SAVING SIERRAS

Motivating Public-Private Collaboration to Reduce Fire Severity in the Southern Sierra Nevada Mountains

UNIVERSITY OF CALIFORNIA
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A Group Project submitted in partial satisfaction of the requirements for the degree of Master of Environmental Science and Management for the Bren School of Environmental Science & Management.

Prepared by:
Justin Heyerdahl, Christopher Hughes, Tess Morgridge, Craig O'Neill, and Jason White

Prepared for:
The Sierra Resource Conservation District

Faculty Advisor:
C. Naomi Tague

PhD Advisor:
Christopher Heckman

External Advisors:
John Jostes
Dr. Max Morritz

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Signature Page

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Justin Heyerdahl

Christopher Hughes

Tess Morgridge

Craig O'Neill

Jason White

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The Project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

Naomi Tague

Christopher Heckman

23 March 2018
Date

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PhD Candidate Advisor

Christopher Heckman

Primary External Advisors

John Jostes, Dr. Max Moritz

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Abstract

Fire is a natural process for the Sierra Nevada landscape. However, a decade of fire suppression and outdated forest management has allowed forests to grow overly dense, increasing flammable fuel loads and leaving the landscape vulnerable to severe wildfire. Severe wildfires pose a risk to human safety, infrastructure, and ecological characteristics of the landscape. While forests on publics lands in the Wildland-Urban Interface are being thinned to lower densities and reduce woody fuel loads, such actions are not being employed on private lands. Being that the protection of human life and infrastructure are the primary motivating factors for pre-emptive fire risk reduction and fire suppression, funds should be directed towards employing fuel treatments directly to at-risk private lands. Private landowners cannot employ fuel treatments at scale without external support mechanisms because significant capacity gaps exist that have limited the feasibility of community-driven fuel treatment implementation on the landscape. This project aimed to (1) examine the impacts of different scales of fuel treatments on fire severity for private lands in the southern Sierra Nevadas, (2) assess the costs and benefits of implementing fuel treatments for private landowners and public entities, and (3) identify strategies for increasing community capacity for implementing fuel treatments.

Section 1—Executive Summary

Executive Summary:

Decades of fire suppression in the southern Sierra Nevada Mountains have led to unnaturally dense forest stands and high levels of combustible fuels on the landscape. The amount of fuel on the landscape and the connectivity of the fuels from the forest floor to the forest canopy has left the southern Sierra Nevada Mountains vulnerable to high severity, stand-replacing fires that pose health, safety, and economic risks to communities in the Wildland-Urban Interface. on the fringes of national forest land, and may cause drastic environmental damage to the landscape. Although the United States Forest Service (USFS) has begun to change their forestry practices on public lands to allow natural fires to burn in places that are not a risk to human life and to incorporate prescribed burns into their restoration strategies, the USFS's budget is still prioritizes fire suppression activities over pre-emptive fire risk management. Even in the areas where pre-emptive fire management is performed through fuel thinning activities, private lands, despite being a significant portion of the fire landscape, are mostly excluded from active management. Because severe fire poses an immediate threat to individuals and infrastructure to private landowners adjacent to national forest lands, fuel reduction treatments should be regarded as a critical action for implementation directly on these private lands.

The Dinkey Collaborative Forest Landscape is a federally designated landscape whose mission is to create a collaborative body of local stakeholders to increase the involvement of communities bordering public lands in the planning of the restoration of those lands. The Dinkey Landscape is located in the foothills of the southern Sierra Nevada Mountains east of the City of Fresno in the Sierra National Forest. The landscape is a matrix of 130,000 acres of public lands and 24,000 acres of private lands. Since its inception in 2010, the Dinkey Collaborative has instituted multiple fuel reduction treatments in the Wildland-Urban Interface, but very few have ever been implemented directly on private lands. This disparity between fuel reduction treatments on public versus private lands highlights the need for increased inclusion and participation of private landowners to perform fuel treatments.

Private landowners on the Dinkey Landscape form two distinct groups: second-home owners in the Shaver Lake area and permanent residents in the dispersed parcels of the central and southwest sections of the landscape. The Shaver Lake area has been identified as an area lacking in community buy-in identified as a lack of investment in the community by second-home owners. Despite the higher household income of Shaver Lake residents, the community's financial capital is constrained by limited community investment. The residents of the dispersed parcels are also financially constrained, though typically because of a dwindling local economy and older age demography. Overall, the age structure, lack of community cohesion, and financial limitations preclude private landowners from successfully implementing fuel reduction treatments on their lands without the support of public entities. The Sierra Resource Conservation District (SRCD) – a member of the Dinkey Collaborative and an advocate for its private landowner constituents – is keenly aware of the disparity between fuel reduction activities that are employed on public lands versus those that are employed on private lands, and they would like more projects to directly address the issue of heavy fuel loads on private lands.

This project addresses the desire of the SRCD to increase fuel treatments on private lands by (1) modeling how fuel reduction treatments on private lands reduce fire severity across the private parcel landscape of the Dinkey Collaborative, (2) analyze the costs and benefits of performing fuel reduction treatments directly on private lands to both the public and private stakeholders that would bear costs and/or accrue benefits, and (3) explore funding options and strategic uses of those funds to achieve fuel reduction implementation on private lands.

To analyze fire severity, a forest vegetation model (FVS) was used to simulate vegetation growth and recruitment for the private parcels on the Dinkey landscape through 2050. The vegetation simulator, a tool developed by the Forest Service to model the impacts of fuel treatments and other forest management strategies on vegetation structure, has very specific data requirements. Because of the lack of data for private land forest structure beyond remotely sensed data incompatible with FVS, public forest stand data from plots on the landscape adjacent to private parcels were used to simulate forest regrowth and recruitment under multiple fuel treatment reduction scenarios and a no treatment scenario. The output of the forest vegetation model is a fuel profile for the landscape, which acts as an input for a fire behavior model (FlamMap) that simulates stochastic fire starts, subsequent fire spread and severity for the landscape. The fire behavior model produces spatial outputs of conditional flame length – a metric for fire severity – for the entire modeled landscape. After fire behavior was modeled for public lands, an ordinal logistic regression was used to crosswalk the public fire severity results to private lands fire severity results.

Results from fire severity modeling found that fuel reduction treatments on private parcels do reduce fire severity across the entire private parcel landscape compared to a status quo or no treatment option. Additionally, these significant reductions in fire severity can be achieved even if just **21% of private land** is treated with fuel reductions. A fire probability model developed by fire researchers Mann et al. 2016, which modeled fire frequency for California through 2050 under two climate projections was applied to our fire severity outputs to explore overall fire risk: potential fire severity and its probability of occurring. This project shows that the locations for fuel reduction activities can be prioritized based on a number of factors, including, but not limited to, potential fire severity, potential fire risk, land value, cost of treatment, and ecological features of the landscape, while still achieving significant reductions in fire severity across the landscape.

Coupled with our initial landscape scale modeling, three separate cost benefit analyses were performed to examine the costs and benefits of overall fire risk reduction (fire severity and fire frequency through 2050) for this project's three stakeholders: (1) private landowners, (2) the SRCD, and (3) the USFS. Benefits of fire risk reduction included the avoided cost of damage from high severity fires, the avoided cost of fire suppression for high severity fires, the potential for revenue generation through the sale of merchantable wood from fuel reduction activities, and environmental benefits including carbon sequestration and improved air quality. The costs of fuel reductions treatments include costs associated with hand thinning treatments, in which fuel reduction crews use chainsaws and hand tools to reduce shrubby growth and trees on the landscape, and mechanical treatments, which make use of heavy machinery to clear undergrowth and trees. The cost-benefit analyses analyzed the net present value of investing in fuel treatments for the three stakeholders through 2050 under the two different climate scenarios of the fire frequency model and two discount rates: 5% and 7%.

The cost-benefit analyses showed that under every scenario net present values for private landowners and the SRCD are always positive. Benefits to the USFS are also positive as they are not made to bear any of the costs of fuel treatment implementation. Finally, the cost-benefit analyses showed that hand-thinning was far more expensive and produced more negative net present values than mechanical treatment. These cost-benefit analyses demonstrate although it is in the best financial interest of private landowners to implement fuel treatments on their lands they are unlikely to be able to cover the up-front costs of treatments without financial assistance, that mechanical thinning is more cost-efficient than hand-thinning, and that public entities are the stakeholders that benefit the most from private land fuel treatments.

Results from the exploration of grant funding opportunities identified three distinct grant packages that the SRCD is eligible for and whose funds can be used to implement fuel treatments on private lands. Additionally, three programs, that are currently under-utilized in the area, were identified which provide private landowners with direct partial reimbursement for the costs of fuel treatments on private lands. Two primary uses of funds garnered by the SRCD were identified to support the implementation of fuel treatments on private lands: (1) pay contractors directly to perform fuel treatments on the lands of willing private landowners, and (2) cover the difference between the reimbursement provided by existing assistance programs and the actual cost of fuel treatments to make these programs more accessible to private landowners in the area. While these identified grant packages could support the SRCD in providing financial and technical assistance to private landowners to perform such treatments, the SRCD should remain adaptable, as not all grants are guaranteed and the timing of such grant receipts and needs of potential project partners could dictate how grant funds are utilized most optimally.

This project is meant to serve as a framework for future studies of fire severity risk potential and reduction, aid in the SRCD's outreach to private landowners about the benefits of reducing heavy fuel loads on private lands, and help inform and support the grant applications of the Sierra Resource Conservation District for funds to begin the implementation of fuel treatments on private lands. While this project clearly demonstrates that fuel treatments will reduce fire severity on private lands, the fire behavior analysis was limited by the need to crosswalk public land results to private lands, which decreased the strength and nuance of the analysis. Additionally, although the impact of climate was incorporated into the frequency of fire occurrence, thus adjusting overall fire risk, the impacts of climate change were not incorporated into the forest vegetation model. Previous research has shown that climate change may significantly impact vegetation type and the fuel profile of a landscape, subsequently impacting fire behavior. The results of this project's analyses are thus likely conservative and analysis using a fire behavior model that can use currently available, remotely sensed data from private lands and incorporate the impacts of climate change on landscape fuel profile would be useful as a next step to generate stronger fire severity results for private lands.

Although more robust fire modeling for private lands is an important next step, this report's findings paired with previous research suggest that seeking immediate implementation of fuel reduction treatments on private lands would reduce the landscape's vulnerability to severe wildfire. However, this project identified two critical capacity gaps for the private landowner community of the Dinkey Landscape that limit fuel treatment implementation and will need to be addressed before treatments are feasible at an appropriate scale for landscape-level fire severity reduction. These capacity gaps are a lack of financial capital to pay for fuel treatment implementation and a lack of labor and physical capacity to carry out the fuel treatments. In the local community only one contractor exists that can perform mechanical fuel treatments and only three local hand-thinning contractors have been identified. The lack of contractors severely constrains the capability of the community to implement enough fuel treatments over a short enough timeframe to be effective in reducing fire severity. A public-private collaboration that involves both the SRCD and the USFS is the best way to fill the identified capacity gaps so that the communities in the Wildland-Urban Interface of the southern Sierra Nevada Mountains can increase their resiliency to economic, ecological, and social change.

