-Lankao. 2015. Exploring the relationships between urbanization trends and climate change vulnerability. *Climatic Change* 133(1):37–52.

Handmer, J. 1996. Policy Design and Local Attributes for Flood Hazard Management. *Journal of Contingencies and Crisis Management* 4(4):189–197.

Hartig, J. H., N. L. Law, D. Epstein, K. Fuller, J. Letterhos, and G. Krantzberg. 1995. Capacity-building for restoring degraded areas in the Great Lakes. *International Journal of Sustainable Development & World Ecology* 2(1):1–10.

Hessburg, P. F., D. J. Churchill, A. J. Larson, R. D. Haugo, C. Miller, T. A. Spies, M. P. North, N. A. Povak, R. T. Belote, P. H. Singleton, W. L. Gaines, R. E. Keane, G. H. Aplet, S. L. Stephens, P. Morgan, P. A. Bisson, B. E. Rieman, R. B. Salter, and G. H. Reeves. 2015. Restoring fire-prone Inland Pacific landscapes: seven core principles. *Landscape Ecology* 30(10):1805–1835.

Hicks, C. C., A. Levine, A. Agrawal, X. Basurto, S. J. Breslow, C. Carothers, S. Charnley, S. Coulthard, N. Dolsak, J. Donatuto, C. Garcia-Quijano, M. B. Mascia, K. Norman, M. R. Poe, T. Satterfield, K. St. Martin, and P. S. Levin. 2016. Engage key social concepts for sustainability. *Science* 352(6281):38–40.

Highfield, W. E., W. G. Peacock, and S. Van Zandt. 2014. Mitigation Planning: Why Hazard Exposure, Structural Vulnerability, and Social Vulnerability Matter. *Journal of Planning Education and Research* 34(3):287–300.

Hoque, M., S. Tasfia, N. Ahmed, and B. Pradhan. 2019. Assessing Spatial Flood Vulnerability at Kalapara Upazila in Bangladesh Using an Analytic Hierarchy Process. *Sensors* 19(6):1302.

Huayhuaca, C. 2019. The state of collaboration: An analysis of form and function in Colorado's natural resource collaboratives. Dissertation, Colorado State University, Fort Collins, Colorado.

Huayhuaca, C., A. S. Cheng, T. Beeton, J. Sanderson, A. Barton, A. Kimple, M. Colavito, J. Zebrowski, J. Dunn, N. vonHedemann, and A. Slack. 2023. Preparing landscapes and communities to receive and recover from wildfire through collaborative readiness: A concept paper. *Southwest Ecological Restoration Institutes*.

Jabbar, F. K., K. Grote, and R. E. Tucker. 2019. A novel approach for assessing watershed susceptibility using weighted overlay and analytical hierarchy process (AHP) methodology: a case study in Eagle Creek Watershed, USA. *Environmental Science and Pollution Research* 26(31):31981–31997.

Jacobs, F. 2019. Black feminism and radical planning: New directions for disaster planning research. *Planning Theory* 18(1):24–39.

Jakes, P. J., K. C. Nelson, S. A. Enzler, S. Burns, A. S. Cheng, V. Sturtevant, D. R. Williams, A. Bujak, R. F. Brummel, S. Grayzeck-Souter, and E. Staychock. 2011. Community wildfire protection planning: is the Healthy Forests Restoration Act's vagueness genius? *International Journal of Wildland Fire* 20(3):350.

Keane, R. E., A. W. Schoettle, and D. F. Tomback. 2022. Effective actions for managing resilient high elevation five-needle white pine forests in western North America at multiple scales under changing climates. *Forest Ecology and Management* 505:119939.

Kelly, E. C., S. Charnley, and J. T. Pixley. 2019. Polycentric systems for wildfire governance in the Western United States. *Land Use Policy* 89:104214.

Kodis, M., M. Bortman, and S. Newkirk. 2021. Strategic retreat for resilient and equitable climate adaptation: the roles for conservation organizations. *Journal of Environmental Studies and Sciences* 11(3):493–502.

Kolden, C. A., and C. Henson. 2019. A Socio-Ecological Approach to Mitigating Wildfire Vulnerability in the Wildland Urban Interface: A Case Study from the 2017 Thomas Fire. *Fire* 2(1):9.

Lambrou, N., C. Kolden, A. Loukaitou-Sideris, E. Anjum, and C. Acey. 2023. Social drivers of vulnerability to wildfire disasters: A review of the literature. *Landscape and Urban Planning* 237:104797.

Lavoie, A., K. Sparks, S. Kasperski, A. Himes-Cornell, K. Hoelting, and C. Maguire. 2018. Ground-truthing social vulnerability indices of Alaska fishing communities. *Coastal Management* 46(5):359–387.

Leslie, H. M., X. Basurto, M. Nenadovic, L. Sievanen, K. C. Cavanaugh, J. J. Cota-Nieto, B. E. Erisman, E. Finkbeiner, G. Hinojosa-Arango, M. Moreno-Báez, S. Nagavarapu, S. M. W. Reddy, A. Sánchez-Rodríguez, K. Siegel, J. J. Ulibarria-Valenzuela, A. H. Weaver, and O. Aburto-Oropeza. 2015. Operationalizing the social-ecological systems framework to assess sustainability. *Proceedings of the National Academy of Sciences* 112(19):5979–5984.

Lichter, D. T., and J. P. Ziliak. 2017. The Rural-Urban Interface: New Patterns of Spatial Interdependence and Inequality in America. *The ANNALS of the American Academy of Political and Social Science* 672(1):6–25.

Loh, C. G., A. J. Ashley, L. Durham, and K. Bubb. 2022. Our Diversity Is Our Strength: Explaining Variation in Diversity, Equity, and Inclusion Emphasis in Municipal Arts and Cultural Plans. *Journal of the American Planning Association* 88(2):192–205.

Lyons, C., C. Carothers, and K. Reedy. 2016. Means, meanings, and contexts: A framework for integrating detailed ethnographic data into assessments of fishing community vulnerability. *Marine Policy* 74:341–350.

Madsen, R. S., H. J. G. Haynes, and S. M. McCaffrey. 2018. Wildfire risk reduction in the United States: Leadership staff perceptions of local fire department roles and responsibilities. *International Journal of Disaster Risk Reduction* 27:451–458.

Mahmood, S., and K. Hamayon. 2021. Geo-spatial assessment of community vulnerability to flood along the Ravi River, Ravi Town, Lahore, Pakistan. *Natural Hazards* 106(3):2825–2844.

Malecha, M. L., A. D. Brand, and P. R. Berke. 2018. Spatially evaluating a network of plans and flood vulnerability using a Plan Integration for Resilience Scorecard: A case study in Feijenoord District, Rotterdam, the Netherlands. *Land Use Policy* 78:147–157.

McDermott, M. H., and K. Schreckenberg. 2009. Equity in community forestry: insights from North and South. *International Forestry Review* 11(2):157–170.

Miller, B. A., L. Yung, C. Wyborn, M. Essen, B. Gray, and D. R. Williams. 2022. Re-Envisioning Wildland Fire Governance: Addressing the Transboundary, Uncertain, and Contested Aspects of Wildfire. *Fire* 5(2):49.

Modaresi Rad, A., J. T. Abatzoglou, E. Fleishman, M. H. Mockrin, V. C. Radeloff, Y. Pourmohamad, M. Cattau, J. M. Johnson, P. Higuera, N. J. Nauslar, and M. Sadegh. 2023. Social vulnerability of the people exposed to wildfires in U.S. West Coast states. *Science Advances* 9(38):eadh4615.

Monroe, M. C., S. Agrawal, P. J. Jakes, L. E. Kruger, K. C. Nelson, and V. Sturtevant. 2013. Identifying Indicators of Behavior Change: Insights From Wildfire Education Programs. *The Journal of Environmental Education* 44(3):180–194.

Morrow, B. H. 1999. Identifying and Mapping Community Vulnerability. *Disasters* 23(1):1–18.

Ojerio, R., C. Moseley, K. Lynn, and N. Bania. 2011. Limited Involvement of Socially Vulnerable Populations in Federal Programs to Mitigate Wildfire Risk in Arizona. *Natural Hazards Review* 12(1):28–36.

Otter.ai. 2023. Otter.ai. Otter.ai Inc.

Palaiologou, P., A. A. Ager, M. Nielsen-Pincus, C. R. Evers, and M. A. Day. 2019. Social vulnerability to large wildfires in the western USA. *Landscape and Urban Planning* 189:99–116.

Palsa, E., M. Bauer, C. Evers, M. Hamilton, and M. Nielsen-Pincus. 2022. Engagement in local and collaborative wildfire risk mitigation planning across the western U.S.—Evaluating participation and diversity in Community Wildfire Protection Plans. *PLOS ONE* 17(2):e0263757.

Parisien, M.-A., D. A. Dawe, C. Miller, C. A. Stockdale, and O. B. Armitage. 2019. Applications of simulation-based burn probability modelling: a review. *International Journal of Wildland Fire* 28(12):913.

Paton, D., and P. T. Buergelt. 2012. Community engagement and wildfire preparedness: the influence of community diversity. Pages 241–259 *Wildfire and Community: Facilitating preparedness and resilience*. Charles C. Thomas, Springfield, Illinois.

Paveglio, T. B., J. Abrams, and A. Ellison. 2016. Developing Fire Adapted Communities: The Importance of Interactions Among Elements of Local Context. *Society & Natural Resources* 29(10):1246–1261.

Paveglio, T. B., M. S. Carroll, P. J. Jakes, and T. Prato. 2012. Exploring the Social Characteristics of Adaptive Capacity for Wildfire: Insights from Flathead County, Montana. *Human Ecology Review* 19(2):110–124.

Paveglio, T. B., P. J. Jakes, M. S. Carroll, and D. R. Williams. 2009. Understanding Social Complexity Within the Wildland–Urban Interface: A New Species of Human Habitation? *Environmental Management* 43(6):1085–1095.

Paveglio, T. B., C. Moseley, M. S. Carroll, D. R. Williams, E. J. Davis, and A. P. Fischer. 2015. Categorizing the Social Context of the Wildland Urban Interface: Adaptive Capacity for Wildfire and Community "Archetypes." *Forest Science* 61(2):298–310.

Pelling, M., and M. Garschagen. 2019. Put equity first in climate adaptation. *Nature* 569(7756):327–329.

QSR International. 2020, March. NVivo. Lumivero.

Radeloff, V. C., R. B. Hammer, S. I. Stewart, J. S. Fried, S. S. Holcomb, and J. F. McKeefry. 2005. THE WILDLAND–URBAN INTERFACE IN THE UNITED STATES. *Ecological Applications* 15(3):799–805.

Ratcliffe, C., W. Congdon, D. Teles, A. Stanczyk, and C. Martín. 2020. From Bad to Worse: Natural Disasters and Financial Health. *Journal of Housing Research* 29(sup1):S25–S53.

Rodman, K. C., T. T. Veblen, S. Saraceni, and T. B. Chapman. 2019. Wildfire activity and land use drove 20th-century changes in forest cover in the Colorado front range. *Ecosphere* 10(2):e02594.

Scarlett, L., and M. McKinney. 2016. Connecting people and places: the emerging role of network governance in large landscape conservation. *Frontiers in Ecology and the Environment* 14(3):116–125.

Schultz, C. A., and C. Moseley. 2019. Collaborations and capacities to transform fire management. *Science* 366(6461):38–40.

Schultz, L. 2009. Nurturing resilience in social-ecological systems: Lessons learned from bridging organizations. Doctoral Thesis, Stockholm University, Sweden.

Schweizer, D., T. Nichols, R. Cisneros, K. Navarro, and T. Procter. 2020. Wildland Fire, Extreme Weather and Society: Implications of a History of Fire Suppression in California, USA. Pages 41–57 *in* R. Akhtar, editor. *Extreme Weather Events and Human Health*. Springer International Publishing, Cham.

Seong, K., C. Losey, and D. Gu. 2022. Naturally Resilient to Natural Hazards? Urban–Rural Disparities in Hazard Mitigation Grant Program Assistance. *Housing Policy Debate* 32(1):190–210.

Smit, B., and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16(3):282–292.

Spies, T. A., E. M. White, J. D. Kline, A. P. Fischer, A. Ager, J. Bailey, J. Bolte, J. Koch, E. Platt, C. S. Olsen, D. Jacobs, B. Shindler, M. M. Steen-Adams, and R. Hammer. 2014. Examining fire-prone forest landscapes as coupled human and natural systems. *Ecology and Society* 19(3):art9.

Steelman, T. A. 2016. U.S. wildfire governance as social-ecological problem. *Ecology and Society* 21(4):3.

Steffey, E., M. Budruk, and C. Vogt. 2020. The Mitigated Neighborhood: Exploring Homeowner Associations' Role in Resident Wildfire-Mitigation Actions. *Journal of Forestry* 118(6):613–624.

Stephens, S. L., A. L. Westerling, M. D. Hurteau, M. Z. Peery, C. A. Schultz, and S. Thompson. 2020. Fire and climate change: conserving seasonally dry forests is still possible. *Frontiers in Ecology and the Environment* 18(6):354–360.

Trenberth, K. E., A. Dai, G. Van Der Schrier, P. D. Jones, J. Barichivich, K. R. Briffa, and J. Sheffield. 2014. Global warming and changes in drought. *Nature Climate Change* 4(1):17–22.

Turner, B. L., R. E. Kasperson, P. A. Matson, J. J. McCarthy, R. W. Corell, L. Christensen, N. Eckley, J. X. Kasperson, A. Luers, M. L. Martello, C. Polsky, A. Pulsipher, and A. Schiller. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences* 100(14):8074–8079.

Understanding Institutional Diversity. 2009. . Princeton University Press, Princeton, NJ.

United States Census Bureau. 2021. QuickFacts Colorado.

U.S. Fire Administration. 2023. *Retention and Recruitment for the Volunteer Emergency Services*. Page 148. U.S. Fire Administration, FEMA.

Walker, S. E., E. A. Smith, N. Bennett, E. Bannister, A. Narayana, T. Nuckols, K. Pineda Velez, J. Wrigley, and K. M. Bailey. 2023. *Defining and Conceptualizing Justice and Equity in Climate Adaptation*. preprint, SSRN.

Wigtil, G., R. B. Hammer, J. D. Kline, M. H. Mockrin, S. I. Stewart, D. Roper, and V. C. Radeloff. 2016. Places where wildfire potential and social vulnerability coincide in the coterminous United States. *International Journal of Wildland Fire* 25(8):896.

Williams, D. R., P. J. Jakes, S. Burns, A. S. Cheng, K. C. Nelson, V. Sturtevant, R. F. Brummel, E. Staychock, and S. G. Souter. 2012. Community Wildfire Protection Planning: The Importance of Framing, Scale, and Building Sustainable Capacity. *Journal of Forestry* 110(8):415–420.

Wolters, E. A. 2023. Homeowner firewise behaviors in fire-prone central Oregon: An exploration of the attitudinal, situational, and cultural worldviews impacting pre-fire mitigation actions. *Journal of Environmental Management* 327:116811.

CHAPTER 2:
THE PROCESS BEHIND TRANSLATING COMMUNITY CAPACITY INTO WILDFIRE MITIGATION OUTCOMES

2.1 INTRODUCTION

Wildfire is a natural process that has shaped landscapes for millennia, but its exclusion since Euro-American settlement has had negative effects on forest health and composition. Due to fire suppression strategies, landscapes have become overcrowded with higher density vegetation, decreased biodiversity, a loss of fire-resilient forest structure, and increased risk of large, high-severity wildfires (Hessburg et al. 2015, Schweizer et al. 2020). This increased risk is compounded by climate change effects (e.g., lengthening of fire seasons, increased summer temperatures, and increased drought and wind) (Trenberth et al. 2014, Dunn et al. 2020), and human encroachment into the Wildland Urban Interface (WUI) (Radeloff et al. 2005).

Several strategies exist to reduce a community's negative wildfire impacts, which include home hardening (e.g., replacing shake roofs with fire resistant roofing) and fuel treatments like hand thinning, mechanical thinning, prescribed burning, chipping, pile burning, and fuel breaks. Many of these projects are done at larger scales involving various landowners with varying levels of capacities and capabilities, and guided by various policy frameworks, and objectives (Scarlett and McKinney 2016). Adaptive governance describes the process whereby numerous organizational scales and stakeholders interact and make decisions based on opportunities and constraints of the system (Kelly et al. 2019). Previous work has shown that the spatial and temporal scales of the wildfire governance system have not fit the social-ecological dynamics well. For example, a rigid, top-down governance structure may be ineffective at implementing adequate mitigation measures across various land management, community, and land cover types (Steelman 2016). Because of this, others have suggested that improving wildfire governance requires new policies that influence management behaviors at multiple spatial, temporal, and organizational scales, while also engaging in collaborative efforts across organizations (Fischer et al. 2016). Additionally, stakeholders have become disillusioned by top-down centralized governance,

questioning their ability to promote equitable and sustainable management of natural resources, leading to a movement towards more community-based or participatory management in the wildfire space (Berkes 2010, Kelly et al. 2019).

Decentralized wildfire governance emerged from this recognition that top-down systems were not working. Existing literature argues for a polycentric approach to governance, defined as multiple centers of power/authority that overlap at various scales that make and implement policies and rules for shared wildfire risk decisions (Chaffin et al. 2014, Fleming et al. 2015, Kelly et al. 2019); polycentricity in the case of wildfire is inclusive of community-based and collaborative approaches. Currently, various federal agencies, state agencies, counties, and municipalities are all operating to address wildfire mitigation. Polycentric governance stresses the importance of these separate actors coordinating with one another across scales (organizational and spatial) (Armitage 2010).

As fire management strategies have shifted to recognize the importance of polycentric and decentralized approaches to governance, communities have been burdened with a disproportionate amount of work (Steelman et al. 2004, Abrams 2019, Cheng and Dale 2020). While processes for institutional development for adaptive governance are at play, they are slow and take resources (Armitage et al. 2009). Further, little attention has been paid to precisely how community-level organizations (with limited capacities, such as collaborative non-profits) can implement actions when making management decisions. Communities can thus be vulnerable when organizations have little capacity to devote to implementing actions. Vulnerability can be thought of as being comprised of three characteristics: 1) exposure to wildfire, 2) sensitivity of the exposed population, and 3) adaptive capacity (Eriksen and Simon 2017). This vulnerability has been described as "the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor" (Turner et al. 2003), and is critical to understanding and managing risk (Wigtil et al. 2016, Kolden and Henson 2019).

Capacity is discussed in many ways across disciplines, as both "adaptive capacity" and "capacity" (Williams et al. 2012, Fischer and Jasny 2017, Cinner and Barnes 2019), and adaptation and mitigation

are also discussed similarly across disciplines (for further discussion see Walker et al. (2023)). Here, we focused on how certain communities cope with hazards, or their capacity to mitigate wildfire impacts, defined as "the combination of local social characteristics and external forces (including ecological processes or larger social forces) that influence whether and how human communities" mobilize toward a set of goals (Paveglio et al. 2015).). Several elements make up capacity for wildfire impacts mitigation, which Paveglio et al. (2015) organized into four categories: 1) access to and ability to adapt scientific or technical knowledge, 2) place-based knowledge and wildfire experience, 3) demographic and structural characteristics, and 4) interactions and relationships within the community.

Much has also been written about the relationship between vulnerability and capacity in the wildfire space (Wigtil et al. 2016, Davies et al. 2018, Palaiologou et al. 2019). Recent research has identified that low-income people and people of color have a disproportionate risk of experiencing natural and human-caused disasters (David and Enarson 2012, Highfield et al. 2014, Ratcliffe et al. 2020), and wildfire is no exception (Davies et al. 2018, Palaiologou et al. 2019). There is a correlation between social vulnerability (the susceptibility of certain social groups or communities to adverse impacts of external hazards) and race/ethnicity due to historical patterns of settlement, displacement, income, and migration (Davies et al. 2018). Further, wildfires disproportionately impact the poor due to inadequate housing, social exclusion, lack of property insurance, lower ability to evacuate, and increased emotional stress, among other factors (Palaiologou et al. 2019). Certain differences in wildfire impacts may also be patterned by urban vs rural communities, with urban communities generally having more capacity to support planning processes, more financial resources, as well as more technical expertise and dedicated staff (Berke and Godschalk 2009, Loh et al. 2022). As a result, there are calls for critical approaches to understanding vulnerability that instead point to systems of oppression that deny communities access to resources (Jacobs 2019).

Disparities in vulnerability to wildfire particularly materialize as capacity disparities (Davies et al. 2018). Capacity disparities- places where there is a high level of risk but low capacity and lack of funding to do mitigation projects- have been identified (Courtney et al., unpublished), but research on

local nuances to building capacity and getting wildfire risk mitigation work completed has yet to be explored. There is currently a gap in our understanding of the process by which capacity (or resources) affects mitigation (or actions), and the different pathways that may enhance or deter communities' ability to leverage capacity into action. As such, the purpose of the study is to understand 1) the process through which communities can build on or work with elements of capacity and translate those into work, 2) how communities deal with deficiencies in resources, and 3) where opportunities might exist to improve wildfire risk mitigation work. This has important implications for both our theoretical and conceptual understanding of vulnerability to wildfire at the community scale, as well as implications for the policy levers that can be pulled to support community capacity. Therefore, the overarching research question this study seeks to answer is: what are the processes that link different types of capacity to mitigation outcomes across different communities?

2.2 METHODS

This research investigates the links between capacity and mitigation outcomes in a fireprone region of the western U.S. through qualitative analysis of interviews with community wildfire practitioners.

2.2.1 Study Area: Colorado, USA

Colorado has experienced several large and costly wildfires in the recent past, which have been associated with increased temperatures and earlier snowmelt in the spring (Stephens et al. 2020, Colorado State Forest Service 2022). Previous fire suppression strategies/policies have contributed to denser forests that are increasingly spatially continuous, which support large crown fires that are of greater risk to people living near forests (Keane et al. 2022). Additionally, Colorado has experienced population growth of 14.8% to 5.8 million people in the last 10 years (United States Census Bureau 2021). The state is made up of six different type III Ecoregions: Wyoming Basin, Colorado Plateau, Southern Rockies, Arizona/New Mexico Plateau, High Plains, and Southwestern Tablelands (Chapman et al. 2006). Precipitation varies greatly across the state, but average annual precipitation is 43 cm, with parts of south-

central Colorado receiving an average of less than 18 cm, and mountain regions receiving between 63 and 101 cm of precipitation per year (Doesken et al. 2003).

The governance and management context of the study system is also highly variable with state agencies (e.g., Colorado State Forest Service, Colorado Division of Fire Prevention and Control), federal agencies (e.g., US Forest Service, Bureau of Land Management, National Park Service), counties, cities, fire protection districts, and collaborative organizations (e.g., Big Thompson Watershed Coalition, Coalitions and Collaboratives) all working to address wildfire risk mitigation across the state. Landownership also varies greatly across the state with about 36% of the state managed by the federal government and 60% privately owned (Figure 2.1). As of 2021, Colorado had 259 Community Wildfire Protection Plans (CWPPs), which can vary in format but generally are collaborative plans that contain information about the wildfire risks to a certain area and propose wildfire mitigation strategies and actions to reduce negative impacts (Palsa et al. 2022). On average, the state is 61% white, has a median income of $75,000 per year, has a median age of 37, and has varying levels of social vulnerability (United States Census Bureau 2021). The main grant programs at the state level for wildfire risk reduction include the Forest Restoration and Wildfire Risk Mitigation (FRWRM) program through the Colorado State Forest Service and Colorado Strategic Wildfire Action Program (COSWAP) through the Colorado Department of Natural Resources.

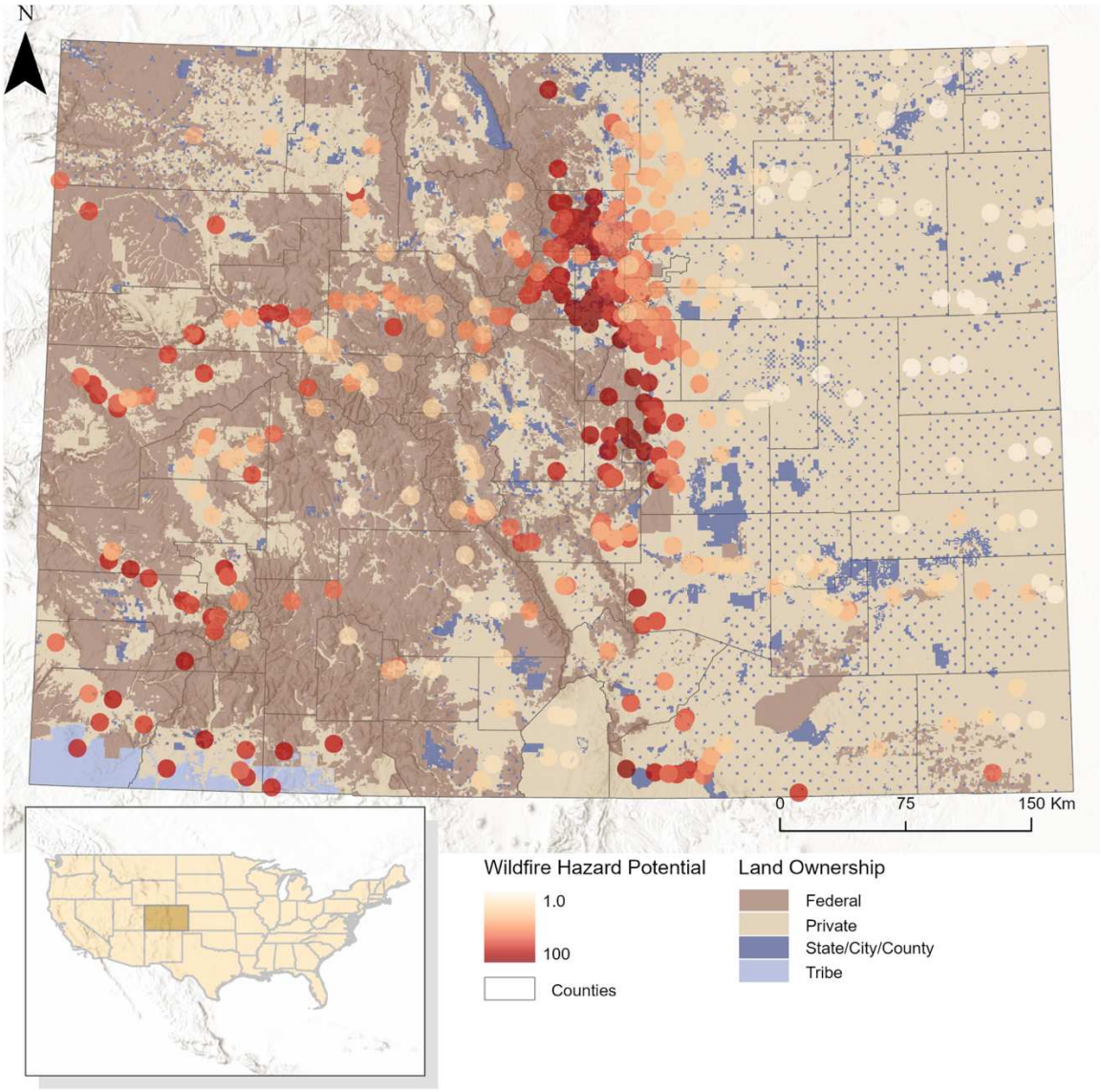


Figure 2.1. Study region where 11 group interviews took place to understand community capacity to mitigate wildfire risk in Colorado. Study communities are not shown. Red to white dots signify the wildfire hazard potential, to depict the relative potential for wildfire that would be difficult for suppression resources to contain (www.wildfirerisk.org) of the city/town location, where 100 (dark red) is the highest wildfire potential and 1 (white) is the lowest. Land ownership is identified in the background, with dark brown federal land, light tan private, dark blue state/city/county, and light blue Tribal lands.

2.2.2 Community Selection

To answer the research question, we conducted interviews with wildfire managers regarding work in their local communities. This allowed us to better understand the decision-making and social-ecological context shaping wildfire in each location. Sample selection was conducted among forested

communities with moderate to high wildfire risk (n=242), as defined by Wildfire Risk to Communities (https://wildfirerisk.org/) (Figure 2.1). These data facilitated community sample selection because they identify the relative potential for wildfire that would be difficult for suppression resources to contain in specific communities. To achieve a representative sample across moderate-to-high wildfire risk and capacity as our two focal strata, key informant interviews with practitioners working at a broader scale across the state aided in identifying a subset of communities. Eleven communities were then purposefully selected from this subset, representing a range of social-ecological factors, including population size, median income, median age, percent white (non-Hispanic) population, and ecoregion (Chapman et al. 2006) (Table 2.1). While our focus remained on forested landscapes, we defined this in the broadest sense, including forest scrub, urban green spaces, high forest, and nearby forested areas (McDermott and Schreckenberg 2009). Locations are kept anonymous to protect community and respondent identities.

Table 2.1. Table of selection criteria for 11 communities in Colorado. Population is the average population at the 2020 census, average elevation, median income as of 2020, median age as of 2020, the percent white population (non-Hispanic) as of 2020, and the level IV Ecoregion as defined by the USGS (Chapman et al. 2006).