Section 2—Project Overview

Purpose

The Rim Fire in the central Sierra Nevada Mountains burned from August 2013 to October of 2014, causing evacuations, widespread degraded air quality, extraordinary suppression costs, and concerns over the availability of water supply from the Hetch Hetchy Reservoir. The Rim Fire alerted fire-prone communities and communities outside the direct influence of fire not only to their vulnerability to severe wildfire, but also to the destruction that severe fires can cause to private property, local economic stability, natural resources, and life itself. These consequential elements, amongst many other regional considerations, provide motivation for creating and consolidating resources, informative tools, and funding to encourage and assist private landowners with executing land management practices on private lands that reduce the potential for high severity fires.

The purpose of this report is to explore feasible land management activities that private landowners in the southern Sierra Nevada WUI can enact themselves or with assistance from local, state, federal, or tribal entities. Moreover, this report attempts to explore different prioritization schemas for the placement of vegetation management and fuel treatments on private lands to reduce the risk of severe fires using vegetation growth simulation models, fire behavior modeling, and cost benefit analyses that account for the existing constraints on land management as defined by local, state, and federal regulations. This report is meant to be guiding document for the Sierra Resource Conservation District (SRCD) to motivate WUI residents towards performing vegetation management on their lands and to garner support for these activities using cross-agency collaboration. Additionally, this report is intended to provide the SRCD with technical information specific to their jurisdiction and stakeholders of interest to support the success of, and increase the scope of, grant funding opportunities that the SRCD may pursue to assist in financing these vegetation management practices. The current framework for public-private collaboration that exists for the landscape – the Collaborative Forest Landscape Restoration Program – is unlikely to receive renewed funding after its ten-year project lifespan ends in 2020. Because fuel reduction treatments are intended to help restore natural fire regimes to a landscape, they must be performed on a cyclical basis for a number of years before the forest becomes more or less self-sustaining. Climate change is expected to exacerbate the shift away from the landscape's historic fire regime by causing vegetation shifts and changes in precipitation. As such, the need for cyclical fuel treatments and adaptive management of those treatments will outlive the current framework for collaboration that ideally would help implement treatments on the landscape. Because this work analyzes fire risk over time with consideration to climatic variability that accounts for future projected fire presence conditions within the Southern Sierra Nevada landscape, this report aims to act as a long-term planning tool for the SRCD and other applicable agencies to inform future land management decisions and partnerships to implement those decisions.

Significance

In the United States, 32% of housing units fall into the transition zone between unoccupied human land and human development called the WUI (Stein et al. 2013.) Of these homes, 4.5 million, the largest number in any one state, are located in the WUI of California, and 35% of all the land area burned in the State of California since 2000 has been located within this transition zone (Schoennagel et al. 2017). The growing WUI population has led to decades of fire suppression and improper forest management strategies on both private and public lands in the southern Sierras. The result of these actions is an ecologically altered landscape that poses a multitude of risks to communities in the WUI (Stein et al. 2013).

Although the United States Forest Service (USFS) has begun to change its forest management practices by allowing wildfires to burn when they do not threaten lives or infrastructure and by employing restoration activities such as prescribed burns, their efforts are limited by budgetary and time-constraints. With such large tracts of land in USFS management, very little of it is treated to reduce hazardous fuels for pre-emptive fire control: between 2001 and 2013 only 1% of USFS lands received any form of fuel treatment each year (Omi 2015). Studies have shown that, while fuel treatments reduce risk of fire spread for the entirety of the landscape, untreated areas in close proximity to treated plots do not experience spill-over benefits of the reductions in fire severity that treated landscapes experience (Moghaddas et al. 2010). This suggests that, while actions taken on public lands to reduce hazardous fuels may help control the spread of wildfire to private lands, if fire occurs on private lands those lands will experience a fire whose severity has not been adjusted by nearby treatments. Therefore, to reduce the risk of severe fires on private lands, fuel treatments must be applied directly to those lands. While private land interests are represented in the conversation about how to address these concerns through their inclusion in working groups and collaboratives such as the Dinkey Collaborative – a group of diverse stakeholders working with public agencies to formulate forest restoration plans on the Dinkey Landscape in the southern Sierras under the Collaborative Forest Landscape Restoration Program – there still exists a significant disconnect between the actions of public agencies in their restoration activities and those of private landholders ("Dinkey Collaborative Charter" 2011; Figure 2-1).

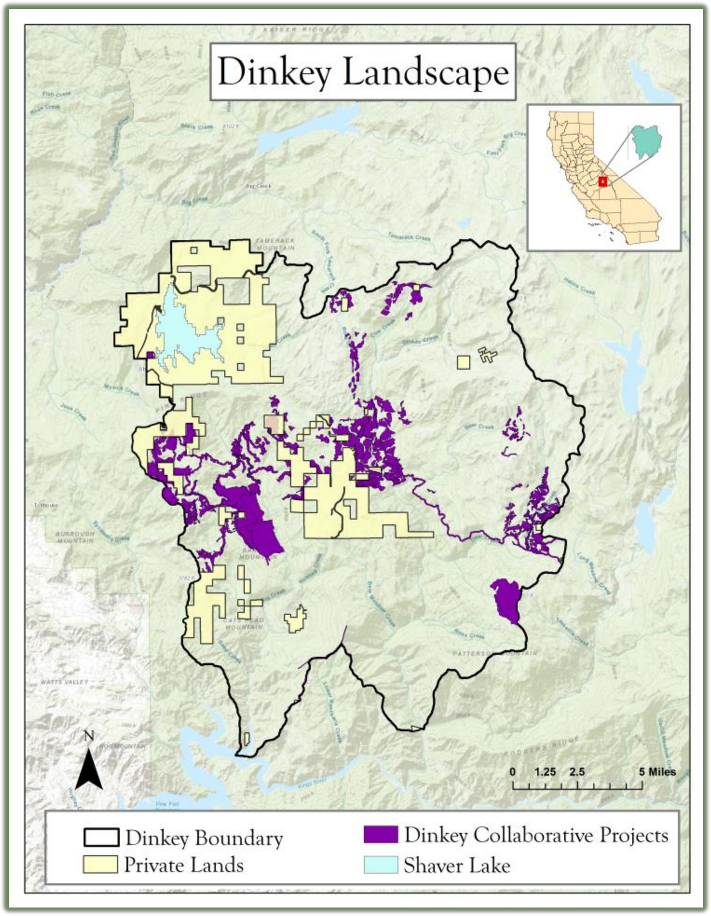

Figure 2-1. Dinkey Collaborative forest management and fuel thinning projects and their disconnect with private lands.

The SRCD aims to address this disconnect by incorporating private landholders as active participants in forest management with the goal of reducing the risk of catastrophic fire for the landscape and helping restore the ecological function of forest processes. The barriers to involving private landholders in the forest management process primarily arise from the prohibitive cost of vegetation management activities to reduce hazardous fuels that contribute to catastrophic fire and alter forest resiliency to fires. To a lesser extent, landholder resistance to participation is due to a lack of information about, and perception of risks associated with, certain restoration strategies or the dislike of regulatory oversight (Winter, Vogt, and Fried 2002).

Our project will work to identify feasible restoration strategies for implementation on private lands, while providing motivation to private landholders to pursue and invest in restoration strategies on private lands in the WUI. This project plans to benefit the SRCD by providing information and tools that explore fuel management strategies in the WUI and their potential impacts on fire risk and ecological characteristics of the forest to aid the SRCD in their efforts to secure grants and funding to support the stewardship of private lands in their district. Further, the project will enable private landholders to make informed decisions on whether or not, and how, to implement vegetative management strategies on their parcels given their potential impacts on future fire risk and associated costs. Public agencies will benefit from the results of the project by gaining access to data that has been consolidated from both agency and scientific sources to produce a unique data analysis of fuel treatment strategies applied to private lands and how they impact the health and structure of public forests using agency metrics of success.

Project Objectives

1. Define and quantify fire severity on private lands under fuel treatment scenarios of different scope and intensity.
2. Identify the costs and benefits of fire severity reduction to this project's three primary stakeholders: the private landowners, the SRCD, and the USFS.
3. Determine the implementation feasibility for identified fuel treatment strategies on the private parcel landscape.

Designing a Strategic and Collaborative Approach

The barriers to engaging private landowners on the Dinkey Landscape as active land stewards in reducing the potential for catastrophic fire across the landscape formed the framework for this study. A socioeconomic study of the communities in the landscape identified both severe financial constraints from some parts of the community – primarily the older residents living on the dispersed private parcels in the central and southwest quadrants of the landscape – and a lack of community engagement from the younger, wealthier second-home owners in the Shaver Lake area in the Dinkey Landscape (Kusel et al. 2015). Although the financial constraints are considerable, limited infrastructure – in the form of roads and fuel treatment machinery - and low levels of exposure to public sources of funding and technical support are additional barriers that private landowners are likely to face in their effort to reduce fire severity on the Dinkey Landscape (S. Haze, personal communication, April 19, 2017; R. Evans, personal communication, February 12, 2018; Kusel et al. 2015). As such, this study addressed each of these issues, outlined in the following report chapters, to culminate in a number of recommendations delineated in the report's final chapter.

Vegetation and fire behavior modeling was undertaken to explore the effects of simulated fuel reduction treatments on potential fire severity for private lands. Methodology and results from vegetation and fire behavior modeling are detailed in Section 4 of this report. The results of the models, paired with maps detailing feasible fuel treatment locations on the landscape and possible prioritized areas for treatment, directly influenced final report recommendations with the goal of providing critical technical assistance for private landowners to implement vegetative management effectively. While the modeling was critical to understanding how different scales and intensities of fuel treatments reduce potential fire severity, the core of this study's approach to motivating public-private collaboration to reduce fire severity on private lands is formed by the cost-benefit analyses of fuel treatment costs and benefits and the identification of programs and grants that can address some of the disparities uncovered by the cost-benefit analysis.

Cost-benefit analyses, informed by the results of vegetation and fire behavior modeling, address the issue of limited financial resources available for implementing fuel treatments. The cost-benefit analyses compare the estimated costs of implementing fuel treatments against the benefits of reducing the risk of catastrophic fire over the long-term – through the year 2050. These cost-benefit analyses attempt to monetize the cost-avoidance of damage due to severe wildfire – such as loss of property or suppression costs – benefits from carbon sequestration and improved air quality, and potential revenue streams generated by fuel treatments to provide perspective on the value of investing in vegetation management. The cost-benefit analyses are intended to provide the SRCD with greater quantitative evidence with which to expand and support their grant proposals. The cost-benefit analysis methodology and results are detailed in Section 5 of this report.

Section 6 provides recommendations concerning fuel treatment implementation, funding sources and strategies, and potential partnerships to aid in achieving an effective land stewardship plan for private parcel fuel reductions on the Dinkey Landscape.

Section 7 provides a summation and synthesis of report findings and recommendations from the vegetation and fire modeling, the cost-benefit analysis, and the funding sources and strategic planning sections.