COMM	POP	ELEV (M)	MED INCOME	MED AGE	% WHITE	LEVEL IV ECOREGION
1	5,001-9,500	2,001-2,500	<$90,001	42-46	90+	Crystalline mid-elevation forests and shrublands
2	1,000-5,000	2,001-2,500	$60,000-$70,000	42-46	71-90	Sagebrush surrounded by Sedimentary Subalpine Forests, Crystalline mid-elevation forests and shrublands, and Sedimentary Mid-Elevation Forests and Shrublands
3	100,000-500,000	1,501-2,000	$60,000-$70,000	32-36	90+	Foothills grasslands surrounded by foothills shrublands and Crystalline mid-elevation forests and shrublands
4	1,000-5,000	2,501-3,000	$80,000-$90,000	47-51	51-70	Sedimentary subalpine forests surrounded by Crystalline subalpine forests
5	5,001-9,500	2,001-2,500	$40,001-$50,000	42-46	71-90	Foothills and shrublands surrounded by Sedimentary Mid-Elevation Forests and Shrublands and Crystalline Subalpine Forests
6	5,001-9,500	1,501-2,000	$30,001-$40,000	42-46	30-50	Piedmont Plains and Tablelands surrounded by Foothills and Shrublands and Sedimentary Mid-Elevation Forests and Shrublands
7	5,001-9,500	2,001-2,500	$30,001-$40,000	27-31	30-50	Alluvial Flats and Wetlands surrounded by salt flats, Foothills and Shrublands, Crystalline Subalpine Forests, Sedimentary Mid-Elevation Forests and Shrublands, and Volcanic Subalpine Forests
8	1,000-5,000	2,001-2,500	$20,000-$30,000	27-31	51-70	Semiarid Benchlands and Canyonlands surrounded by Sedimentary Mid-Elevation Forests and Shrublands and Monticello-Cortez Uplands
9	20,000-65,000	1,000-1,500	$40,001-$50,000	37-41	71-90	Shale and Sedimentary Basins surrounded by Semiarid Benchlands and Canyonlands, Sedimentary Mid-Elevation Forests and Shrublands, Volcanic Subalpine Forests, and Escarpments
10	9501-15,000	1,501-2,000	$60,000-$70,000	32-36	51-70	Shale and Sedimentary Basins surrounded by Semiarid Benchlands and Canyonlands, Escarpments, Sedimentary Mid-Elevation Forests and Shrublands, and Sedimentary Subalpine Forests
11	9501-15,000	2,001-2,500	$70,001-$80,000	37-41	71-90	Foothills and shrublands surrounded by Crystalline mid-elevation forests and shrublands

2.2.3 Recruitment

Our aim was to select participants for small group interviews working in the forestry and wildfire space that focus on mitigation (e.g., state forest service, US Forest Service, Bureau of Land Management, county emergency managers, fire department chiefs, wildfire collaborative organization directors) in each selected community location. We identified several initial points of contact by Google searching agencies and organizations in each area and referencing it against previous contact lists. In several cases snowball sampling (Naderifar et al. 2017) was utilized where an initial point of contact connected us with another individual that they felt was more relevant to the study.

Recruitment involved emailing individuals to participate in this study and included information about the study's aims and their rights as a participant (Supplementary Material 2.1). In total, 43 people voluntarily participated. We informed interviewees of their rights as study participants at the beginning of each interview and obtained verbal consent from each participant before conducting the interview (IRB#: 3466).

2.2.4 Group Interviews

Group interviews (2-7 participants) were conducted between April 10, 2023, and May 31, 2023, and lasted c. 90 minutes each. Two researchers facilitated each interview and followed a semi-structured protocol with seven questions (Supplementary Material 2.2). Group interviews were utilized to understand multiple perspectives on mitigation capacity and to gather large amounts of data in a short time frame (Fusch and Ness 2015). Due to the nature of the research topic and our desire to speak with experts in each area, in all but one interview all participants knew one another, which likely affected the group dynamics and their comfort level in speaking and sharing their thoughts.

Groups were asked to focus on their community, with the definition of community left broad and open to the participants to interpret (e.g., one town/city, one county, or a small region of several counties). We first provided a definition of capacity to the group, and they were then asked to self-assess elements related to the wildfire mitigation capacity of their community into three categories: low (what they do not

have), medium (what they have but need more of), and high (what they definitely have) (Figure 2.2a). Participants were presented with an initial list of thirteen elements based on those identified in Paveglio et al. (2015) and cross-checked with key informants:

1. Wealth of community
2. Presence of forestry/wildfire collaborative organizations
3. Presence of contractors
4. Presence of facilities
5. Presence and involvement of fire protection districts
6. percent full-time residents
7. Acquisition of wildfire mitigation grants
8. Presence of a Community Wildfire Protection Plan (CWPP)
9. Firewise certification
10. Presence of building codes
11. Presence of land-use codes
12. Presence of local champions (or engaged/enthusiastic community members)
13. Tight-knit community

The groups could add to or adjust the list however they desired; they then worked from their list of elements for the remainder of the interview. Self-assessments of low, medium, and high capacity categories were decided as a group through iterative discussion until a consensus was reached. They utilized these elements to discuss examples of successes and challenges and the processes behind them (Figure 2.2b). Finally, they were asked how their community could increase their capacity more generally.

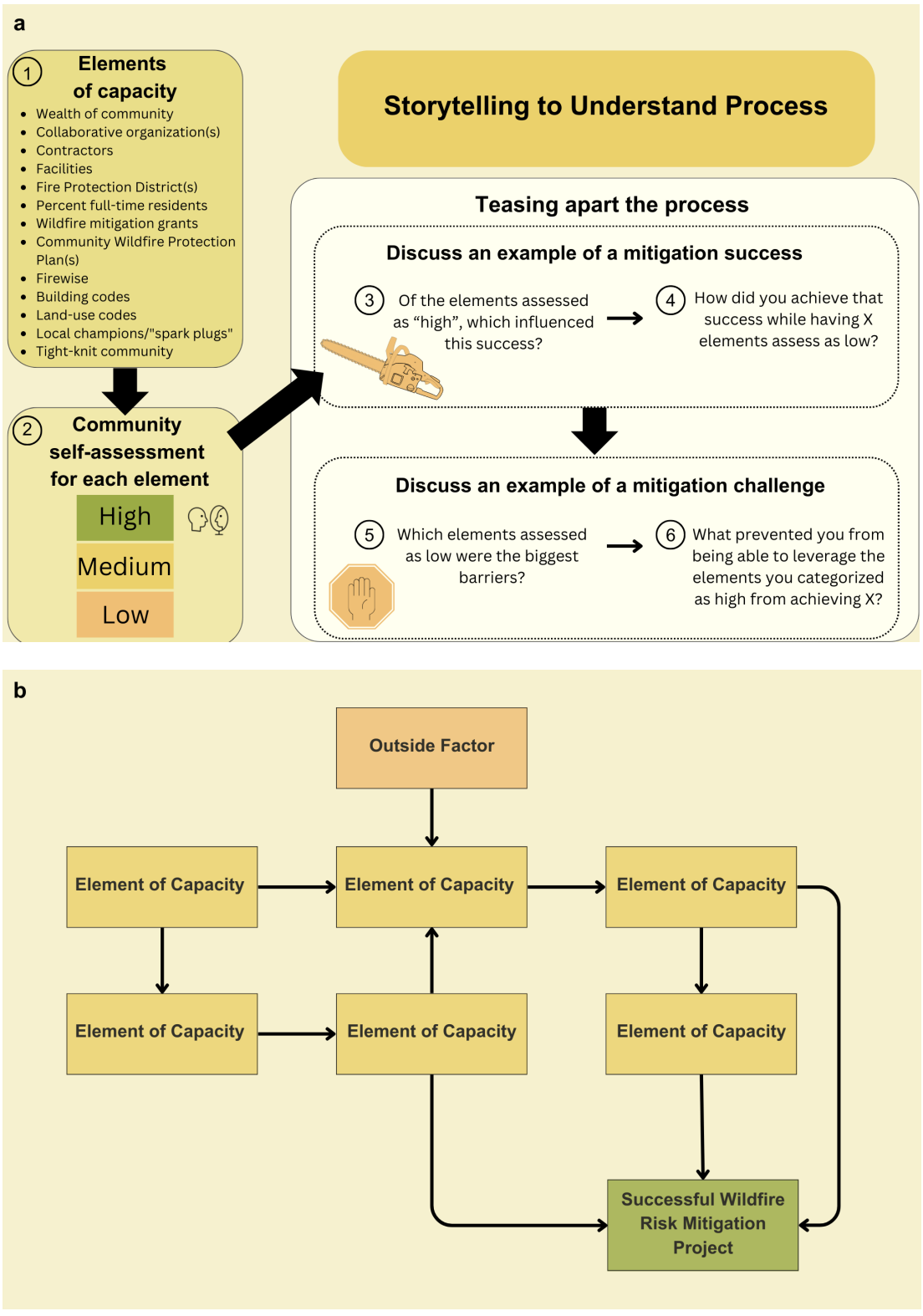


Figure 2.2. Group interview process to elicit concepts of capacity A) Flow of the interview prompts to discuss the process to mitigation work. B) General illustrative diagram of what could have come out of the interviewees while exploring process for one of questions 3-6 asked in part a.

2.2.5 Ethical Framework & Positionality

Research can be extractive, and we did our best to represent people's true responses and attribute knowledge production to all people interviewed. I recognize that the approach to the study and interpretations are informed by my background, experiences, and identities as a white woman in academia born in the United States. Throughout the interview process I was considering who I was reaching out to, thinking about the time I was asking for from participants, and reflecting on my insider-outsider positions. The wildfire and forestry spaces are often primarily dominated by white men. Because of this, my position as a white person allowed me easier access to those spaces, and potentially more open responses from participants. Conversely, because myself and the other researcher conducting interviews were both small women, it's possible that interviewees saw us as outsiders (consciously or unconsciously). This could have been exacerbated by the fact that both of us are young as well (in our twenties) and were still in school or recently graduated. Many of the interviews that included firefighters and fire chiefs required that I prove myself as knowledgeable of these systems and interactions, as it was assumed I knew very little since I do not have the lived experience of working in that profession. Most of the people interviewed also lived in the Wildland Urban Interface (WUI) and had the experience of living and dealing with fire in more direct ways than I do living in a city in the Front Range of Colorado. This could have contributed to the outsider dynamics as well because I do not understand what it's like to own a home that may be at risk. Being originally from the Pacific Northwest, I also was an outsider, as I did not grow up in Colorado and likely do not understand the full context. However, I have lived in Colorado for over four years and during that time have participated in a related study where I drove around the state and interviewed many other people involved in wildfire risk mitigation planning. I believe that experience helped bring me more inside, as I knew many of the people that interviewees mentioned and had heard about some of the projects and issues previously. Overall, all these dynamics likely influenced the results we obtained.

2.2.6 Data Analysis

Recorded interview transcripts were transcribed using Otter.ai software (Otter.ai 2023) and then manually cleaned to correct for transcription error. We then thematically coded the transcripts using NVivo software (QSR International 2020) to identify themes from the interviews guided by Braun and Clarke's protocol for conducting thematic analysis (2006). One researcher individually open-coded each interview to answer the main research question (What are the processes that link different types of capacity to mitigation outcomes across different communities?), iteratively building on the list of pre-existing codes as the process continued. A second researcher then assessed the coding to highlight any disagreement in codes. The two researchers then came together and created themes out of all the organized codes (Braun and Clarke 2006). Finally, we went back and organized all codes in NVivo to match the themes to be able to pull examples.

To compare results across different community types, we grouped communities into three categories: low, medium, and high capacity based on their self-assessments of the elements we provided (13 total). Communities designated as low had one to three elements self-assessed in the high category, medium had even numbers across all three self-assessment categories, and high were those with very few in low and many in high (six to ten).

2.3 RESULTS

Respondent self-assessment of elements of community capacity to mitigate impacts of wildfire varied (Supplementary Table 2.1) across low (4), medium (3) and high (4) categories and were utilized in for the rest of the interview (Table 2.2). In addition to elements drawn from the literature that were ranked by respondents, other elements were identified, and respondents reached consensus on their importance (Supplementary Table 2.2). The following subsections outline the themes that emerged from respondents describing the process through which community capacity is translated into mitigation work.

Table 2.2. Categorization of communities into high, medium and low capacity based on self-assessments for 13 elements provided in 11 different group interviews across Colorado, USA looking at community capacity to mitigate wildfire risk. The numbers in each self-assessment category indicate how many elements were self-assessed in that low, medium or high category by that community. For the full dataset, see Supplementary Table 2.1.

CAPACITY	SELF ASSESSED ELEMENTS		
	HIGH	MEDIUM	LOW
HIGH	8	3.75	1.25
MEDIUM	4.67	4.67	3.67
LOW	1.5	6	5.25

2.3.1 Inter-organizational Collaboration

Participants talked extensively about collaborations that exist to advance wildfire mitigation in their communities, from understanding how to facilitate groups and build consensus, to knowing who to work with and how to access funding. Participants noted how partner organizations (e.g., Land Trusts) need to understand wildfire, and how wildfire can often be a driver in working across jurisdictional boundaries. One participant also highlighted how other fire-related impacts (e.g., flooding, erosion, water quality) can be important catalysts to begin collaborating across sectors for wildfire in the future. Several participants also mentioned the benefits of collaborating with other organizations to access grants and other funding opportunities, specifically through extending relationships and processes built by others. One interviewee said:

> *"It's just really our collaboration, because we're always talking about who's going to do what, what you're going to spend here, what can we throw in? I think we horse trade a lot to try to get, and we talk enough that I think we all have a good idea of where our priorities are. Yeah, but it's funny how we tend to work hard together... it comes from the relationships."*

Specific collaborators were also discussed frequently, which included the State Forest Service, local government, federal partners, and fire departments/districts. With respect to federal partners and fire departments, participants discussed the pros and cons of these types of partnerships. For private landowners living adjacent to federal lands, there are some benefits to working with government entities, such as being eligible for certain grants or being part of a larger initiative (e.g., Rocky Mountain

Restoration Initiative, Collaborative Forest Landscape Restoration Programs). However, federal bureaucracy can stall work, high turnover rates lead to a loss of momentum and can erode trust, and often federal partners have few resources themselves to offer support.

The pros and cons of collaborating with fire departments were explored by many participants. Participants articulated that it is helpful if fire department staff are cross-trained in wildland fire. There is often a confusing gap between structure fire and wildland fire in the WUI. However, cross-training prioritization often depends on who the chief is and their preferences. If there are fewer local champions, the fire departments often step up, but mainly those with paid staff. In contrast, volunteer-only departments find it difficult to contribute to collaborative processes. Finally, some participants also said that fire departments may not want to push mitigation and impose on their community because they do not want to degrade existing trust. One participant explained this apprehension of fire departments and their varying levels of involvement:

> *"We're pretty proactive when it comes to fire mitigation and working with these guys too. But I'll say, for example, our neighbors such as [FIRE DEPARTMENT NAME]...they're very closed off, very shut off, hands off, very unengaged. I'm not saying that to be mean, that is just observation...I think I can say this on behalf of fire departments, there's a lot of departments that are very apprehensive, or maybe they don't even have the personnel. They're volunteer fire departments...they come in and do volunteer time, and to engage in something much deeper like this takes a lot more time commitment."*

When comparing high- and low-capacity communities, some clear differences emerged in the way inter-organizational collaboration was discussed. Self-assessed lower capacity and medium capacity communities (Table 2.2) emphasized bringing partners together and pooling resources through collaborations. They also discussed challenges of working with fire district collaborators, due to the limitations of volunteer-based wildfire protection activities. Finally, one person in a lower capacity community discussed the trust that he has built with his community and being reluctant to engage with other organizations to push mitigation.

Self-assessed high-capacity communities generally felt confident in their current and past collaborations because of frequent communication and resource coordination among partners, but also discussed how collaboration across the larger system of wildfire actors (state, county, and federal

partners) sometimes presented challenges. They discussed how collaborative grant applications have been successful, and in contrast to the other community categories, they discussed how their organizations and different fire districts collaborate/work together, because these career departments had the time and energy to devote to mitigation. In contrast, one high-capacity community also discussed the challenge of decentralized governance, suggesting a need for coordination among agencies at larger scales:

> *"There's so many special districts and diffusion of roles and responsibilities regarding wildland fire, that it blurs to where it's almost impossible to understand where staffing goes...There's just so much diffusion of roles and responsibilities, and that's at the county level. But then you look at the state level, there's DNR, there's DFPC, there's Emergency Management with the post-disaster mitigation dollars. There's just all this diffusion without a centralized hub of awareness and that political...spearhead at the state level and at the county level."*

2.3.2 How Funds are Obtained and Utilized

Accessing funding to implement mitigation and education efforts was a major focus among participants across groups when discussing the pathways to mitigation work and included needing workarounds for existing fiscal structures (e.g., limited county budgets). While access to funds is often considered an indicator of capacity, participants identified the process of how these funds are leveraged as critical for fire mitigation efforts. Further, the focus group discussions highlighted the diversity of ways in which funds are acquired for mitigation work in communities. Examples include relying on wealthy people in the community to pay for work, having a dedicated funding source from the county or city, water providers, or specific taxes. Accessing grant dollars was another way participants and their organizations obtained funding but can be very problematic for communities, especially those with no prior grant experience or grant writing capability. Participants mentioned that already having grant money allowed their organization to get more, as previous grant experience equipped them to do more wildfire mitigation work with additional funds.

Other obstacles or workarounds that participants mentioned included state fiscal structures such as local taxes and state spending caps (e.g., Tabor cap). With community funding, one participant noted how there is no real system in place for matching fund grants to be implemented. To work around this, they started their own 501(c)(3) nonprofit to be the fiscal agent since the County and Fire Protection

District cannot serve that role. Another participant described working around one federal agency's policy that allows states to mandate their own funding requirements, limiting the kinds of projects that can receive money:

> *"What I would say is more actually hindering work getting done on the ground, related to this massive pot of money that we have, is that the [FEDERAL AGENCY] ...allows states to mandate the requirements for money to get spent state by state. And so, in Colorado, sort of the state leadership of that organization, is really tied to the idea of long-term planning. And it's really based in science, which makes sense if you're writing like a ten-year implementation schedule on a property, but if you're trying to spend the money to do all of the work on a given acreage parcel in one fell swoop, then what you really need is a couple of pages about: here's what the stand conditions are, here's what the recommended actions are."*

We did not find clear patterns between capacity and success or challenges with getting grants. Funds appear difficult to obtain across the board, but higher capacity communities were better equipped to work around that by leveraging partnerships, relationships, and community buy-in.

2.3.3 Prioritization and Planning

Most of our participant groups highlighted the importance of prioritizing projects and having plans in place for mitigation work to ensure communities are using their limited resources effectively. Being flexible and seeking community input also emerged as important elements during the planning process. One interviewee mentioned that breaking the planning process into smaller pieces was helpful. Finally, combining efforts and prioritizing projects that are multi-benefit emerged as effective approaches. One participant mentioned coordinating multiple plans at once, rather than creating independent plans:

> *"The [COUNTY] comprehensive master plan, the comprehensive transportation plan, the community wildfire protection plan, and all-hazard evacuation plan, and a code and regulation review with a component that will then go to the board for a policy level change and law change. Completely funded to do at the same time by the same vendors. Historically, and probably always up to this point, those plans were all done in separate timings with separate people, separate data. There was no unification."*

There were a few differences between the self-assessed community types in how they talked about prioritization and planning. Low-capacity communities mentioned that following a successful model can be helpful, such as from other organizations or counties across the state that have more funding capacity. High-capacity communities mentioned looking to other counties to see how they do things, but also emphasized having an iterative mindset to refine planning processes and seek community feedback to structure prioritization.

2.3.4 Having Dedicated Staff for Wildfire Mitigation

Often, indicators of capacity for fire mitigation focus on having dedicated staffing, but participants noted that just having staff is not enough, and that the roles and responsibilities of these staff are crucial for mitigation success. There are many barriers to existing staff having enough time to devote to mitigation, such as staff required to serve multiple roles, only having one person applying for grants, the fact that mitigation work requires substantial time from all staff regardless of role, and challenges retaining staff in certain areas due to the context.

> *"I feel like what we lack...to build and manage relationships with those tight knit communities...we've got resources that people can find, but behavioral sciences, relationship based, and trust based, we just don't have enough people to build and mentor those communities."*

Several participants mentioned how just having volunteers is often not enough to get work done. There is a need to utilize current staff time well and have some staff dedicated fully to wildfire education, technical assistance, Firewise programming, and grant administration, as well as a general need to streamline processes. One participant highlighted the need for staff dedicated to education and engaging with community members:

> *"We have at the local level, a lot of dual role individuals like myself. The [DEPARTMENT NAME] that I'm a part of... there's three of us total, counting myself. And there's nine departments held underneath that. Doing more for less. So we've had to try and learn how to be as efficient as possible, in order to give our taxpayers you know, what they're paying for..."*

All communities talked about staff time similarly. A notable difference was that low and medium capacity communities mentioned how overworking and burn-out are occurring due to staff filling multiple roles.

> *"I mean, I hope [ORGANIZATION] hires more people. It's one of the reasons I left my position is because I was tired of being the only person. I was maxed out."*

2.3.5 Community Buy-in

2.3.5.1 Encouraging Community Buy-in by Building Trust

Building trust is arguably one of the most important pieces of getting buy-in and educating the community, as several interviewees stressed. Many participants highlighted how just living with their

community and seeing people over and over has built relationships and trust. One person described the time that it takes to build this trust:

> *"And that takes years of pushing the rope uphill, and meeting with people over and over and over and over until they get that comfort level and that level of trust...and trust with the community, that they have a frequent face. They have somebody that's responsive. They have somebody that's getting stuff done. And that level of trust is engaged. And that just goes to show also at the land management level. There's trust amongst us. Trust amongst our peers, to meet, train, work collaboratively and effectively. And that trust reciprocates to those public entities when they see that, and they see us managing lands cohesively."*

Several individuals talked about how fire departments and firefighters are some of the most trusted people in the community and how leaning on that trust can be important. One participant mentioned how community members trust the fire department, and, for example, would not allow other agencies access to their land. Some participants mentioned that hearing from the public, getting their input, and truly listening is also important in building that trust. They also highlighted that transparency, such as informing the community about plans for fuels reduction projects, can be a key piece to trust building overall.

2.3.5.2 Communication and Education Strategies

Participants discussed how another part of building trust is through making educational materials accessible, such as through using electronic and physical media and translating media into different languages, thereby acknowledging that people access material in various ways. Participants explained having the community in support of and engaged in the mitigation work is critical, especially if the work is on private land. Participants also noted that effective education requires understanding your audience. This includes recognizing that community members care about different things or have different values at risk (e.g., oil and gas vs. recreation), which can influence buy-in, and professionals may have to work around what residents are okay with. Interviewees noted the other hazards that come with wildfire such as flooding, landslides, and water quality issues, suggesting that community members may listen better when presented with other impacts of wildfire. Participants articulated another way of framing the necessity of mitigation work, by explaining how fire suppression often costs way more than mitigation projects do. Additionally, getting people on board with mitigation may require different routes and discussions because not everyone cares about the same things. Participants explained that this requires

using a diversity of educational approaches and finding ways to educate at events and different topics in which people are already engaged. Relatedly, participant discussions highlighted the importance of recognizing and respecting culture when conducting outreach and building conversational and collaborative skills.

Participants also mentioned the need for consistent messaging about wildfire to gain community buy-in. One interviewee described how this has worked across their agencies, so that the community does not get confused, uninterested or overburdened with mixed messages:

> *"All of these different agencies have come together. We have 11 different voting bodies...And I think here's my point is, we have agreed to speak the same language so that when any one of us go out and interface with the public, we're sending the same message. Nothing's confusing, and it's really driven by this: Be engaged, create defensible space on your property."*

However, participants cautioned organized communication efforts from derailing into information overload. They highlighted how wildfire is competing for attention with so many other causes that their messages often get lost in the noise of other interests. Part of this consistent messaging is also about getting visitors on board and educating them while they are in town, as one person recommended. Interviewees also emphasized the usefulness of re-envisioning wildfire mitigation and showing landowners examples of mitigated areas to manage expectations of what projects may look like in the end. Participants warned, however, that this means explaining that mitigation is continuous due to plant and tree regeneration/regrowth. However, several participants emphasized that telling success stories was critical for gaining and maintaining buy-in:

> *Speaker 1: "Yeah, so that would lead to the one other piece would be like celebration, and in tracking and report out. You know, like, when we're done for the season, we-*
> *Speaker 2: "can tell a really fun story. Yeah, how many piles of slash and how many hours of time people spent and all that good stuff*
> *Speaker 1: "And pictures, and so now we're to the point where when I call up the community leaders, the people I knew this year to say, hey, [COUNTY PROGRAM] is coming. I felt like Santa Claus, it was super fun. You know, they know exactly what it is. They're really excited. And they immediately jump on board and start planning for it. And they're so thankful.*

Comparing across self-assessed capacities, some differences emerged. All groups mentioned needing to see examples of mitigation to increase buy-in (e.g., having field trips to see treated areas), as well as having relationships with people in the community. Both low and medium capacity communities

discussed the need for a dedicated person for education and also for new ways of sharing information in addition to flyers, signs, and websites. They also mentioned peer pressure to encourage buy-in:

> *"One of the other potentials, contributing factors, there's sort of that peer pressure you get. One part of the neighborhood getting started sometimes leads into the other one of the neighboring neighborhoods. Work in progress tends to lead to more work in progress."*

Both medium and high-capacity communities mentioned the competition with other causes and fighting for people's attention as well as the importance of telling success stories and having resources accessible in multiple ways. Only high-capacity communities described actually using creative outreach techniques, like creating videos, and were equipped with dedicated educational staff. These groups also discussed more in-depth the need for trust, and how that takes time, requires transparency and listening to people in the community.

2.3.6 Engaging with Stakeholders

2.3.6.1 Elected Officials and Politicians

Elected and appointed officials are key actors in mitigation work. Many participants highlighted the potential elected officials have to be local champions and the significant need for educating these people on wildfire and mitigation to transform them into local champions for mitigation. Often, people like county commissioners can help increase the availability of funding for specific causes such as mitigation work.

All community types discussed engaging elected officials similarly, especially highlighting the need for local governments to be on the same page and set mitigation as a priority. One lower capacity community also highlighted political issues between districts and local government as a large hurdle:

> *Speaker 1: "I was just going to say from the local level, because that's where I work, some of the biggest issues are just the political battles within the area. And that was one thing that was holding up [PROJECT NAME] as well. It's just the political issues between the districts and the local governments.*
> *Interviewer: "Can you share some specifics about that?"*
> *Speaker 1: "I think they're all on board with hard facts. But when it comes down to well, my cousin didn't like this family, and now they're running the fire district, and I'm a county commissioner...One of the issues we did run into was the willingness to fund mitigation projects on other districts' property."*

2.3.6.2 Private Landowners

As briefly mentioned in the previous section, 2.3.5, engaging private landowners can be complex, often due to personal feelings of ownership and independence. Several participants mentioned a similar notion as described here:

> *"'It's my property, don't tell me what to do on it,' is basically what it is."*

Consistent across communities, interviewees noted how it can be difficult to educate landowners in areas with higher absenteeism and residents constantly moving in and out. This education and engagement are very important, especially in parts of the state that are primarily privately owned and dependent upon property owners to implement mitigation projects. Participants frequently discussed the lack of action from property owners:

> *"I would like to see more public involvement. I mean, more folks trying to... get educated and do more on their land after we speak to them. The fire departments can't do it all. The tree contractors can't get it all. We can't just educate these homeowners or... the property managers of these short-term rentals. This is a community thing. This is just what Firewise or a fire adapted community is all about. You can't just do one house and an HOA without connecting all the dots... I'd love to see those homeowners pick up the loppers and do some work and take advantage of our chipping days or come up with their own community chipping events.. We got to stop pointing the fingers on: It's the fire departments,iIt's Colorado State Forest, it's a national thing, like look in your own backyard and do some work."*

Part of this issue is, again, staff time because private landowners need support, as some participants explained. Interviewees further described that agencies often do not know where to start to get owners to mitigate on their land. When they do get owners on board, they have to help the landowners do the work. They warned that other landowners do not want any help due to pride, but mitigation can be the last thing on their list and might not get done. Additionally, a common issue that several participants complained about is that landowners are reluctant to remove trees on their property. Landowners can be against doing mitigation work due to a lack of buy-in, time, and/or money. Wildfire mitigation work can be expensive (e.g., paying for tools/equipment, paying contractors) and landowners are often not eager to pay for this expense. Interviewees noted how landowners may need incentives such as cost-sharing, although there are drawbacks to that as well.