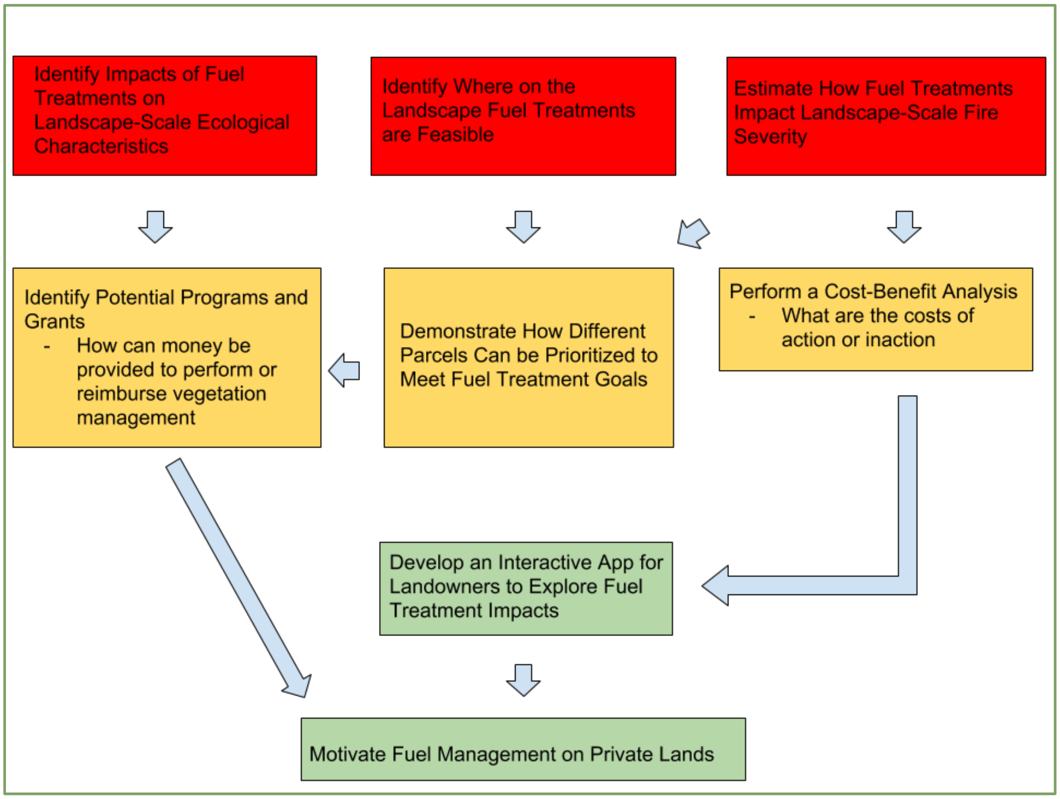

Figure 2-2. General methodology for motivating private landowners to perform fuel reduction activities.

Geographic Scope

This report is targeted specifically to the WUI communities of the southern Sierra Nevada foothills of eastern Fresno County: Shaver Lake, Exchequer Heights, Providence, and Chamber Tract and dispersed parcels in the southwest quadrant of the landscape.

Although this study's results are site specific to communities located within the Dinkey Landscape, the overall approach and methodology can be extrapolated to other WUI communities within the bounds of the SRCD jurisdiction (Figure 2-3) and the rest of Western United States.

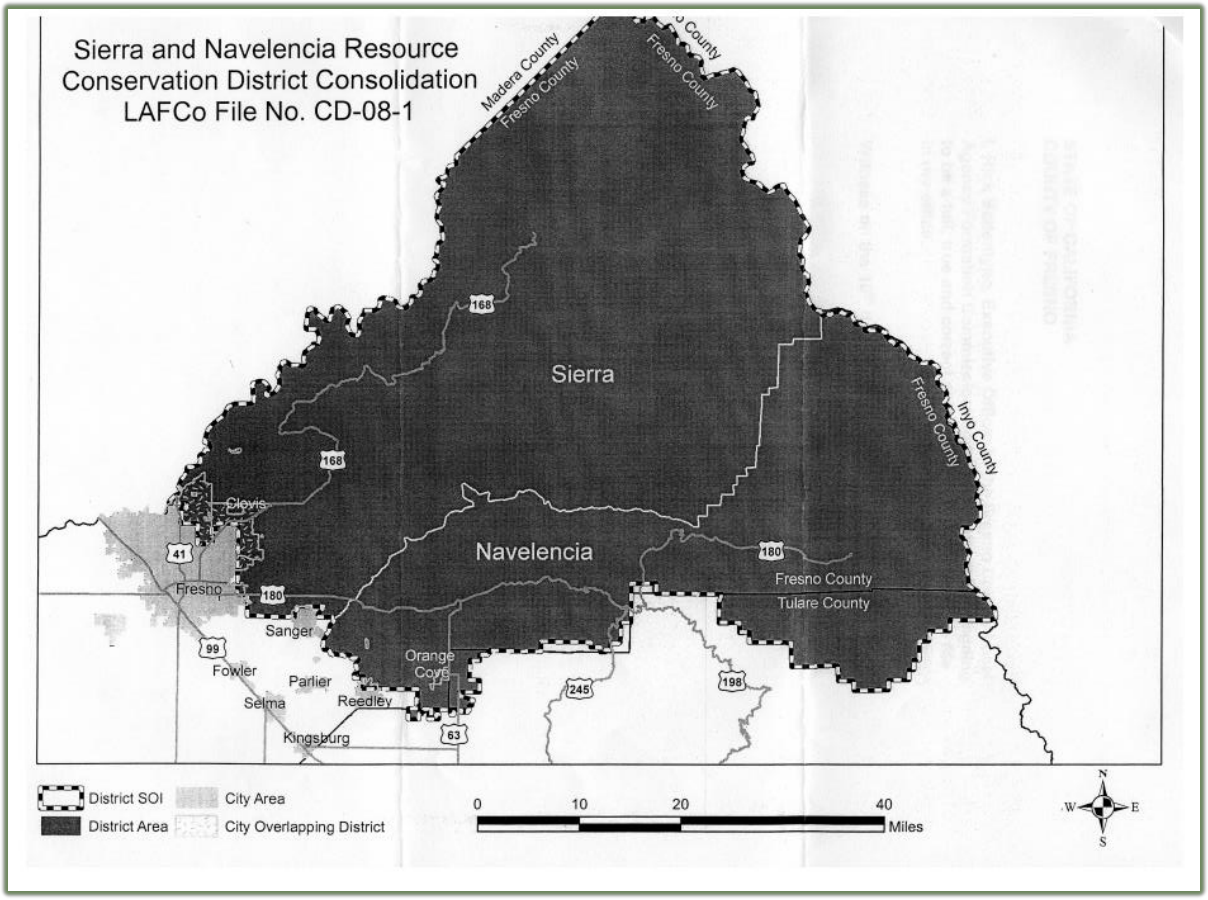

Figure 2-3. SRCD jurisdictional boundary (figure source: SRCD 2011).

Project Partnerships

Sierra Resource Conservation District

The SRCD is a governmental entity tasked with collaborating with governments and private persons or entities to enhance the adoption of conservation practices across all landscapes and resources within its jurisdiction (SRCD 2011). The SRCD encompasses the lands east of the City of Fresno and bounded by Inyo, Tulare, and Madera counties.

As the entity responsible for ensuring a balance of representation in conservation actions, the SRCD was concerned about the lack of action, specific information, and support for implementing fuel treatments on private lands. The Bren School of Environmental Science & Management at the University of California at Santa Barbara was approached to assist in addressing this disconnect. This report is the culmination of that effort.

USFS

The USFS, more specifically High Sierra Ranger District, has been a key source for project guidance and data resources. Currently, there is a framework for collaboration between private residents and public entities, primarily the USFS, to implement forest restoration practices on the landscape in and around the Sierra National Forest. Because this framework already exists, the continuation and strengthening of the relationship between private landowners and the USFS is likely to be an instrumental future relationship that improves the community's capability to implement fuel treatments on the landscape. Because buy-in from the USFS is likely to be important to carry out this project's findings, the results had to be compelling to the USFS. As such, in developing our methodology for this project, a conscientious effort was made to utilize USFS models and technical guidance documents, such as DOC GTR-220, to ensure that this project's results are in-line with agency constraints and requirements, making them easy to accept by the USFS, thereby increasing agency buy-in.

Dinkey Landscape Restoration Collaborative

Figure 2-4. Dinkey Collaborative members (photo credit: Dinkey Collaborative).

The Dinkey Collaborative Forest Landscape Restoration Program is part of the Collaborative Forest Landscape Restoration Program: a program created by the federal government to involve local communities in the restoration of forest landscapes to reduce the risk of catastrophic fire, increase forest resiliency, and encourage community economic health ("Collaborative Forest Landscape Restoration Program" 2017). Because of its location in the southern Sierra Nevada foothills, the Dinkey Collaborative is currently dealing with the impacts of the 2015 tree mortality that devastated the Sierra Nevada (Pile 2017). The mortality event has changed the fuel structure of the Dinkey Landscape to one that is not only overly dense, but is also host to large swaths of dead trees that are highly flammable and act as efficient ladder fuel able to transform a low-severity wildfire on the forest floor to a high-severity wildfire in the forest canopy by creating fuel continuity from the ground to the crown of the trees (A. Hernandez, personal communication, October 19, 2017). This new state of the forest has created additional urgency in implementing fuel treatments on the landscape.

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Appendix—2

Item A—Key Fire Definitions

Source: ("Fire Terminology" 2017)

Aspect: Direction toward which a slope faces.

Buffer Zones: An area of reduced vegetation that separates wildlands from vulnerable residential or business developments. This barrier is similar to a greenbelt in that it is usually used for another purpose such as agriculture, recreation areas, parks, or golf courses.

Chain: A unit of linear measurement equal to 66 feet.

Control Line: All built or natural fire barriers and treated fire edge used to control a fire.

Crown Fire (Crowning): The movement of fire through the crowns of trees or shrubs more or less independently of the surface fire.

Curing: Drying and browning of herbaceous vegetation or slash.

Defensible Space: An area either natural or manmade where material capable of causing a fire to spread has been treated, cleared, reduced, or changed to act as a barrier between an advancing wildland fire and the loss to life, property, or resources. In practice, "defensible space" is defined as an area a minimum of 30 feet around a structure that is cleared of flammable brush or vegetation.

Environmental Assessment (EA): EAs were authorized by the National Environmental Policy Act (NEPA) of 1969. They are concise, analytical documents prepared with public participation that determine if an Environmental Impact Statement (EIS) is needed for a particular project or action. If an EA determines an EIS is not needed, the EA becomes the document allowing agency compliance with NEPA requirements.

Environmental Impact Statement (EIS): EISs were authorized by the National Environmental Policy Act (NEPA) of 1969. Prepared with public participation, they assist decision makers by providing information, analysis and an array of action alternatives, allowing managers to see the probable effects of decisions on the environment. Generally, EISs are written for large-scale actions or geographical areas.

Extreme Fire Behavior: "Extreme" implies a level of fire behavior characteristics that ordinarily precludes methods of direct control action. One of more of the following is usually involved: high rate of spread, prolific crowning and/or spotting, presence of fire whirls, strong convection column. Predictability is difficult because such fires often exercise some degree of influence on their environment and behave erratically, sometimes dangerously.

Fire Behavior: The manner in which a fire reacts to the influences of fuel, weather and topography.

Fire Break: A natural or constructed barrier used to stop or check fires that may occur, or to provide a control line from which to work.

Fire Intensity: A general term relating to the heat energy released by a fire.

Fire Perimeter: The entire outer edge or boundary of a fire.

Fire Season: 1) Period(s) of the year during which wildland fires are likely to occur, spread, and affect resource values sufficient to warrant organized fire management activities. 2) A legally enacted time during which burning activities are regulated by state or local authority.

Flame Height: The average maximum vertical extension of flames at the leading edge of the fire front. Occasional flashes that rise above the general level of flames are not considered. This distance is less than the flame length if flames are tilted due to wind or slope.

Flame Length: The distance between the flame tip and the midpoint of the flame depth at the base of the flame (generally the ground surface); an indicator of fire intensity.

Fuel: Combustible material. Includes, vegetation, such as grass, leaves, ground litter, plants, shrubs and trees, that feed a fire. (See Surface Fuels.)

Fuel Loading: The amount of fuel present expressed quantitatively in terms of weight of fuel per unit area.

Fuel Reduction: Manipulation, including combustion, or removal of fuels to reduce the likelihood of ignition and/or to lessen potential damage and resistance to control.

Ground Fuel: All combustible materials below the surface litter, including duff, tree or shrub roots, punchy wood, peat, and sawdust, that normally support a glowing combustion without flame.

Hazard Reduction: Any treatment of a hazard that reduces the threat of ignition and fire intensity or rate of spread.

Heavy Fuels: Fuels of large diameter such as snags, logs, large limb wood, that ignite and are consumed more slowly than flash fuels.

Ladder Fuels: Fuels which provide vertical continuity between strata, thereby allowing fire to carry from surface fuels into the crowns of trees or shrubs with relative ease. They help initiate and assure the continuation of crowning.

Litter: Top layer of the forest, scrubland, or grassland floor, directly above the fermentation layer, composed of loose debris of dead sticks, branches, twigs, and recently fallen leaves or needles, little altered in structure by decomposition.

Peak Fire Season: That period of the fire season during which fires are expected to ignite most readily, to burn with greater than average intensity, and to create damages at an unacceptable level.

Prescribed Fire: Any fire ignited by management actions under certain, predetermined conditions to meet specific objectives related to hazardous fuels or habitat improvement. A written, approved prescribed fire plan must exist, and NEPA requirements must be met, prior to ignition.

Prescription: Measurable criteria that define conditions under which a prescribed fire may be ignited, guide selection of appropriate management responses, and indicate other required actions. Prescription criteria may include safety, economic, public health, environmental, geographic, administrative, social, or legal considerations.

Prevention: Activities directed at reducing the incidence of fires, including public education, law enforcement, personal contact, and reduction of fuel hazards.

Rate of Spread: The relative activity of a fire in extending its horizontal dimensions. It is expressed as a rate of increase of the total perimeter of the fire, as rate of forward spread of the fire front, or as rate of increase in area, depending on the intended use of the information. Usually it is expressed in chains (a unit of measure equaling 66 ft) or acres per hour for a specific period in the fire's history.

Slash: Debris left after logging, pruning, thinning or brush cutting; includes logs, chips, bark, branches, stumps and broken understory trees or brush.

Snag: A standing dead tree or part of a dead tree from which at least the smaller branches have fallen.

Suppression: All the work of extinguishing or containing a fire, beginning with its discovery.

Surface Fuels: Loose surface litter on the soil surface, normally consisting of fallen leaves or needles, twigs, bark, cones, and small branches that have not yet decayed enough to lose their identity; also grasses, forbs, low and medium shrubs, tree seedlings, heavier branchwood, downed logs, and stumps interspersed with or partially replacing the litter.

Underburn: A fire that consumes surface fuels but not trees or shrubs.

Wildland Fire: Any non-structure fire, other than prescribed fire, that occurs in the wildland.

Wildland Urban Interface: The line, area or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels.

Section 3—Background

State of the Forest

The Sierra Nevada Mountains are one of the most pristine and resource rich landscapes in California. Starting near Tehachapi Pass, California and extending north to Lassen Peak, the mountain range comprises 25% of California's land area and contains three national parks, two national monuments, and 20 designated wilderness areas (Sierra Nevada Conservancy 2014). The area provides ecological and socioeconomic benefits that are shared locally, statewide, and nationally. The range serves as the primary source of water for the Central Valley's prominent agricultural economy and also provides a source of hydropower for California's energy needs. Over 60% of California's total consumptive water supply originates in the Sierras (Bales et al. 2011; Sierra Nevada Conservancy 2014). Millions of tourists visit the Sierras each year to experience its beautiful landscapes and historic significance.

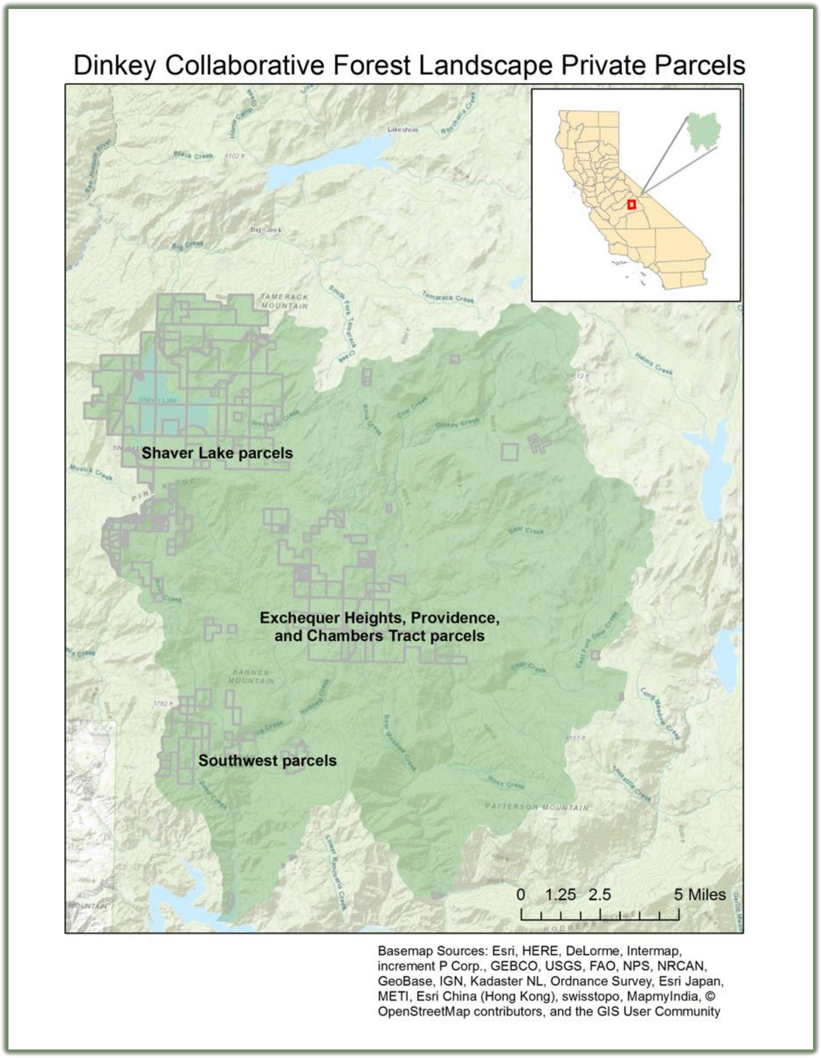
Unfortunately, prolonged drought, historical fire suppression, and bark beetle infestation have caused unprecedented tree mortality throughout the vast range (Pile 2017). The tree mortality event spurred increased attention to the outdated forest management strategy of fire suppression and the potential for catastrophic fire events in the Sierra Nevada range (Pile 2017; Haze, personal communication, May 2017). While fire science still suffers from a dearth of site specific studies and legitimate generalizations, vegetation management strategies such as prescribed burning and fuel thinning, have been shown to have positive impacts on both the ecological characteristics of forest stands and the potential for high intensity fire (Moghaddas et al. 2010; Stephens et al. 2009; Fettig et al. 2006). While these forest management strategies would be beneficial for implementation across the southern Sierra Mountain landscape to improve forest resiliency to environmental stressors, it is critical that fuel treatments are prioritized for implementation on private lands in Wildland-Urban Interface/Intermix (WUI) to protect human populations vulnerable to severe fire.

Figure 3-1. Visible tree mortality above Shaver Lake, CA (photo credit: CalFire 2016).

Study Site

Geographic Setting

This report specifically addresses fuel treatments and fire risk for private lands in three private parcel sections of the Dinkey Collaborative Forest Landscape in the southern Sierra Nevada foothills of eastern Fresno: Shaver Lake; Exchequer Heights, Providence, and Chamber Tract; and dispersed parcels in the southwest quadrant of the landscape (SRCD 2011; "Dinkey Collaborative Charter" 2011).


Dinkey Collaborative Forest Landscape Private Parcels

Basemap Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 3-2. The Dinkey Collaborative Forest Landscape and private parcel areas of interest.

These private lands compose a patchwork of over 24,000 acres interspersed with public lands managed by the United States Forest Service (USFS) (Figure 3-2). Communities cover a range of elevations with parcels in the southwest quadrant of the landscape spanning elevations from 527 meters to just under 1,000 meters. Exchequer Heights, Providence, and Chamber Tract are higher at 1,300 m to over 2,000 m, with the Shaver Lake area achieving a similar range of elevations. The dominant vegetation for Shaver Lake, Exchequer Heights, Providence, and Chamber Tract is comprised of mixed-conifer forest with characteristic tree species of ponderosa pine, white fire, incense cedar, black oak, sugar pine, and Jeffrey pine, whereas the vegetation for the southwest parcels is dominated by hard chaparral and oak savannahs (SRCD 2011; USFS Sierra National Forest Existing Vegetation polygon layer 2016). Pines, specifically ponderosa and sugar pines, were severely impacted by a mortality event that began in 2015 (Pile 2017).

The forests on the Dinkey Landscape comprise part of the San Joaquin and King's River watersheds (SRCD 2011). Waters draining from the forest contribute to regional water supply, irrigation, hydropower, waste disposal, mining, flood control, timber harvest, and recreation activities (SRCD 2011).

Although these private parcels of interest are above, and somewhat removed, from the San Joaquin Valley, they experience the impacts of the Valley's degraded air quality and are subject to the restrictions of the San Joaquin Valley Air Pollution Control District. Air quality in the San Joaquin Valley air basin, consistently exceeds state 24-hour standards for pollution due to particulates $PM_{2.5}$ and PM_{10}. From 2000 to 2013 $PM_{2.5}$ exceeded state standards nearly 50 days each year, and PM_{10} levels – particulates associated with "exceptional events" such as large wildfire – for 2000-2013 exceeded state standards 100 days or more for every year but 2010 (Kusel et al. 2015). Standard emission levels for ozone, another pollutant wildfires can emit, are also consistently exceeded (Kusel et al. 2015).