2.3.6.3 Contractors

Engaging contractors is an important piece needed for mitigation work. Participants explained that contractors are often more interested in accepting larger projects than working on smaller-scale areas of land. A way around this issue, as one participant mentioned, was grouping smaller projects together to be competitive:

> *"The other aspect of support, when you have multiple landowners in an area, and each landowner might have 15 to 35 acres, in order to sell what they're mitigating, we need someone to help coordinate. So that's the other piece that we've talked about with capacity like for the forest product industry piece of it, the mill is not going to come down here for 15 acres. In order to boost sales of those products, and use those products, we have a lot of these like larger acreage subdivisions that desperately need to be mitigated. But we need somebody that can coordinate that, right? Or even coordinate a contractor that's maybe specialized, depending on the terrain, or what's being recommended. Then these landowners kind of get together, if we've got to pull in an outside contractor, they know they might have 250 acres, but it might be ten landowners."*

Additionally, most communities we spoke with described the importance of investing in training and education to increase the number of contractors in the region required to do the mitigation work. Participants also underscored the importance of accurately planning for how much contractors may cost and reflect that in their budgets. Interviewees discussed how inflation is making this work even more expensive than before and how budgets are stagnant with not enough funds to cover the true cost of services today:

> *"Our budgets don't change, but the cost per acre goes up exponentially. And what we used to do for 5,6,8 hundred dollars an acre, is now $3,500 an acre. So, we're getting asked, why are we not doing more? Well, we're not able to do as many acres because we can't afford to, and our budgets don't change with the changes of inflation or the public safety sales tax."*

2.3.7 Creative Workarounds

Regardless of community resources, participants from across several communities discussed creative 'workarounds' they used to circumvent common barriers to getting mitigation work done. These barriers included HOA policies or city codes that prevent tree removal, limit certification of contractors, and restrict treatments in areas that are not considered the WUI. For example, there are policies in some areas regulating who can cut trees within city limits, requiring the practitioners to work with the forestry board to overcome that roadblock:

Speaker 1: "I was thinking like the city has some codes against, fuel- tree removal without with or having certifications..."
Speaker 2: "I think it's a problem...Because...we have the code requirement that you have to be licensed to do tree work...."
Speaker 1: "In city limits they're supposed to be licensed in order to do work, and the contractors don't meet those regulations. And so then we're having to make exceptions. I think we are working on that on the forestry board. But it's just one of those things, like there are some roadblocks that we've had to work through to make sure things are moving forward."

Participants also discussed issues with certain funding sources and qualifiers for using the funds on certain types of land. They highlighted the need to work around this by creating a fund for general fire mitigation for any land type:

"So, part of the conversation [PERSON NAME] and I and others have been having is how do we deal with public lands? So, Parks and Rec, Trails and Open Space, we've got public reserve, stormwater, we have all this other grassy area, goes back to the Marshall Fire, right? That stuff will always burn everywhere. But it's not in the definition of the wildland urban interface. But we are struggling with how to get that, and we need to get a general fund disbursement to enable us to mitigate those grasslands and those other areas that are not in the wildland urban interface.... For general fire mitigation, there is no funding."

Every interviewee also described the many workarounds for the lack of facilities to process mitigated material. The four main ways people are overcoming this challenge is by having landfill programs (some charge money to dump and others do not), burning, having designated dump sites, and offering chipping material. A caveat that participants stressed was that these workarounds remain less than ideal options because there is no market for small-diameter timber in Colorado, which is a statewide issue that is hindering further mitigation.

2.4 DISCUSSION

The processes connecting capacity to mitigation access remain complex, but we have highlighted seven process themes that fire experts in our study described as important for translating capacity into mitigation actions: inter-organizational collaboration, obtaining funds, prioritization and planning, having dedicated staff, community buy-in, stakeholder engagement (i.e., elected officials, contractors, and landowners), and creative workarounds. The themes are not additional elements of capacity, but parts of the process that translate those elements of capacity into wildfire mitigation actions. These themes do not exist in isolation, and based on how participants discussed these topics, are connected in specific ways

(Figure 2.2). We also recognize that these themes have been discussed in relation to wildfire risk mitigation in previous literature (Fleeger 2008, Berkes 2009, Champ et al. 2012, Lambrou et al. 2023), but to our knowledge, they have not been explored in relation to process.

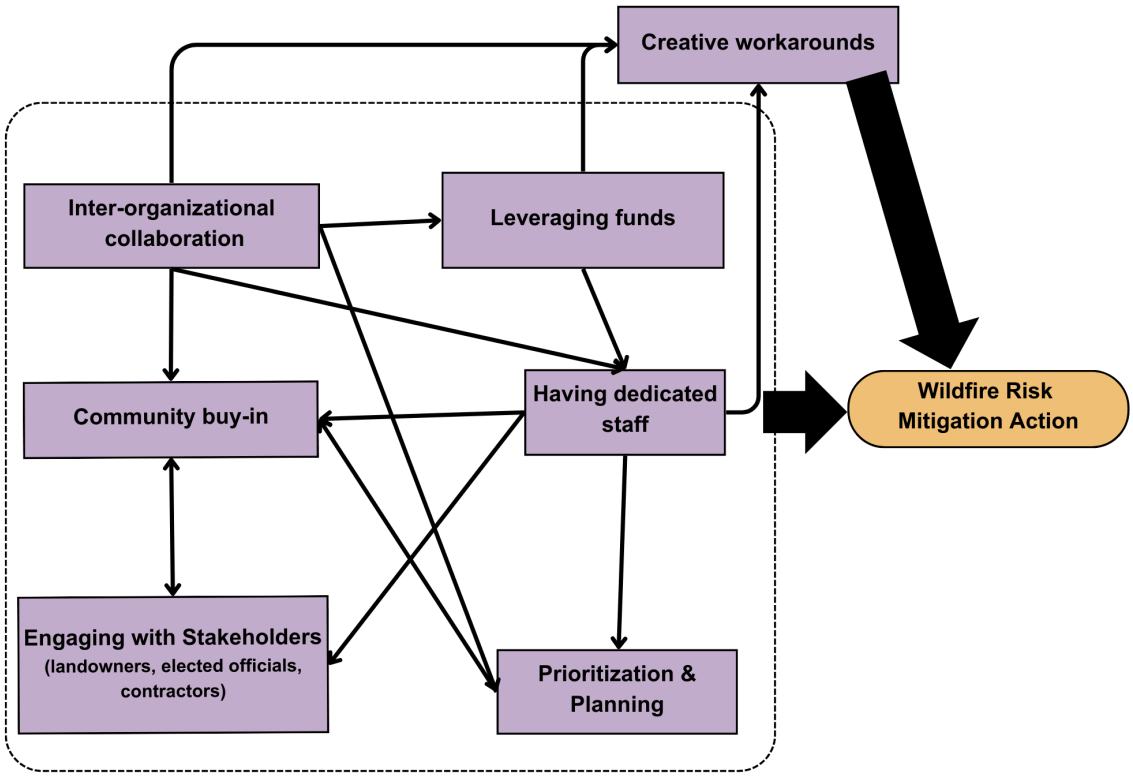


Figure 2.2. Pathways linking elements of capacity to mitigation outcomes following 11 group interviews across Colorado, USA to better understand wildfire risk mitigation. The dashed line groups the regular pathways one might consider for getting to mitigation work, with creative workarounds outside of that. Arrows delineate assumed linkages based on group interviews and how participants talked about each theme in relation to one another.

2.4.1 The Process to Wildfire Mitigation Actions

Efforts to conceptualize elements or characteristics of capacity have made important contributions to applied work in wildfire risk mitigation (Paveglio et al. 2012, 2015, Cheng and Sturtevant 2012, Davies et al. 2018), but little empirical evidence has focused on the process of translating those elements of capacity into wildfire risk mitigation outcomes. Here, we have focused on that process, and while the themes that emerged are not necessarily new, the way in which we are conceptualizing these themes as processes rather than discrete elements/characteristics is unique. Overall, low-capacity communities often struggled to build lasting collaborations/partnerships, educational

programs, and community buy-in, largely because they did not have the funds to build these programs, nor many dedicated staff to oversee wildfire risk mitigation work.

Collaboration was one of the main themes that emerged as part of the process to move from elements of capacity to mitigation actions. Participants in almost every interview stressed the importance of collaborations and building relationships with partners, aligning with previous literature (Fleming et al. 2015, Huayhuaca 2019). While there are drawbacks to collaborations with government entities and fire departments, benefits highlighted by interviewees suggest that these partnerships around mitigation are important to cultivate. Further, issues of decentralized governance emerged, highlighting that collaboration at smaller scales in communities is going well, but across scales is more challenging. This points to the need for more bridging organizations (e.g., Fire Adapted Colorado, Colorado Forest Collaboratives Network) to bring partners together. This fits within the larger body of literature around collaboration and governance identifying that collaboration is a process that contributes to more effective governance and associated institutions (Wyborn and Bixler 2013, Schultz and Moseley 2019, Kelly et al. 2019, Miller et al. 2022). Flexible institutions that are aligned across scales can further contribute through learning and capacity for wildfire mitigation (Abrams et al. 2015).

Interviews also revealed that communities rely on multiple funding streams and work around existing policies to leverage additional funding opportunities, but challenges remain for communities that lack prior experience with securing grants. Cheng and Dale (2020) found the Colorado Wildfire Risk Reduction Grant (WRRG) to be disproportionately beneficial to higher-capacity communities that could produce the 1:1 cost match requirement, develop detailed and data-rich proposals, and implement projects at larger spatial scales to affect fire behavior. Likewise, more socially vulnerable communities may be significantly less likely to obtain wildfire mitigation grants (Ojerio et al. 2011).

Acknowledging the risk of wildfire and the importance of wildfire mitigation was also key, with one approach having plans devoted to wildfire mitigation and coordinating these with other planning initiatives within the community. Many studies have shown that Community Wildfire Protection Plans can assist in convening collaborations around wildfire mitigation (Brummel et al. 2010, Evans et al. 2015,

Palsa et al. 2022). Whether the collaborations our participants mentioned started or were continued by CWPP planning, participants highlighted the usefulness of CWPPs in prioritization. Communities often face challenges with integrating multiple plans (e.g., CWPPs, Hazard Mitigation Plans, County Comprehensive Master Plans), and resolving tensions across plans can be crucial to building capacity and reducing vulnerability (Malecha et al. 2018).

Our findings suggest that these communities need more paid, permanent staff and staff solely focused on specific areas, such as community engagement and grant administration. These resources enable the collaborative and information sharing process noted above while increasing potential to acquire funds. Research in the flood mitigation space has found that internal organization (i.e., the organization(s) implementing mitigation strategies) capacity, which includes financial resources, staffing, technical expertise, communication, and leadership (Hartig et al. 1995, Handmer 1996) is a foundation upon which strong mitigation programs rest (Brody et al. 2010). More funding agencies in the future should consider staff time as eligible costs and devote more funding overall to support designated staff.

Our conversations also emphasized the importance of community buy-in for advancing wildfire mitigation, specifically around engagement with elected officials, private landowners, and contractors. Our findings highlighted several areas to focus on: developing consistent messaging across organizations, making educational material more accessible, tailoring information to make it relevant for different audiences, sharing examples of success, and delivering information via trusted entities. Past community engagement research has found that motivating and educating homeowners in the WUI to mitigate can be essential to avoid severe losses (Champ et al. 2012, Wolters 2023). However, others have also emphasized the need to actively educate (as opposed to passively) in a broad range of ways to reach everyone, which is consistent with our findings here (Paton and Buergelt 2012, Monroe et al. 2013).

4.2 Limitations

There were several limitations to this study. First, we interviewed wildfire practitioners from only 11 communities across Colorado and are therefore cautious with generalization. Further, we limited our

study to practitioners, which is only one group of stakeholders involved in wildfire mitigation. Thus, future studies could benefit from drawing evidence from a more representative sample of actors, including community members or government officials. Additionally, there are diverse communities represented in our sample, but participants did not always reflect racial and ethnic diversity. Some participants may also have emphasized their barriers and challenges more than their successes because they believed we could potentially assist them in the future because of who some of our project partners were (e.g., Colorado State Forest Service). While we heard about planning and prioritization, it was beyond the scope of this work to identify specific elements of these wildfire planning processes that are helpful; this represents an areas of future research. Other future research should focus more explicitly on the workarounds that communities employ to enact mitigation work, as well as prioritize looking at the systems at play in wildfire mitigation, rather than on community vulnerabilities and capacities to explore ways forward.

4.3. Implications for Policy and Practice

One of the most striking findings from this study is the emphasis communities across contexts placed on the importance of employing creative workarounds to overcome existing structural barriers. Examples of these barriers include caps on funding, policies restricting tree removal, and codes limiting which contractors can be hired for projects. Policies and codes, for instance those set by HOAs and municipalities, regulate what mitigation actions can be taken and where such as tree thinning. Therefore, risk reduction, and thus community capacity, not only depends on access to resources, but the ease of using those resources in ways that the community needs or wants. This also then depends on the access to power and decision-making that community members have (Lambrou et al. 2023). Importantly, such structural barriers work against the trend toward more decentralized and collaborative wildfire risk mitigation governance. Our findings yield valuable examples that other communities with limited resources or similar barriers inhibiting their efforts could draw from to advance wildfire mitigation. This is directly related to the broader national conversation about systems disadvantaging communities

(Morrow 1999, Jacobs 2019, Lambrou et al. 2023) and is especially true for work that examines the rural/urban divide (Paveglio et al. 2015, Lichter and Ziliak 2017, Loh et al. 2022).

The salience of workarounds, points to, perhaps a renewed focus on the barriers and the systems that create the barriers that prevent action, rather than solely focusing on increasing the capacity of communities. A way to refocus back on systems while still making changes for wildfire management could be through the ideals of equitable adaptation, which argue that policymakers need to put the needs of the most vulnerable first while also providing funding (Pelling and Garschagen 2019). Additionally, adaptation policies must align at all scales because community-based adaptation will be ineffective if it runs counter to national policies that disadvantage the most marginalized (Pelling and Garschagen 2019). Overall, we have four recommendations for policymakers and funders:

1. *Build more avenues for funding staff time and equipment to support (especially marginalized) communities*

We heard again and again that funding for forest restoration and fuels treatments is insufficient. These findings suggest that communities need staff to implement projects, yet staffing is insufficient and under-resourced. Grant programs are needed specifically for capacity-building, which includes funding time and equipment (e.g., chippers, masticators). Some existing funding outlets may be expanded or better leveraged to fill these gaps, like the FRWRM program, and programs through the National Forest Foundation and Federal Emergency Management Agency (FEMA).

The *Justice40* initiative enacted by the federal government, and the US Forest Service Equity Action Plan are also attempting to address some of the barriers that exist for underserved communities. The *Justice40* initiative seeks to have "40 percent of the overall benefits of certain Federal investments flow to disadvantaged communities that are marginalized, underserved, and overburdened by pollution." There are many departments and programs eligible for this initiative, including "Reducing Wildfire Risk to Tribes, Underserved, and Socially Vulnerable Communities". However, because so many programs are eligible across the entire country, there is great demand and competition for these funds. The USFS Equity Action Plan also claims to "target wildfire prevention where it is needed most" (p. 9) and will

"recruit, hire, and train dedicated staff to support engagement and potential future recruitment within disadvantaged communities, including Tribes" (p. 10) to help with internal capacity issues. By doing so, communities will ideally be able to rely on the USFS more for wildfire mitigation, as we heard was often an issue. With these initiatives and programs, we hope to see more funding go to marginalized communities and those that need money to build capacity by paying for increased staff and equipment. We argue that even more related programs should adopt similar priorities.