Dinkey Collaborative Forest Landscape Restoration Project

The Dinkey Landscape Restoration Project, created under the federal Collaborative Forest Landscape Restoration Program, was created with the mission to accelerate forest restoration on the public and private parcels of the identified Dinkey Landscape. The program aims to incorporate the input of diverse landscape stakeholders into directives for restoration efforts that include watershed restoration, species habitat restoration, and fire hazard reduction. The program is currently in its ninth year of its ten-year project lifespan ("Dinkey Collaborative Charter" 2011). Should the program not be renewed, it will still be critical for private landowners to continue with independent fire hazard reduction and restoration efforts while attempting to engage and integrate with USFS efforts on public lands.

Socio-Economic Setting

The private parcels in the Dinkey Landscape are generally small and dispersed, as in the case of Exchequer Heights, Providence, and Chamber Tract and the southwest parcels (Kusel et al. 2015). Shaver Lake is more densely populated, though a greater percentage of the inhabitants are seasonal or temporary residents (Kusel et al. 2015). In Shaver Lake 81% of the homes are occasional, recreational, or seasonal use, and the area's population has decreased since 2000 due to the 2008 economic downturn (Kusel et al. 2015). Population demographics of communities associated with the Dinkey Landscape are primarily white, excepting Cold Springs Rancheria, which is 83.3% American or Alaskan native (Kusel et al. 2015).

Despite it being outside of the bounds of the Dinkey Landscape and the SRCD jurisdiction, the community of Terra Bella is a critical community to consider in a socio-economic overview of the highlighted WUI communities. Terra Bella is home to the Sierra Forest Products Terra Bella mill, is the closest mill to the Dinkey Landscape despite it being over 200 miles away (Kusel et al. 2015). The region's historic timber economy and the necessity for end-of-life disposal for trees killed by the recent mortality and subsequent fuel treatments, links communities in the Dinkey Landscape to that of Terra Bella. Between 2009 and 2014 Sierra Forest Products received 28% of USFS contracts on the Sierra National Forest, and, through doing so, has helped Dinkey Landscape private landowners and the USFS stretch their treatment funds by maintaining bid competition for the contracts precluding non-local firms from gaining unilateral control of the bargaining process. The purchase of timber by Sierra Forest Products helps offset the cost of fuel treatments and the mill is reliant on the Dinkey Landscape for a large portion of their processed timber. Despite this inter-reliance and the local capture of contracts, working with the USFS is considered a complicated process that suffers from limited effective dispersal of contract opportunity announcements to local communities (Kusel et al. 2015).

Capacity exists for the completion of vegetative management work by workers from local communities, especially as many of these communities suffer from limited local employment opportunities with many workers holding seasonal, part-time, or intermittent jobs. The limited employment opportunities have led to the out-migration of young adults from the area. Employment opportunities have not been enhanced by recreation and seasonal homeownership due to a lack of local investment by tourists and second-home owners, and, as such, the recreation industry has not made up for the loss of timber jobs in the area. The Shaver Lake community is an exception on the landscape in that the median household income in this community exceeds the $61,400 median for California (Kusel et al. 2015).

Beyond community concerns over economic opportunity, the communities are also concerned with water shortages and fire risk. Aquifers have dropped, especially in low elevations and below housing developments, which has raised concerns over limited potential for new developments and tensions over water rights and forest management. A perception of limited local firefighting capacity and the risk of severe wildfire has also raised concerns over economic opportunity, as the forest is identified as an essential economic source for the community. This concern has redoubled the efforts of local Native American tribes to become more deeply involved in fuels management as firefighters, fuel treatment monitors, and cultural consultants for the USFS (Kusel et al. 2015).

Drivers and Stressors of Altered Forest Health and Increased Catastrophic Fire Risk

The 2015 tree mortality in the Sierra Nevada is the result of a culmination of environmental stressors that resulted in decreased forest resilience to bark beetle infestation (Pile 2017). Foremost among these stressors is the preceding three years of unprecedented drought, which produced some of the lowest water year precipitation in the observable climate record (Griffin and Anchukaitis 2014). Intense droughts, like the recent one in California, have been linked to extensive tree mortality globally (Williams et al. 2010). The practice of fire suppression has exacerbated the impacts of the recent drought due to fire suppression's tendency to decrease down-slope soil moisture, which, in turn increases susceptibility to drought and bark beetle infestation (Williams et al. 2010; Stevens, Safford, and Latimer 2014). The region has experienced an increase in high severity fires as a result of the cessation of anthropogenic burning by Native Americans at the end of the 1800's (Anderson 2005), the removal of large trees during the height of the railroad expansion (Stephens 2000), fire exclusion activities since the early 1900's (Stephens and Ruth 2005), and the creation of homogeneous forest stands through older vegetative management practices on public lands (Hirt 1996). A combination of fire suppression, drought, and bark beetle infestation has resulted in an unprecedented tree mortality event, with mortality exceeding 100 million trees in the southern and central Sierra Nevada and the delayed impacts beginning to cause widespread mortality in Northern California (Pile 2017; Stevens, Safford, and Latimer 2014). The mortality event has increased the urgency of agencies and individuals to increase pre-emptive wildfire risk reduction in the southern Sierra Nevada foothills.

2011-2017 Drought

While drought in the southwestern United States is a common occurrence, California has recently suffered one of the most severe droughts of the last century (Figure 3-3). This drought is defined by reduced precipitation and record high temperatures resulting in diminished snowpack. The drought has had both ecological and economic impacts as decreased precipitation, record high temperatures, and diminished snowpacks have lowered stream flows and reservoir levels across the state (Griffin and Anchukaitis 2014). Although most of California is no longer officially suffering from drought conditions, climate change is expected to intensify the impacts of drought as extreme droughts more often occur simultaneously with heatwaves (AghaKouchack et al. 2014). Drought, as a driver of inter-tree competition and reduced vegetation moisture, drastically increases the risk of severe wildfire through an increase in dead and low moisture fuels (Williams et al. 2010).

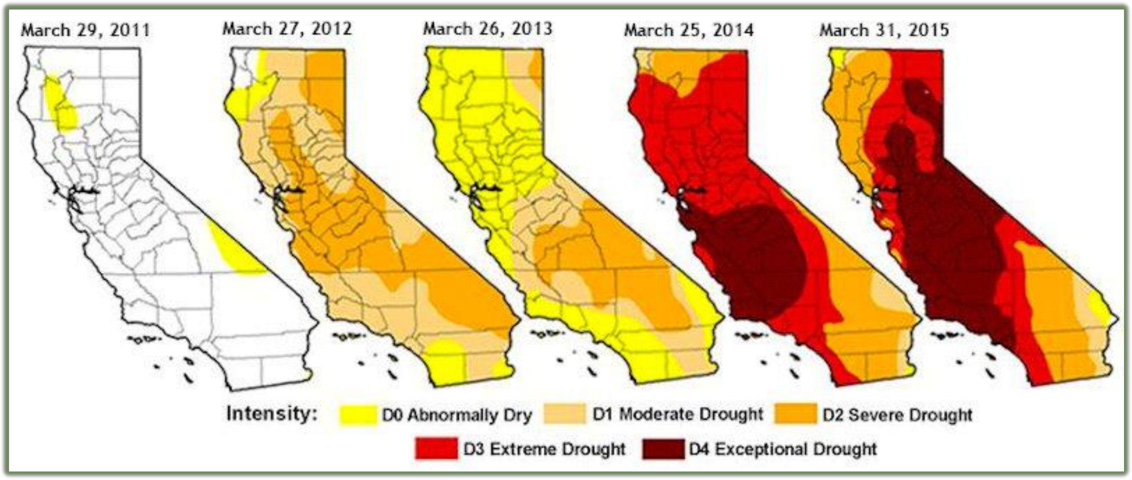


Figure 3-3. California drought 2011-2015 (figure credit: U.S. Drought Monitor).

Fire Suppression

Over the last century federal U.S. policy has been to suppress wildfires to protect communities intermingled or adjacent to forests. Without the disturbance of fire, forest productivity outpaces decomposition, resulting in an accumulation of surface fuel loads (Stephens et al 2009, 2014; Reinhardt et al. 2008). Under this policy of fire suppression and subsequent increases in forest stand density, western forests since the 1900's have become a carbon sink, but catastrophic fires, made possible by the accumulation of surface and ladder fuels, threaten this sink (Hurteau and North 2009). Additionally, fire suppression has allowed for a shift in forest species composition through artificial selection towards species that are not fire adapted, such as white fir, douglas fir, and juniper, while promoting unnaturally dense stands of young trees, which increases competition with large trees for water (Allen et al. 2002). More intense competition between trees, due to overly dense forest stands, decreases forest health and increases tree susceptibility to bark beetle infestation (Fettig et al. 2006). High tree density also increases the susceptibility of Southern Sierra Nevada lower montane forests to drought by reducing stream flows and water down-slope (Allen et al. 2002).

Figure 3-4. USFS fire suppression activities (photo credit: Montana Public Radio).

Beetles

Bark beetles are a diverse group of insects that feed off the phloem tissue of trees and are recognized as the most important agent of mortality in coniferous forests (Fettig et al. 2006). Bark beetles feed on phloem tissue – the primary transport tissue of sugars and nutrients in woody plants – so that tree susceptibility to mortality by bark beetle infestation is the result of drought, inter-tree competition, or a combination of both (Fettig et al. 2006). When adequate moisture is available, trees exude a resin that drowns and expels bark beetles. However, in moisture-limited conditions, moisture stress causes trees to be unable to produce this resin, making them vulnerable to fatal bark beetle infestation (Vité and Wood 1961). Long-term deficiencies in moisture, such as the severe and extended drought in southern California, are correlated with unprecedented bark beetle outbreaks (Fettig et al. 2006). The recent tree mortality has created large swaths of highly flammable dead wood that acts as an efficient ladder fuels, which can transform low-severity wildfires on the ground's surface to high-severity forest canopy fires and has increased the need for fuel reduction treatments across the landscape (A. Hernandez, personal communication, October 19, 2017).

Community Capacity Limitations

The existence of the environmental stressors is exacerbated by the limited capacity with which the communities and the agencies in the region are able to mitigate those stressors. Socio-economic assessments of the communities associated with the Dinkey Landscape have found that the communities lack significant financial, human, social, cultural, and physical capacity that could be critical for mitigating community stressors such as fire risk. These capacity gaps identify a lack of funds, critical experience and capability, social cohesion, and infrastructure to address the mitigation of community stressors (Kusel et al. 2015). While the Dinkey Collaborative Forest Landscape Restoration Program was intended to engage the community to address these environmental stressors, such as fire risk, and provide some of the missing capacity, the projects implemented by the collaborative are heavily weighted towards addressing those issues on primarily public land (Figure 3-5). While many of these projects occur in lands adjacent to private lands as part of the WUI, some

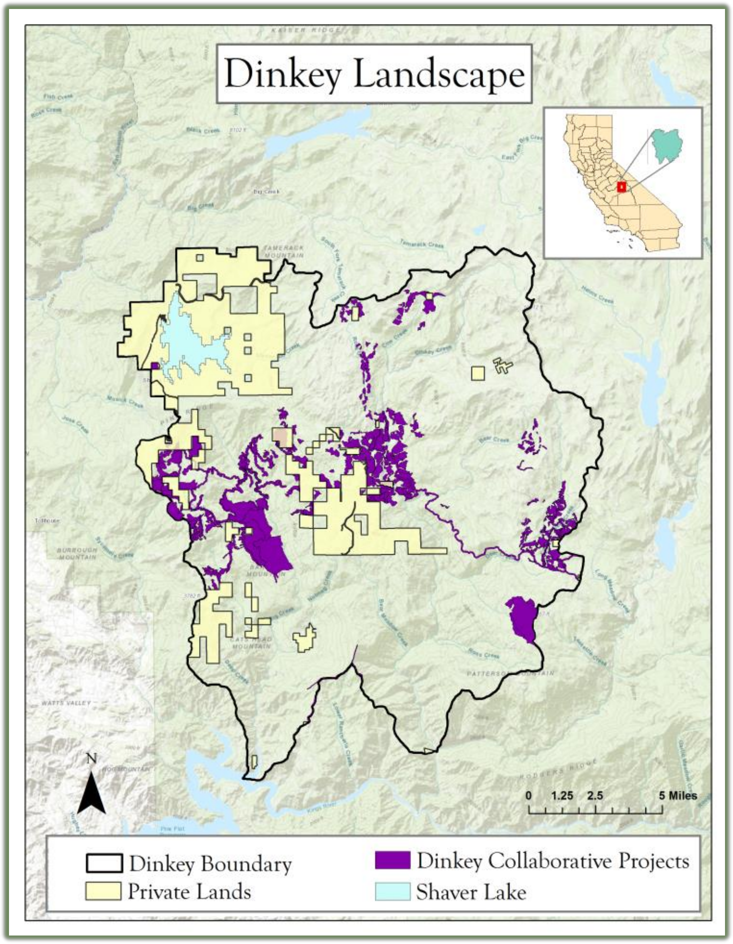


Figure 3-5. Map of forest management practices, including fuel thinning activities, on the Dinkey Landscape, and their coincidence with private lands.

fire behavior studies have shown that, in a checkerboard landscape of treated and untreated lands, fuel treatments will reduce the risk of fire spread for the entirety of the landscape, but untreated areas in close proximity to treated plots will not experience the reductions in fire severity that treated landscapes experience (Moghaddas et al. 2010). Therefore, performing fuel treatments directly on private lands in the WUI is critical.

If the collaborative is discontinued after its 10-year project lifetime, both the Dinkey Landscape communities and the USFS will experience a decrease in financial and human capital for projects that address fire risk reduction. Over the past 20 years the portion of the USFS budget that funds fire suppression efforts has been growing. By 2025 it is projected that 67% of the USFS budget could be devoted to fire suppression activities (Figure 3-6).

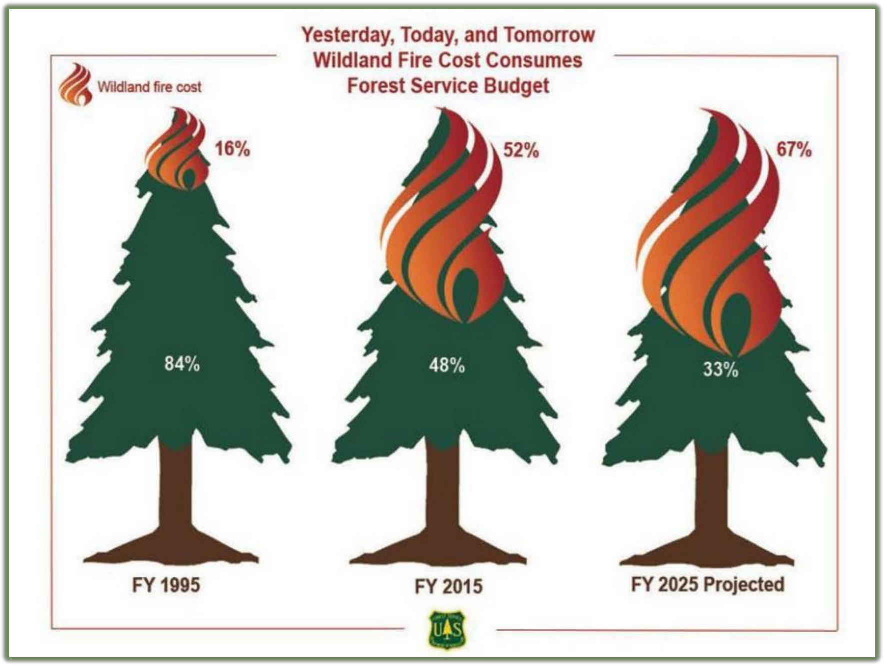


Figure 3-6._The rising costs of wildland fire in the USFS budget (figure credit: USFS 2015).

This allocation of funds not only causes reductions on the order of $700 million for USFS non-fire programs, but also severely decreases funding that could be allocated toward pre-emptive fire hazard reduction (USFS 2015). Without the funding and the structure of the Dinkey Collaborative, fire risk mitigation work could be heavily curtailed. The funding structure of the USFS and the potential end to an important collaborative body for forest management in the region lend more urgency to the need for private landowners to engage with fire risk mitigation strategies by employing fuel treatments on their own private lands.

Fuel Management Strategies

Prescribed Burning

Controlled burning is widely recognized as the most effective fuel treatment to reduce surface fuels (North et al. 2009) and the potential for crown fires and tree mortality due to wildfire (Stephens et al. 2009). Additionally, prescribed burns have been found to successfully reduce overall stand density. Burns performed in the Sequoia and King's Canyon National Park found that, five years after a prescribed burn, stand density was reduced by 61%, mostly through the mortality of smaller trees, successfully recreating forest densities similar to pre-European conditions (Keifer et al. 2000). Not only do prescribed burns reduce stand density, but they also reduce vertical continuity of live and dead fuels and can reduce overstory trees, allowing for increased growing space in the understory (Collins et al. 2007). Because of species adaptations to specific fire regimes, prescribed burning can help reestablish historical species compositions while eliminating undesirable species (North et al. 2009; Certini 2005). Prescribed burns have, however, been found to reduce native species richness, while maintaining overall native species percent cover (Collins et al. 2007). Impacts to water quality are considered to be minimal following prescribed burns, whereas soil health and water supply are typically nominally or positively impacted. Prescribed burns expose mineral soil and produce short-term soil nutrient spikes, which stimulates native pine growth (Stephens et al. 2012; Boerner et al. 2009; Hurteau and North 2009). Controlled burns also tend to improve soil penetration of precipitation, delay and prolong the release of snowmelt, and reduce evapotranspiration, increasing overall water supply (Remucal et al. 2017).

Both public officials and private landowners are legally allowed to perform a prescribed burn. For private citizens, it is required that the private landowner obtain a permit prior to burning. The permit fee covers the services of a CalFire representative who inspects the proposed burn plan and location (D. Dolezal, personal communication, October 9, 2017). Treatment is only permitted on legal burn days as determined by the San Joaquin Valley Unified Air Pollution Control District regulations (S. Haze, personal communication, May 19, 2017). In many locations prescribed burns alone may be sufficient to restore natural conditions, however, the high density forest conditions on the Sierra National Forest may preclude the safe use of prescribed burn on private lands for fuel reduction without some form of pre-treatment thinning (Allen et al. 2002).

Figure 3-7. Prescribed burning treatment in Yosemite National Park (photo credit: PBS 2015).

Mechanical Thinning

Mechanical thinning, at its core, is a vegetation management strategy that uses machines to reduce stand density by thinning surface, ladder, and canopy fuels. For the purposes of this analysis, mechanical thinning includes thinning from below to reduce stand density using cut-to-length machinery and feller-bunchers to remove small trees and ladder fuels (Figure 3-8). In situations where prescribed fire is unsafe, thinning allows managers to reduce fuel loads so that controlled burns are more containable, while increasing forest resiliency to wildfire (Stevens, Safford, and Latimer 2014). Thinning, unlike controlled burns, gives forest managers the ability to select for desirable species while removing non-fire resistant species such as white fir, Douglas-fir, and juniper (Allen et al. 2002). Mechanical thinning has been shown to significantly reduce tree density by targeting certain size classes – typically small trees of <25 inches DBH – for removal (Collins et al. 2007). Additionally, canopy and overstory trees can be thinned or removed to increase growing space in the understory (Collins et al. 2007) and to reduce the potential for severe crown fires (Pollet and Omi 2002). Although mechanical thinning can produce benefits through the reduction of fire intensity or spread, many mechanical thinning strategies, can create undesirable surface fuel loads through the production of slash or masticated material that either require additional treatment or increase short-term fuel loading (Busse et al. 2014).

Figure 3-8. Mechanical treatment by feller-buncher (photo credit: USFS Yeti Fuels Reduction Project).

Additionally, mechanical thinning has the potential to negatively affect soil health through compaction, erosion, and disturbance that allow for invasive species recruitment (Keifer et al. 2000; Busse et al. 2014; Dyrness 1965; Steinbrenner and Gessel 1955). While mechanical thinning can increase water supply on the watershed scale and decrease water stress by reducing competition between trees, water quality may be negatively impacted by increased erosion and sedimentation (North et al. 2009; Remucal et al. 2017).

Hand Thinning

Hand thinning – brush and tree removal using hand crews and chainsaws – while far less impactful to soil and riparian health than mechanical thinning, it is also less efficient than mechanical treatments or prescribed burns (North et al. 2015). Hand thinning can be performed on more land area of the landscape than mechanical thinning because of the slope restrictions that impede the use of heavy machinery, but the rate of thinning and the man-hours required for hand-thinning severely limits the amount of land over which hand-thinning can take place in a reasonable time-frame.

Pile Burning

Pile burning is a treatment strategy used in conjunction with many forms of thinning treatments. In this treatment strategy, post-thinning slash and small trees are piled by hand or machine and left to cure for at least six weeks prior to burning when conditions allow (De Lasaux and Kocher 2006). While pile burning is an effective method of surface fuel removal following a fuel treatment, it can have mixed impacts on soil health. Some of these impacts are also experienced when treating with prescribed burns, however, while pile burning has the potential to burn hotter and longer than prescribed burns, the negative impacts of pile burning on erosion and water repellency are offset by their mosaic distribution across the landscape (Imeson et al. 1992). In the Sierras, it was found that pile burning caused extreme heating of the soil if logs greater than 8.5 inches made up the majority of the pile (Hubbert et al. 2013). This extreme heating was limited to the top 4 inches of soil, but was still capable of killing seed banks and allowing for invasive species colonization (Beadle 1940; Busse 2014; Korb et al. 2004; Wolfson et al. 2005). These high temperatures could also cause a decrease in microbial biomass and soil aggregate stability, however the "ash-bed" effect of the burning causes a release of nutrients that increases soil fertility (Badía and Martí 2003; Guerrero et al. 2005; Glass et al. 2008).