2. *Generate greater support for higher-level collaborative organizations to coordinate across agencies and scales*

We heard from participants how it can be challenging to develop a unified message with other agencies and sustain partnerships. Higher-level collaborative organizations (also called "bridging organizations" (Berkes 2009)) can help bridge those gaps. They are necessary to coordinate across agencies and scales and often are the missing piece in decentralized polycentric governance (Armitage 2010). Examples of organizations that operate in this way in Colorado include Fire Adapted Colorado and Colorado Forest Collaboratives Network. These types of organizations can aid in collaboration formation (Schultz 2009), facilitate knowledge co-production, trust building, and can bring different communities together for peer-to-peer learning and sharing of successes and challenges (Berkes 2009). The federal government has realized the need for greater cohesion as well in their 2023 report, "On Fire: The Report of the Wildland Fire Mitigation and Management Commission", which may indicate greater support for these connector organizations in the near future.

3. *Prioritize finding ways to fund fire departments to have volunteers supported by paid staff at increased levels*

As we continuously heard across interviews, having fire districts/departments involved and leading the charge for wildfire mitigation is often a key contributor to success. Those communities that only have volunteer departments cannot rely on them for wildfire mitigation assistance, and thus are at a disadvantage compared to other communities that can. This is not a unique problem to Colorado; this is a nationwide issue that also heavily affects rural volunteer fire departments in the state. However, fire

departments are also struggling to find volunteers at all. The US Fire Administration recently released a report that found volunteerism in fire and emergency services has significantly declined in the last 40 years by over 220,000 volunteers despite the rise in population overall (U.S. Fire Administration 2023). This is likely due to several factors such as an increase in the cost of living, the significant time commitment, lengthy training requirements, and dangerous work environment that firefighters face (U.S. Fire Administration 2023). This is a broad issue that should be explored further in future research by examining successful districts across the country. However, we recommend prioritization of funding dedicated fire department staff.

4. *Reduce policies and codes that prevent communities from enacting successful wildfire mitigation projects*

Policies and institutional structures, such as municipal and certain land use codes that restrict contracted restoration work, often impeded interviewees and their organizations' wildfire risk mitigation projects. For example, these included HOA and city codes that prevent tree removal. To reduce these types of policies, incentives and innovative educational programs should be explored. Incentives could include education for realtors, developers, fire departments, or consultants to show they are knowledgeable about wildfire. Trainings through the Colorado Timber Industry Association, the Society of American Foresters, Fire Adapted Colorado, and others could be recommended by municipalities. Acknowledging the value of these trainings for city councils, county emergency management, and metro districts might incentivize continued learning. Other incentives could include different tax structures and cheaper insurance (Bayham et al. 2022) if wildfire risk mitigation restrictive codes are removed and education is pursued. However, changing these codes depends on who is engaged in decision-making and has the power to make those decisions and emphasizes a need for community involvement, which may or may not be happening in all places across the state yet (Berkes 2009).

4.4 Conclusions

This study used a novel participatory qualitative method to understand the barriers and pathways to successful wildfire risk mitigation work among forest communities. From this, we have gleaned what

has and has not been working well and what items need to be prioritized in the future, such as a focus on bridging organizations that can enhance cohesion among governance entities. This work has also emphasized the need for more equitable distribution of wildfire risk mitigation funds and prioritization of funding staff time to educate the public, write grants, and coordinate mitigation projects. Connecting capacity to wildfire mitigation outcomes is important and we highlighted how understanding the process behind capacity is key, which cannot be reduced to a checklist of items or cookie-cutter solutions. Future work could explore in more detail the ways in which structures could be altered to better serve communities for reducing impacts of wildfire.

REFERENCES

Abrams, J. 2019. The emergence of network governance in U.S. National Forest Administration: Causal factors and propositions for future research. *Forest Policy and Economics* 106:101977.

Abrams, J., M. Knapp, T. B. Paveglio, A. Ellison, C. Moseley, M. Nielsen-Pincus, and M. S. Carroll. 2015. Re-envisioning community-wildfire relations in the U.S. West as adaptive governance. *Ecology and Society* 20(3):34.

Armitage, D. R., editor. 2010. *Adaptive capacity and environmental governance*. Springer, New York.

Armitage, D. R., R. Plummer, F. Berkes, R. I. Arthur, A. T. Charles, I. J. Davidson-Hunt, A. P. Diduck, N. C. Doubleday, D. S. Johnson, M. Marschke, P. McConney, E. W. Pinkerton, and E. K. Wollenberg. 2009. Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the Environment* 7(2):95–102.

Bayham, J., J. K. Yoder, P. A. Champ, and D. E. Calkin. 2022. The Economics of Wildfire in the United States. *Annual Review of Resource Economics* 14(1):379–401.

Berke, P., and D. Godschalk. 2009. Searching for the Good Plan: A Meta-Analysis of Plan Quality Studies. *Journal of Planning Literature* 23(3):227–240.

Berkes, F. 2009. Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management* 90(5):1692–1702.

Berkes, F. 2010. Devolution of environment and resources governance: trends and future. *Environmental Conservation* 37(4):489–500.

Braun, V., and V. Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3(2):77–101.

Brody, S. D., J. E. Kang, and S. Bernhardt. 2010. Identifying factors influencing flood mitigation at the local level in Texas and Florida: the role of organizational capacity. *Natural Hazards* 52(1):167–184.

Brummel, R. F., K. C. Nelson, S. G. Souter, P. J. Jakes, and D. R. Williams. 2010. Social learning in a policy-mandated collaboration: community wildfire protection planning in the eastern United States. *Journal of Environmental Planning and Management* 53(6):681–699.

Chaffin, B. C., H. Gosnell, and B. A. Cosens. 2014. A decade of adaptive governance scholarship: synthesis and future directions. *Ecology and Society* 19(3):art56.

Champ, J. G., J. J. Brooks, and D. R. Williams. 2012. Stakeholder Understandings of Wildfire Mitigation: A Case of Shared and Contested Meanings. *Environmental Management* 50(4):581–597.

Chapman, S. K., J. A. Langley, S. C. Hart, and G. W. Koch. 2006. Plants actively control nitrogen cycling: uncorking the microbial bottleneck. *New Phytologist* 169(1):27–34.

Cheng, A. S., and L. Dale. 2020. Achieving Adaptive Governance of Forest Wildfire Risk Using Competitive Grants: Insights From the Colorado Wildfire Risk Reduction Grant Program. *Review of Policy Research* 37(5):657–686.

Cheng, A. S., and V. E. Sturtevant. 2012. A Framework for Assessing Collaborative Capacity in Community-Based Public Forest Management. *Environmental Management* 49(3):675–689.

Cinner, J. E., and M. L. Barnes. 2019. Social Dimensions of Resilience in Social-Ecological Systems. *One Earth* 1(1):51–56.

Colorado State Forest Service. 2022. *Colorado's Forests in a Changing Climate*. Colorado State University.

David, E., and E. P. Enarson, editors. 2012. *The women of Katrina: how gender, race, and class matter in an American disaster*. Vanderbilt University Press, Nashville.

Davies, I. P., R. D. Haugo, J. C. Robertson, and P. S. Levin. 2018. The unequal vulnerability of communities of color to wildfire. *PLOS ONE* 13(11):e0205825.

Doesken, N. J., R. A. Pielke, and O. A. P. Bliss. 2003. *Climate of Colorado*. Colorado Climate Center, Atmospheric Science Department, Colorado State University, Fort Collins, CO.
Dunn, C. J., C. D. O'Connor, J. Abrams, M. P. Thompson, D. E. Calkin, J. D. Johnston, R. Stratton, and J. Gilbertson-Day. 2020. Wildfire risk science facilitates adaptation of fire-prone social-ecological systems to the new fire reality. *Environmental Research Letters* 15(2):025001.
Eriksen, C., and G. Simon. 2017. The Affluence–Vulnerability Interface: Intersecting scales of risk, privilege and disaster. *Environment and Planning A: Economy and Space* 49(2):293–313.
Evans, A., S. Auerbach, L. W. Miller, R. Wood, K. Nystrom, J. Loevner, A. Aragon, M. Piccarello, and E. Krasilovsky. 2015. Evaluating the effectiveness of wildfire mitigation activities in the wildland-urban interface. Forest Stewards Guild.
Fischer, A. P., and L. Jasny. 2017. Capacity to adapt to environmental change: evidence from a network of organizations concerned with increasing wildfire risk. *Ecology and Society* 22(1):art23.
Fischer, A. P., T. A. Spies, T. A. Steelman, C. Moseley, B. R. Johnson, J. D. Bailey, A. A. Ager, P. Bourgeron, S. Charnley, B. M. Collins, J. D. Kline, J. E. Leahy, J. S. Littell, J. D. Millington, M. Nielsen-Pincus, C. S. Olsen, T. B. Paveglio, C. I. Roos, M. M. Steen-Adams, F. R. Stevens, J. Vukomanovic, E. M. White, and D. M. Bowman. 2016. Wildfire risk as a socioecological pathology. *Frontiers in Ecology and the Environment* 14(5):276–284.
Fleeger, W. E. 2008. Collaborating for success: Community Wildfire Protection Planning in the Arizona White Mountains. *Journal of Forestry* 106(2):78–82.
Fleming, C. J., E. B. McCartha, and T. A. Steelman. 2015. Conflict and Collaboration in Wildfire Management: The Role of Mission Alignment. *Public Administration Review* 75(3):445–454.
Fusch, P. I., and L. R. Ness. 2015. *Are We There Yet? Data Saturation in Qualitative Research*. Pages 1408–1416. Walden University, Walden Faculty and Staff Publications.
Handmer, J. 1996. Policy Design and Local Attributes for Flood Hazard Management. *Journal of Contingencies and Crisis Management* 4(4):189–197.
Hartig, J. H., N. L. Law, D. Epstein, K. Fuller, J. Letterhos, and G. Krantzberg. 1995. Capacity-building for restoring degraded areas in the Great Lakes. *International Journal of Sustainable Development & World Ecology* 2(1):1–10.
Hessburg, P. F., D. J. Churchill, A. J. Larson, R. D. Haugo, C. Miller, T. A. Spies, M. P. North, N. A. Povak, R. T. Belote, P. H. Singleton, W. L. Gaines, R. E. Keane, G. H. Aplet, S. L. Stephens, P. Morgan, P. A. Bisson, B. E. Rieman, R. B. Salter, and G. H. Reeves. 2015. Restoring fire-prone Inland Pacific landscapes: seven core principles. *Landscape Ecology* 30(10):1805–1835.
Highfield, W. E., W. G. Peacock, and S. Van Zandt. 2014. Mitigation Planning: Why Hazard Exposure, Structural Vulnerability, and Social Vulnerability Matter. *Journal of Planning Education and Research* 34(3):287–300.
Huayhuaca, C. 2019. The state of collaboration: An analysis of form and function in Colorado's natural resource collaboratives. Dissertation, Colorado State University, Fort Collins, Colorado.
Jacobs, F. 2019. Black feminism and radical planning: New directions for disaster planning research. *Planning Theory* 18(1):24–39.
Keane, R. E., A. W. Schoettle, and D. F. Tomback. 2022. Effective actions for managing resilient high elevation five-needle white pine forests in western North America at multiple scales under changing climates. *Forest Ecology and Management* 505:119939.
Kelly, E. C., S. Charnley, and J. T. Pixley. 2019. Polycentric systems for wildfire governance in the Western United States. *Land Use Policy* 89:104214.
Kolden, C. A., and C. Henson. 2019. A Socio-Ecological Approach to Mitigating Wildfire Vulnerability in the Wildland Urban Interface: A Case Study from the 2017 Thomas Fire. *Fire* 2(1):9.
Lambrou, N., C. Kolden, A. Loukaitou-Sideris, E. Anjum, and C. Acey. 2023. Social drivers of vulnerability to wildfire disasters: A review of the literature. *Landscape and Urban Planning* 237:104797.

Lichter, D. T., and J. P. Ziliak. 2017. The Rural-Urban Interface: New Patterns of Spatial Interdependence and Inequality in America. *The ANNALS of the American Academy of Political and Social Science* 672(1):6–25.

Loh, C. G., A. J. Ashley, L. Durham, and K. Bubb. 2022. Our Diversity Is Our Strength: Explaining Variation in Diversity, Equity, and Inclusion Emphasis in Municipal Arts and Cultural Plans. *Journal of the American Planning Association* 88(2):192–205.

Malecha, M. L., A. D. Brand, and P. R. Berke. 2018. Spatially evaluating a network of plans and flood vulnerability using a Plan Integration for Resilience Scorecard: A case study in Feijenoord District, Rotterdam, the Netherlands. *Land Use Policy* 78:147–157.

McDermott, M. H., and K. Schreckenberg. 2009. Equity in community forestry: insights from North and South. *International Forestry Review* 11(2):157–170.

Miller, B. A., L. Yung, C. Wyborn, M. Essen, B. Gray, and D. R. Williams. 2022. Re-Envisioning Wildland Fire Governance: Addressing the Transboundary, Uncertain, and Contested Aspects of Wildfire. *Fire* 5(2):49.

Monroe, M. C., S. Agrawal, P. J. Jakes, L. E. Kruger, K. C. Nelson, and V. Sturtevant. 2013. Identifying Indicators of Behavior Change: Insights From Wildfire Education Programs. *The Journal of Environmental Education* 44(3):180–194.

Morrow, B. H. 1999. Identifying and Mapping Community Vulnerability. *Disasters* 23(1):1–18.

Naderifar, M., H. Goli, and F. Ghaljaie. 2017. Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research. *Strides in Development of Medical Education* 14(3).

Ojerio, R., C. Moseley, K. Lynn, and N. Bania. 2011. Limited Involvement of Socially Vulnerable Populations in Federal Programs to Mitigate Wildfire Risk in Arizona. *Natural Hazards Review* 12(1):28–36.

Otter.ai. 2023. Otter.ai. Otter.ai Inc.

Palaiologou, P., A. A. Ager, M. Nielsen-Pincus, C. R. Evers, and M. A. Day. 2019. Social vulnerability to large wildfires in the western USA. *Landscape and Urban Planning* 189:99–116.