Figure 3-9. Slash wood pile burns (photo credit: Coalition for the Upper South Platte 2015).

The treatment, as a type of burn treatment, does release CO_2, when burn temperatures exceed 200 degrees C, however, the amount of CO_2 emissions is difficult to quantify given the varying conditions under which pile burning is performed (Johnson et al. 2004). Alternative slash disposal strategies, such as chipping or biochar have the potential to reduce this carbon output when such strategies become financially and logistically viable on the landscape for use in place of pile burning. Pile burning's impact on water yield, when divorced from the thinning treatments that precede it, are unlikely to be significant, however, buffers of 23-50 meters around streams are recommended to reduce pile burning's impact on water quality (Hubbert et al. 2013).

Private landowners in the Sierra foothills are permitted to create burn piles four feet in diameter by four feet in height excluding any wood over 12 inches in diameter (De Lasaux and Kocher 2006; CalFire). Private landowners must adhere to burn day regulations from the San Joaquin Valley Air Pollution Control District. Air Quality (J. McBougald, personal communication, 27 October 2017). However, private lands in the Dinkey Landscape currently house thousands of piles comprised of logs greater than the diameter permitted for pile burning. These piles, and the fire risk they pose, are a source of significant concern for local landowners (R. Evans, personal communication, February 12, 2018).

Prescribed Burning Post Thinning

Fuel treatments that combine mechanical thinning and prescribed burns are the most effective at reducing the potential for severe fires (Stephens et al. 2009). This treatment can reduce competition and density in trees stands while promoting growth of tree stands that were thinned prior to prescribed burning. Prior to natural fire events, stands treated using this strategy have been shown to have lower tree cover than untreated areas, however, post-wildfire, the treated areas retain more of their tree cover than untreated lands (Stevens et al. 2014). This indicates the treated lands are more resilient to fire. Although this strategy creates an immediate disturbance to the ecosystem, it has been recorded that there are minimal impacts to songbirds and small mammals, however California spotted owls can experience a decline post-treatment (Stephens et al. 2014).

Additionally, since this treatment is a burn treatment, there are still short-term impacts on soil health and carbon storage. The treatment, because it is paired with mechanical thinning, still produces potentially negative impacts on erosion that could be substantial as the standing dead wood that typically remains post-fire and stabilizes soils would have been minimized by the pre-burn thinning (Stephens et al. 2009). The treatment's impacts on water yield and quality are similar to those of thinning and prescribed burn separately (Remucal et al. 2017).

While this treatment may be effective in reducing high severity fire risk, as prescribed burning post-mechanical thinning is generally successful in meeting short-term fuel reduction objectives (Stephens et al. 2012), the treatment is labor intensive, requires technical knowledge, and has costs that are highly variable (Reinhardt et al. 2008).

Reforestation

While seemingly counterintuitive for a landscape with excessive fuel loads, forest thinning coupled with reforestation enables faster establishment of desired forest conditions by shortening the timeframe for recruitment of desirable, fire-adapted species and enabling lower-severity fire regimes. As of December 2017, the Dinkey Collaborative completed work on a reforestation framework both in response to the catastrophic loss of trees and species diversity from the 2015 mortality event, and building off of ongoing forest thinning and prescribed fires. While the current efforts to manage fuel loading on the landscape are aimed at reducing abundance of shade-tolerant species such as white fir and incense cedar, high levels of competition with other undergrowth such as shrubs makes new pine recruitment difficult and slow. This delay in, or lack of, recruitment of more desirable, fire-resistant species such as ponderosa, sugar, and lodgepole pines has resulted in an overall loss of reproductively mature pine species across the landscape. Coupled with continued stress on remaining trees from prolonged drought conditions and high susceptibility to bark beetle attack, reforestation is now recognized as a necessary component to pair with fuel reductions to reduce the loss of target tree species in the future. The desired current and future conditions identified by the Dinkey Collaborative for forest stands on public lands is to better manage species composition by favoring pines, creating more fire resilient stands, and improving overall heterogeneity across a 1-2 acre scale through site-specific and stakeholder-informed restoration.

Under the Dinkey Collaborative reforestation framework, reforestation objectives fall into two main categories: short-term (stand age 20 -100) and long-term (stand age 20) desired conditions (specific approaches for achieving short-and long-term objectives identified by the Dinkey Collaborative reforestation framework are detailed in Appendix 3, Item A). Long-term desired conditions characterize the typical climax community of heterogeneous forests that existed pre-settlement: fire-adapted, demographic complexity in terms of age and species composition, and structural complexity in terms of vertical and horizontal patchiness – conditions which result in a larger diversity of habitats. Ideal composition would focus on mixed conifer and ponderosa pine communities, interspersed black oaks, and small patches of understory shrubs, herbs, and grasses occurring between canopy gaps. Conversely, short-term desired conditions act as catalyst that propels the natural seral community succession on a trajectory to eventually reach the climax community described in the long-term objective. Using the Big Creek Project as a reference baseline, short-term reforestation focuses on introduction of displaced pine species such as ponderosa and sugar pines through a combination of direct planting and natural recruitment as well as alleviating resource competition. Artificial creation of gaps in concert with fuel reductions increases resource availability within the area for priority species, edges out shade-tolerant species such as white firs and incense cedars, and actively manages encroachment by fast-growing shrubs. Temporary fire suppression in planting sites would serve to allow enhanced pine growth without disturbance, until such a point that either a natural, low-severity fire regime can be restored and/or prescribed burning can be used for continued maintenance.

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Appendix—3

Item A: Dinkey CFLRP Restoration Plan Approaches to Achieving Short- and Long-term Objectives

Six potential approaches to achieving the key objectives are identified in the Dinkey CFLRP restoration framework:

1. Species Composition
    a. Strategic seed/sapling selection focused on rare and displaced species
    b. Preference for local seed/sapling sources to retain genotypic diversity
    c. Identification of additional sources offsite to supplement rare seed/sapling scarcity
    d. Introduction of stock from more resilient stands to improve disturbance response
2. Fuel Loading and Continuity
    a. Maintain fuel loads at less than 10-20 tons/acre in reforested areas
    b. Conduct prescribed burning in the fall while seedlings are dormant
    c. Maintain shrub coverage at 15% or less for planting sites 5 years old or less
    d. Maintain shrub coverage at 30% or less for planting sites 25-35 years old
    e. Consider prescribed burning as pre-treatment before planning where possible
3. Heterogeneity and Tree Spacing
    a. Build upon natural heterogeneity created by fire, insects, and natural regeneration
    b. Utilize cluster planting with spacing of 10-20 ft. apart, depending on fuel objectives
    c. Aim for crown closure 35-45 years after planting depending on rate of growth
    d. Where financially feasible, plant in multiples to offset natural seedling mortality
4. Sequence and Timing
    a. Site preparation should occur within 5 years after disturbance
    b. Use manual treatment (e.g. hoeing) for brush clearance 3-5 years after planting
    c. If feasible, use prescribed burns for brush clearance 6-10 years after planting
    d. If feasible, conduct prescribed burns in fall or winter during seedling dormancy
    e. Build upon existing natural regeneration and couple with thinning, piling, and pruning
5. Stand Development
    a. In planting sites, allow grasses and forbs to dominate for the first 5-10 years
    b. Continue fuel reduction for 5-10 years to prevent shrub encroachment
    c. Maintain the stand initiation phase for 35-50 years with widely spaced plantings
6. Variation in Short-Term Desired Condition by Land Management Emphasis
    a. Plantings must be designed to accommodate strategic fire management goals
    b. Planting design should maximize space between plantings to limit competition
    c. Underburning or thinning should occur no later than 20-25 years after planting
    d. If underburning, limit mortality to planted/natural seedlings to less than 15%

The framework further outlines common and uncommon reforestation methods for integration with the six approaches, such as different types of releasing competition and a variety of ways to remove undesirable brush. Regardless of approach or execution method, safety and fuel loading are recognized as the main limiting factors of where and when to plant.

Section 4—Fuel and Fire Behavior Modeling

Methodology

General Methodology

On the ground tree surveys were conducted by the USFS for the public forest lands adjacent to private parcels in the Dinkey Landscape. The data from these tree surveys were used in FVS to compute and simulate how fuel treatments will affect tree, vegetation, and fuel characteristics of the landscape will change through time. Tree regrowth, recruitment, and mortality are simulated by FVS. Decomposition and size classes of downed trees is also simulated. The simulated composition of live and dead vegetation is calculated and classified as one of 53 types of fuel loads. the Forest Vegetation Simulator (FVS), a vegetation model currently used by the USFS to plan and explore fuel reduction options. FVS generates a fuel profile based on the simulated fuel treatments and forest regrowth for every year following the simulated treatment. The fuel profile generated by FVS serves as the input data for the fire behavior model FlamMap, which is a tool used by the USFS to explore the behavior of fire on the landscape as an average of a specified number of stochastically seeded fires. FlamMap produces outputs of conditional flame lengths – a measure of fire severity under the condition that an ignition source exists. The conditional flame length outputs were mapped using ArcMap (v.10.4.1) via the ArcFuels package, to assess how fuel treatments impact landscape-level fire severity.

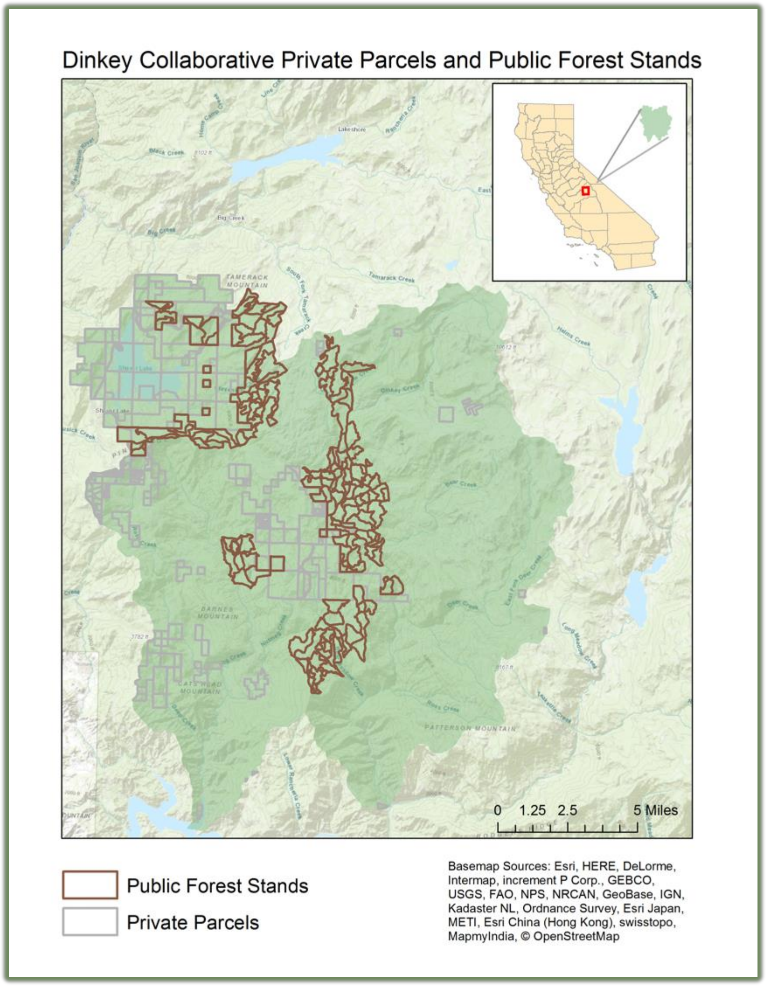


Figure 4-1. The Dinkey Collaborative Forest Landscape public forest stands on which fuel and fire behavior models were run and the private parcels to which the fire severity outputs were translated.