Palsa, E., M. Bauer, C. Evers, M. Hamilton, and M. Nielsen-Pincus. 2022. Engagement in local and collaborative wildfire risk mitigation planning across the western U.S.—Evaluating participation and diversity in Community Wildfire Protection Plans. *PLOS ONE* 17(2):e0263757.

Paton, D., and P. T. Buergelt. 2012. Community engagement and wildfire preparedness: the influence of community diversity. Pages 241–259 *Wildfire and Community: Facilitating preparedness and resilience*. Charles C. Thomas, Springfield, Illinois.

Paveglio, T. B., M. S. Carroll, P. J. Jakes, and T. Prato. 2012. Exploring the Social Characteristics of Adaptive Capacity for Wildfire: Insights from Flathead County, Montana. *Human Ecology Review* 19(2):110–124.

Paveglio, T. B., C. Moseley, M. S. Carroll, D. R. Williams, E. J. Davis, and A. P. Fischer. 2015. Categorizing the Social Context of the Wildland Urban Interface: Adaptive Capacity for Wildfire and Community "Archetypes." *Forest Science* 61(2):298–310.

Pelling, M., and M. Garschagen. 2019. Put equity first in climate adaptation. *Nature* 569(7756):327–329.

QSR International. 2020, March. NVivo. Lumivero.

Radeloff, V. C., R. B. Hammer, S. I. Stewart, J. S. Fried, S. S. Holcomb, and J. F. McKeefry. 2005. THE WILDLAND–URBAN INTERFACE IN THE UNITED STATES. *Ecological Applications* 15(3):799–805.

Ratcliffe, C., W. Congdon, D. Teles, A. Stanczyk, and C. Martín. 2020. From Bad to Worse: Natural Disasters and Financial Health. *Journal of Housing Research* 29(sup1):S25–S53.

Scarlett, L., and M. McKinney. 2016. Connecting people and places: the emerging role of network governance in large landscape conservation. *Frontiers in Ecology and the Environment* 14(3):116–125.

Schultz, C. A., and C. Moseley. 2019. Collaborations and capacities to transform fire management. *Science* 366(6461):38–40.

Schultz, L. 2009. Nurturing resilience in social-ecological systems: Lessons learned from bridging organizations. Doctoral Thesis, Stockholm University, Sweden.
Schweizer, D., T. Nichols, R. Cisneros, K. Navarro, and T. Procter. 2020. Wildland Fire, Extreme Weather and Society: Implications of a History of Fire Suppression in California, USA. Pages 41–57 *in* R. Akhtar, editor. *Extreme Weather Events and Human Health*. Springer International Publishing, Cham.
Steelman, T. A. 2016. U.S. wildfire governance as social-ecological problem. *Ecology and Society* 21(4):3.
Steelman, T. A., G. Kunkel, and D. Bell. 2004. Federal and state influence on community responses to wildfire threats: Arizona, Colorado, and New Mexico. *Journal of Forestry* 102(6):21–27.
Stephens, S. L., A. L. Westerling, M. D. Hurteau, M. Z. Peery, C. A. Schultz, and S. Thompson. 2020. Fire and climate change: conserving seasonally dry forests is still possible. *Frontiers in Ecology and the Environment* 18(6):354–360.
Trenberth, K. E., A. Dai, G. Van Der Schrier, P. D. Jones, J. Barichivich, K. R. Briffa, and J. Sheffield. 2014. Global warming and changes in drought. *Nature Climate Change* 4(1):17–22.
Turner, B. L., R. E. Kasperson, P. A. Matson, J. J. McCarthy, R. W. Corell, L. Christensen, N. Eckley, J. X. Kasperson, A. Luers, M. L. Martello, C. Polsky, A. Pulsipher, and A. Schiller. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences* 100(14):8074–8079.
United States Census Bureau. 2021. QuickFacts Colorado.
U.S. Fire Administration. 2023. *Retention and Recruitment for the Volunteer Emergency Services*. Page 148. U.S. Fire Administration, FEMA.
Walker, S. E., E. A. Smith, N. Bennett, E. Bannister, A. Narayana, T. Nuckols, K. Pineda Velez, J. Wrigley, and K. M. Bailey. 2023. *Defining and Conceptualizing Justice and Equity in Climate Adaptation*. preprint, SSRN.
Wigtil, G., R. B. Hammer, J. D. Kline, M. H. Mockrin, S. I. Stewart, D. Roper, and V. C. Radeloff. 2016. Places where wildfire potential and social vulnerability coincide in the coterminous United States. *International Journal of Wildland Fire* 25(8):896.
Williams, D. R., P. J. Jakes, S. Burns, A. S. Cheng, K. C. Nelson, V. Sturtevant, R. F. Brummel, E. Staychock, and S. G. Souter. 2012. Community Wildfire Protection Planning: The Importance of Framing, Scale, and Building Sustainable Capacity. *Journal of Forestry* 110(8):415–420.
Wolters, E. A. 2023. Homeowner firewise behaviors in fire-prone central Oregon: An exploration of the attitudinal, situational, and cultural worldviews impacting pre-fire mitigation actions. *Journal of Environmental Management* 327:116811.
Wyborn, C., and R. P. Bixler. 2013. Collaboration and nested environmental governance: Scale dependency, scale framing, and cross-scale interactions in collaborative conservation. *Journal of Environmental Management* 123:58–67.

APPENDIX A

Supplementary Material 1.1 Practitioner Survey for Model Weighting

Thank you for taking the time to share with us your experience with wildfire risk mitigation capacity in Colorado!

This is the definition of capacity we are using,
"The combination of local social characteristics and external forces (including ecological processes or larger social forces) that influence whether and how human communities" mobilize toward a set of goals or recovery (Paveglio et al., 2015).

We will be asking you only 2 questions and ask that you answer from your perspective generally as a community or wildfire representative (not as an individual).

This survey is completely anonymous and no identifiable information will be collected. There are no inherent risks or benefits associated with participating.

This survey is part of a larger research product being conducted by graduate student, Karissa Courtney, at Colorado State University (advised by Jonathan Salerno) within the Warner College of Natural Resources (IRB Approval #3466). If you have any comments or questions, please email Karissa at karissa.courtney@colostate.edu or you are welcome to contact CSU IRB regarding research ethics and approvals (CSU_IRB@colostate.edu; 970-491-1553).
If you would like to continue to the survey, please press NEXT at the bottom!

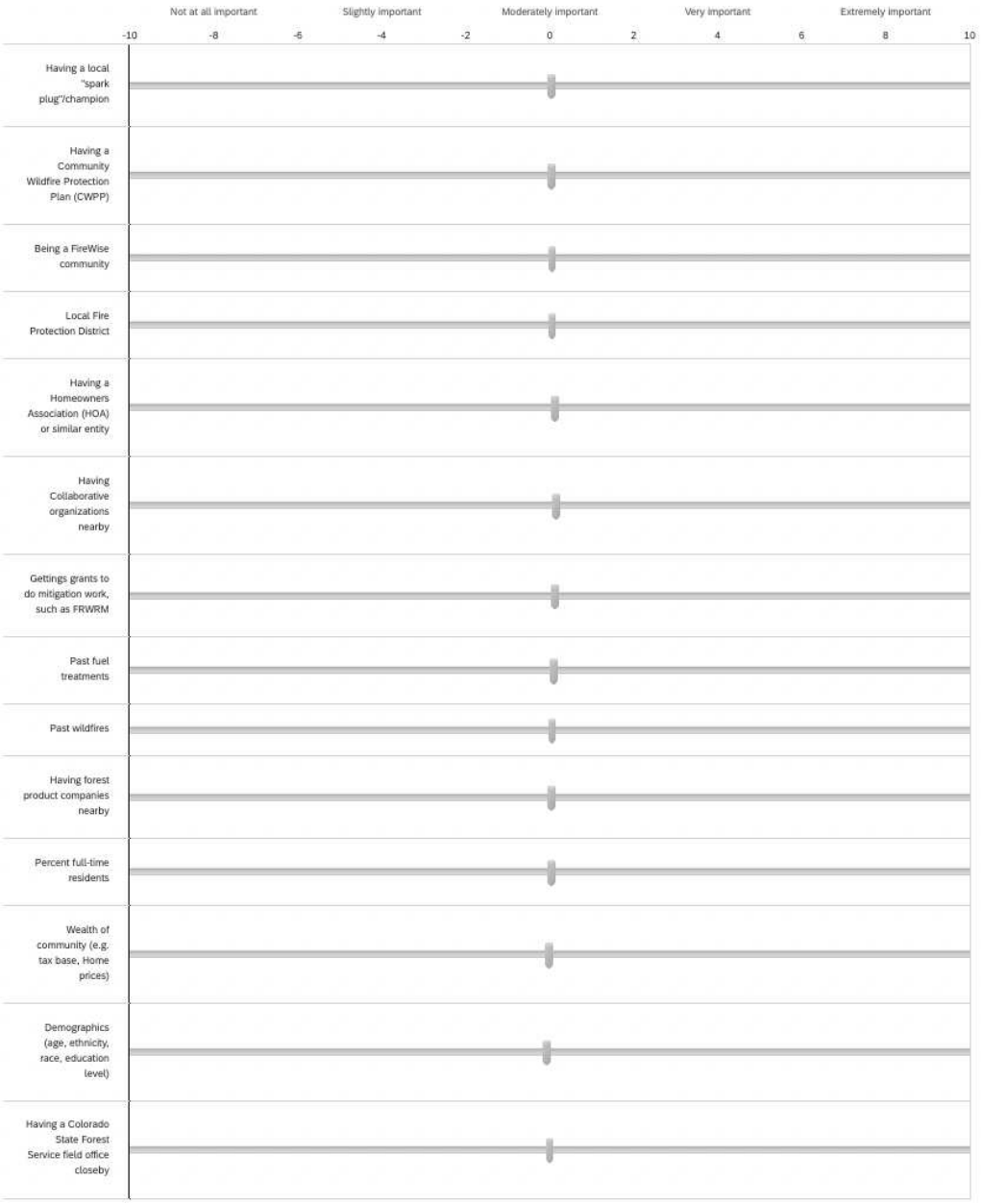
1. Where in Colorado do you live, or experience, or engage most with wildfire risk? Please write the town, county, or other jurisdiction that best describes the location of your experience with risk mitigation.
2. We are curious to hear what indicators are the most impactful or important in your community related to capacity to do wildfire mitigation work. We have listed each indicator we think is important below. Please specify the relative importance of each. We recognize that there are other indicators that are important, but we are focusing here on indicators we can quantify more broadly.

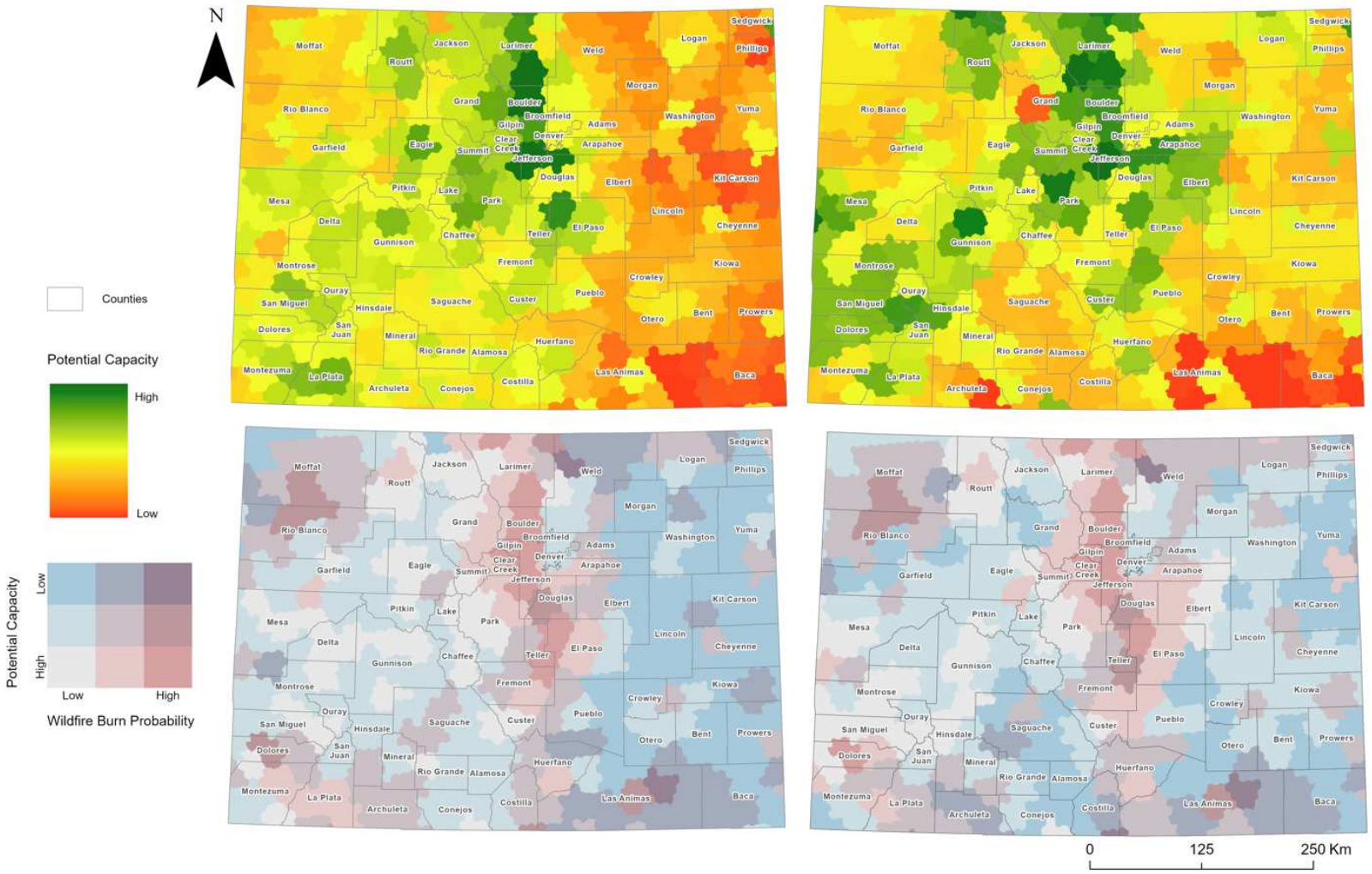
How important is each indicator below in POSITIVELY influencing current wildfire mitigation capacity in your community?
Scale
0 10
Not at all Important Extremely important

- ☐ Having a local "spark plug"/champion
- ☐ Having a Community Wildfire Protection Plan (CWPP)
- ☐ Being a FireWise community
- ☐ Local Fire Protection District
- ☐ Having a Homeowners Association (HOA) or similar entity
- ☐ Having forestry/wildfire/watershed Collaborative organizations nearby
- ☐ Gettings grants to do mitigation work, such as FRWRM
- ☐ Past fuel treatments

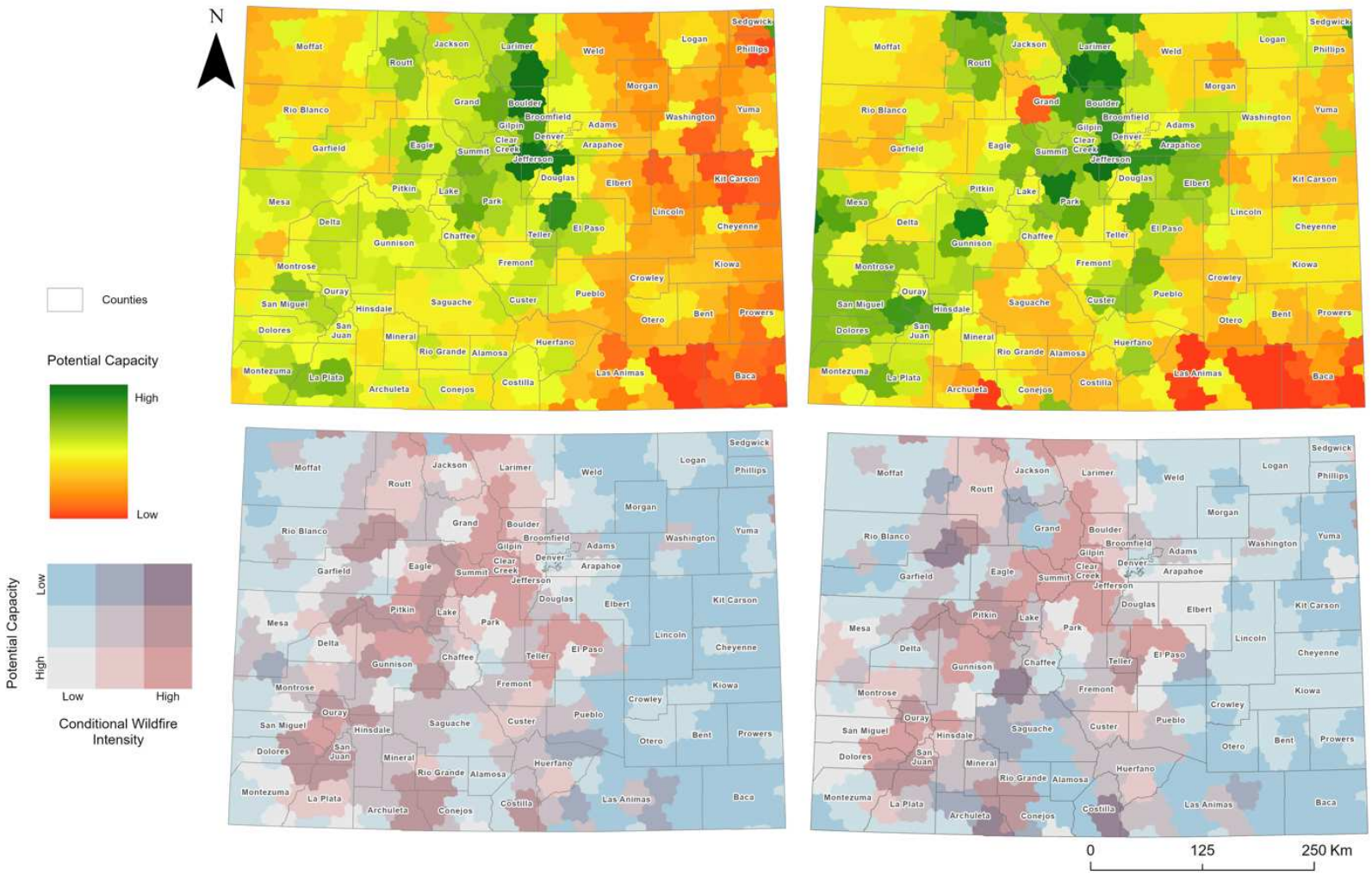
- Past wildfires
- Having forest product companies nearby
- Percent full-time residents
- Wealth of the community (e.g. tax base, Home prices)
- Demographics (age, ethnicity, race, education level)
- Having a Colorado State Forest Service field office close by

[Screenshot below to visualize the question]





Supplementary Figure 1.1. Wildfire Burn Probability.
Potential capacity for wildfire risk mitigation across Colorado, USA using 11 different indicators and aggregated to the fireshed scale where a) unweighted model of potential capacity, b) weighted model of potential capacity, c) unweighted model of capacity against wildfire burn probability, and d) weighted model of capacity against wildfire burn probability. Wildfire data from Colorado All Lands (COAL) 2022. Potential capacity is depicted on a scale from red (lowest) to dark green (highest). Looking at potential capacity against burn probability is depicted on a matrix from light blue to dark blue, light pink to dark pink, with the darkest purple representing the lowest potential capacity with the highest burn probability.



Supplementary Figure 1.2. Conditional Wildfire Intensity.
Potential capacity for wildfire risk mitigation across Colorado, USA using 11 different indicators and aggregated to the fireshed scale where a) unweighted model of potential capacity, b) weighted model of potential capacity, c) unweighted model of capacity against conditional wildfire intensity, and d) weighted model of capacity against conditional wildfire intensity. Wildfire data from Colorado All Lands (COAL) 2022. Potential capacity is depicted on a scale from red (lowest) to dark green (highest). Looking at potential capacity against conditional wildfire intensity is depicted on a matrix from light blue to dark blue, light pink to dark pink, with the darkest purple representing the lowest potential capacity with the highest fire intensity.

APPENDIX B

Supplementary Material 2.1 Recruitment Email

Subject Line: Invitation to participate in a study on wildfire risk mitigation capacity in Colorado

Dear ___,
I am a master's student at Colorado State University working with Dr. Jonathan Salerno and Dr. Tony Cheng. I'm reaching out to invite you to participate in a research study about community wildfire risk mitigation capacity in Colorado. [town] and [xxx] County are a focus of our study because of barriers and opportunities you have experienced, and we are interested in your role in the community working to mitigate wildfire risk.

Participation would consist of a group interview together with 2-3 other participants from the community and will take about 90 minutes.
Our goals are to use your community's experiences, along with those of approximately 10 others, to understand how efforts can increase community capacity to mitigate risk from wildfire, given unique circumstances.
If you can participate, please let me know and fill out this When2Meet poll to help schedule (LINK). We are trying to schedule a time and place that will work for all participants in the next couple of weeks.
If you are unable to participate for any reason, I invite you to reply with a brief note, and if possible, recommend others working in the community who may be good alternatives.

Thank you for your consideration, and I look forward to hearing back from you.
Best,
Karissa

Supplementary Material 2.2 Interview Questions

Introduction

My name is Karissa Courtney, and I am a master's student at CSU working with Jonathan Salerno and Tony Cheng. My graduate thesis is part of the CoNIFER project where we are seeking to better understand how people come together to plan and carry out wildfire risk mitigation at the community and regional scales in Colorado. This past summer we worked across the state and interviewed wildfire managers and stakeholders to discuss Community Wildfire Protection Plans and their creation and implementation.

Here, I am focusing on understanding what it means to have capacity as a community to do wildfire risk mitigation work, including exploring what barriers may or may not exist in regard to getting mitigation work done. I have compiled several datasets to try to understand capacity across Colorado, such as the presence of planning efforts, accessing risk reduction funding, and community characteristics. Other elements will be explored further once we get into the interview. The purpose of this interview is to collectively discuss the various components of capacity to mitigate fire risk. We hope that having multiple people's experiences and expertise in the room will encourage an engaging conversation. This group interview should take 1 hour and there are 8 questions to get through. We are going to ask you to talk collaboratively, and we are interested in the discussion that you all have around this topic of capacity to do wildfire mitigation work.

But before we begin, I need to ask if you are willing to provide your consent to participate in the study. [*Interviewer reads the consent document to the interviewee: Your participation is completely voluntary. You may leave the interview at any time and may choose to only answer questions you would like to answer. Your data will be kept completely anonymous, and we will not be directly quoting and attributing ideas to you directly. In all, there are inherently no risks or benefits to participating, although your responses will be beneficial to this study. Can I get a verbal "yes" from each participant?*] Do you have any questions before we begin?

Great, thank you for agreeing to participate. I also want to ask if it would be OK if we record the interview. To be clear, we will not share the recording with anyone who is not a member of the project team. We will use this recording to analyze data in the future, and so we can be more engaged in conversation instead of having to take detailed notes. Your name or any other identifying information will not be shared or made public. [*Interviewer begins recording if respondent says it's OK to do so; thanks respondent*]

Questions

1) Briefly introduce yourself, the organization you work at, and your role at X organization.
2) Here is a general definition of capacity. [*Have it pulled up so people can read.*] This is just to get your mind thinking about what we mean by capacity. Is there anything that you would change to this definition, setting aside wildfire for now and the specifics of this community? Are you on board?
3) We know many elements influence capacity, but they differ by community, and we are interested in your experiences and perspectives on these elements. Again, we are looking for your experience, not what you think the ideal might be.
    a) Here is the list of elements, do you think anything missing?
    b) Wealth of community (eg, tax base, home values)
    c) Presence of wildfire/forestry/watershed collaborative
    d) Presence of contractors
    e) Presence of facilities
    f) Presence of fire protection district
    g) Percent full-time residents
    h) Acquisition of wildfire mitigation grants
    i) Presence of CWPP
    j) Presence of FireWise certification

k) Building codes
l) Land-use codes
m) Presence of local champions/spark plugs
n) Tight-knit community

4) Now we will move into using the elements we were just talking about. We would like you to use these elements to assess your community. For each element collectively decide if you would assess as high, medium, or low. (i.e., what you have, what you sort of have, what you do not have) [*Use sticky notes and move into categories. Once they feel like they are in the right place, take photo of their designation.*]
   a) Now that we have discussed which elements are most salient in your community, we want to dive a little deeper. From past interviews last summer, we know that your community has done X really well. You've also indicated that your community ranks highly on X, Y, and Z. Have these elements influenced (The example of success)? If so, in what ways?
   b) Alternatively, you assessed your community as low in X, Y, and Z. How have you managed to achieve that success despite having low capacity in these specific areas?
5) We also know from past interviews that your community has struggled to achieve X. Which of the elements that you categorized as low were the biggest barrier(s) to achieving X?
   a) What prevented you from being able to leverage the elements you categorized as high from achieving X?
   b) Based on this conversation, what do you think are the most important steps your community can take to increase capacity to mitigate wildfire?

The point of this study is not just to understand how capacity is different around the state. We are working with folks at the CSFS and policymakers, so the findings from this study should be going to people higher up to hopefully make a difference within the larger context. That being said,

6) If we're to convey anything from this meeting to CSFS or policy-makers or CSU extension, what would that be? [*Prompt: Is there a largest barrier that your community faces in relation to wildfire mitigation, and is there anything you would like to convey to others about this?*]
7) Is there anything that we did not touch on that you think is important to understanding barriers to mitigation work?

Supplementary Table 2.1 Community Self-Assessment Results

Community self-assessments (high, medium, or low) for 13 elements provided, as well as additional elements added by interviewees (indicated by *) in 11 different group interviews across Colorado, USA. Interviews were looking at community capacity to mitigate wildfire risk. Where Comm is the community, n is the number of participants in each interview, "Dspace" refers to defensible space, and "% full time" refers to the percent of full-time residents.

Comm	n	HIGH	MEDIUM	LOW
1	4	Wealth, collaboratives, FPRD, % full time, CWPP, Firewise, local champs	Grants, building codes, land use codes, tight knit, contracts for Dspace*, institutional knowledge*	Home hardening contractors*, % young population*, biomass removal*, county mitigation funding*
2	2	Wealth, collaboratives, FPRD, building codes, land use codes, CWPP, recreationalists*	Contractors, facilities, Firewise	% full time, grants, local champs, tight knit, fuel planners
3	4	Collaboratives, FPRD, tight knit, building codes, Dspace contractors*	Wealth, local champs, grants, CWPP, Firewise, level of community education/awareness*, program support*	Facilities, % full time, land use codes, engaged community*, landscape scale contractors*
4	7	Wealth, collaboratives, FPRD, grants, % full time, CWPP, Firewise, building codes, land use codes, tight knit, local champs, mitigation funding*, community engagement*	Contractors, level of resident education*, access to resources*	Facilities, general mitigation fund*
5	4	Collaboratives, FPRD, contractors, facilities, local champs, grants, CWPP, Firewise, community acceptance/buy-in*	Wealth, building codes, land use codes, % full time, tight knit, county mitigation funds*, social license to treat*, level of awareness/ motivators*	
6	2	% full time	Wealth, collaboratives, grants, tight-knit	FPRD, CWPP, Firewise, contractors, facilities, building codes, land use codes, local champs
7	5	% full time, CWPP, tight knit, contractors	FPRD, facilities, grants, Firewise, land use codes, forestry agency*	Collaboratives, wealth, building codes, local champs, fire codes*, means to apply to grants (writers)*
8	2	Collaboratives, % full time, tight knit, Firewise, understanding of diverse cultures*	Contractors, facilities, FPRD, CWPP, grants, local champs, community willingness*	Wealth, building codes, land use codes

9	5	% full time	Wealth, grants, tight knit, CWPP, collaboratives, local champs, education*, local ordinances/policies*	FPRD, contractors, facilities, Firewise, building codes, land use codes, operational budget*, staff time*, ability to process material*, enforcement of codes*
10	4	Tight knit community	% full time, CWPP, FPRD, grants, collaboratives, contractors, local champs, wealth	Building codes, land use codes, Firewise
11	4	Wealth, collaboratives, tight knit, building codes, land use codes	Contractors, FPRD, grants, CWPP, fire education*	Facilities, Firewise, local champs, % full time, mitigation funding*, Buy-in*

Supplementary Table 2.2. Elements of capacity added to our list of 13 elements by interviewees during 11 different group interviews across Colorado, USA focusing on community capacity to mitigate wildfire risk.

TYPES OF CONTRACTORS	WAYS TO DISPOSE OF MATERIAL	OTHER FUNDING & SUPPORt	EDUCATION & BUY-IN	OTHER	CODES/ POLICIES
Defensible space	Biomass removal	County mitigation funding	Institutional knowledge	% young population	Fire codes
Home hardening	Ability to process material	Program support	Education/awareness	Recreationalists	Local ordinances/ policies
Landscape scale		Access to resources	Community engagement	Understanding of diverse cultures	Enforcement of codes
		Operational budget	Level of resident education	Forestry agency	
		Means to apply to grants (writers)	Community acceptance/buy-in	Staff time	
			Fire education		
			Community willingness		
			Level of awareness/motivators		
			Social license to treat		