Fuel profiles and subsequent fire behavior were explored under four fuel treatment scenarios: a no treatment scenario, two treatment scenarios that simulated the thinning of the entire private parcel landscape to a certain density of trees, and a prioritized treatment scenario that simulated thinning on just select prioritized private parcels. The data required to perform this fuel and fire modeling was available only for forest stands on the public lands of the Dinkey Landscape. To assess the impacts of vegetation management and subsequent fire behavior on adjacent private parcels the data applicable to fire behavior that was available for both public and private lands was used to crosswalk the fire severity outputs from public forest stands to those on the nearby private parcels (Figure 4-1). Fire severity projections from private lands were used in conjunction with a fuel treatment location feasibility analysis to prioritize private parcels that could achieve the fire risk reduction at low relative cost.

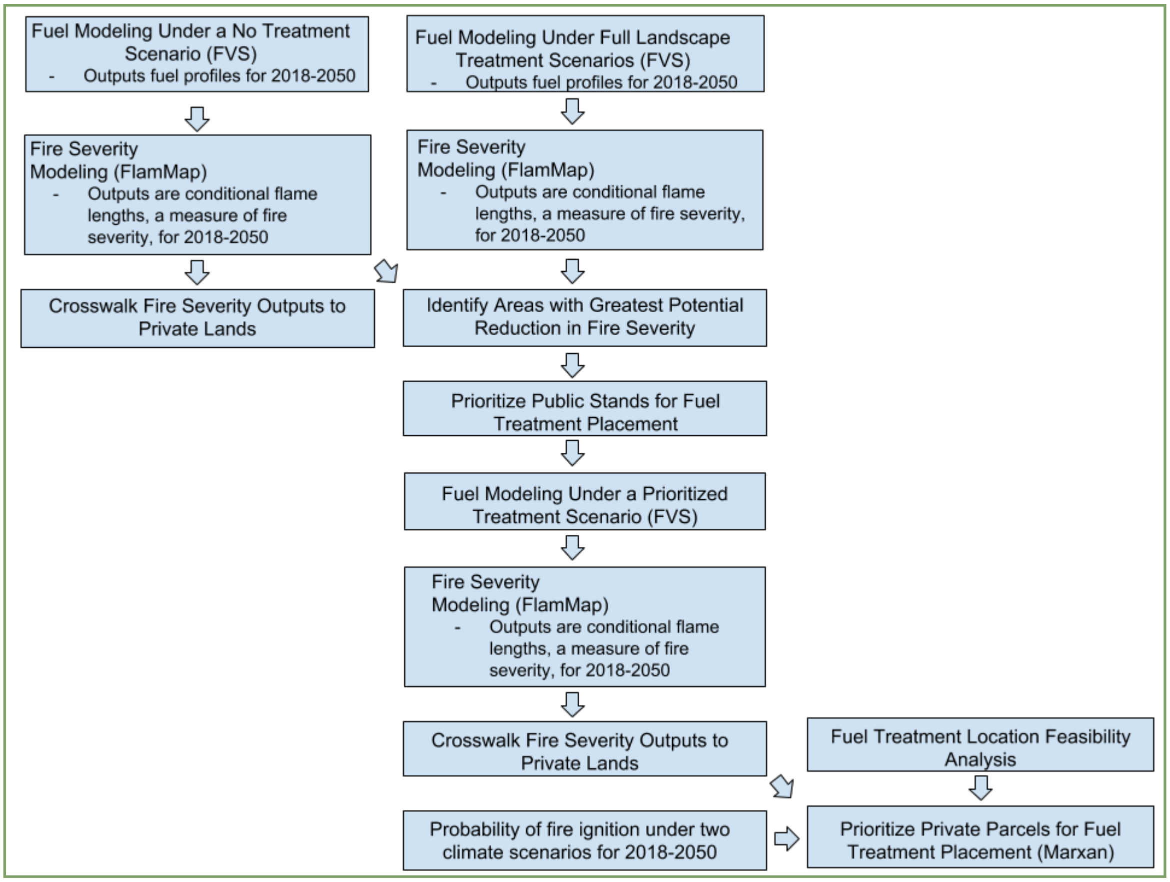


Figure 4-2. Fuel and fire modeling methodology workflow.

FVS Simulated Fuel Reduction Treatments

Public tree stand data compatible with the USFS Forest Vegetation Simulation (FVS) was provided for the Dinkey Landscape tree stands adjacent to private parcels of interest from the USFS High Sierra District. Fuel treatments – a combination of brush and tree thinning and pile burning – were simulated in FVS using the Western Sierra Nevada variant. Four cycles of fuel treatments were simulated, with treatment occurring every ten years. The combination of brush and tree thinning and pile burning was chosen as the primary vegetative management strategy to assess because it is one of the more effective and cost-efficient methods of reducing fuel loads across a large landscape on which prescribed burning is not safely applicable. The simulated treatments most closely resemble fuel reductions which employ mechanical thinning. This is because, although the fuel reduction capabilities of hand thinning are similar to that of mechanical thinning, the timestep with which fuel reductions were modeled – all fuel treatments were modeled to occur during a single year – would only be feasible using mechanical treatment. The targeted intensities and types of biomass for removal are described in detail below. The results of the fire behavior modeling under mechanical thinning and pile burning thusly informs fire behavior under a hand-thinning scenario, as the effect would be similar, though the timeframes are quite different. While prescribed burning could be employed at lower cost over a larger landscape, the high tree densities of the forest would likely preclude the safe use of prescribed fire without first employing a thinning treatment. Thinning and pile burning thus presents the most feasible fuel treatment option for initial fire behavior modeling.

FVS Inputs

Fuel Moisture: 90th-97th percentile fuel moisture levels were used for 1 hr, 10 hr, 100 hr, 1,000 hr, herbaceous, and woody fuel moistures. These values were sourced from FireFamily Plus (v.4.1) – a tool used by the USFS to inform weather inputs for FVS – from data collected at the Fence Meadow Weather Station (Station ID: 044503, Lat: 36.96667, Long: -119.18333). During the period from 2000-2016 (2000 being the first year the weather station began collecting fuel moisture data year-round) 90th-97th percentile fuel moisture conditions were found to occur for an average of 87.6 days, or 24% of the year. Year-round fuel moisture data was used because the California fire season is, and is expected to lengthen from the historical fire season.

Wind Speed and Direction: Prevailing wind directions and average wind speeds were determined from data collected at the Fence Meadow Weather Station and analyzed through Fire Family Plus. The prevailing wind direction was West with a speed of 10 mph.

Fuel Model: This analysis used FVS fuel model 53.

Mortality Adjustment: Tree stand data provided by the USFS pre-dated the 2015 tree mortality event, so the tree stand data were adjusted to reflect the impacts of the mortality event prior to simulating fuel treatments. The tree stands were adjusted to account for the mortality event using a methodology created by Ramiro Rojas of the UFSF who adjusted recent satellite imagery using ground-truthed stand-level surveys to develop a FVS mortality adjustment for the event. See Appendix 4, Item B for additional details on the mortality adjustment methodology.

Regeneration Parameters: An FVS kcp file was created to randomize the regeneration of major tree species in the study stands to override the default regeneration, which limited regeneration primarily to oak species and shrubs. The kcp file used in the regrowth simulations allowed only for regeneration of species in a plot if the species was present in the starting conditions of the stand and the species ratio for regeneration was based on a weighted average of the basal area of the existing vegetation following the fuel treatment. The file is coded such that 75 seeds per stand are proportioned out by basal area of existing tree species following treatment with 100% of those seeds surviving to maturity at 5 years ("Restoration Framework," 2017). FVS default heights of trees at age of maturity were used, and seedlings were dispersed preferentially in areas of less overstory, more overstory, or uniformly across the landscape depending on species shade tolerance or intolerance.

Black Oak: Less overstory
Sugar Pine: Less overstory
Dogwood: Less overstory
Incense Cedar: More overstory
Ponderosa Pine: Less overstory
Lodgepole Pine: Less overstory
White Fir: More overstory
Jeffery Pine: Less overstory
Other Hardwoods: Uniform distribution
Red Fir: Less overstory

Treatment Scenarios

No Treatment:

Under the no treatment scenario, tree stand regrowth simulations in FVS were allowed to grow undisturbed except for the mortality adjustment made in 2016. Output files were generated through 2050.

Full Landscape Treatment:

For the full landscape treatment scenarios, tree stands were updated for the mortality event in 2016 and thinning treatments were performed every 10 years (2018, 2028, 2038, and 2048). Thinning was followed by a fuel move in the same year of all materials greater than 12 inches in diameter and a pile burn in the year following the thinning treatment of all materials less than 12 inches in diameter.

The thinning target chosen for simulation in FVS was based on stand density index (SDI). The target stand density index was determined to be 260, a historical SDI from conditions in 1935, early in the fire suppression era (Harrod et al. 1999). This stand density index falls within the range that is prescribed for limited tree mortality by bark beetle, wherein an SDI of 230 allows for endemic bark beetle populations to cause the mortality of some trees while overall growth remains positive and an SDI of 365 is the limiting SDI for high mortality from bark beetle infestation (North 2012). The SDI_{max} for mixed-conifer forests is 550, however, many of the forest stands on the Dinkey Landscape exceed this SDI (Long & Shaw 2012). Because of the intensity of thinning that would be necessary to reduce current tree stands to an SDI of 260 an additional full landscape treatment simulation was performed with a target SDI of 300. The efficiency level for the thinning treatment was maintained at the default: 90% efficiency.

The simulated thinning treatment preferentially removed all woody material in the size class 2-12 inches DBH first, followed by 12-24 inches DBH, and finally 24^+ inches DBH to achieve the SDI target of 260 or 300. Thinning was also preferentially performed by tree species. White fir, incense cedar, and dogwood were preferentially removed while ponderosa pines, lodgepole pines, jeffrey pines, sugar pines, giant sequoias, black oaks, and other hardwoods were preferentially maintained. These species preferences were based off species fire resiliency characteristic and preferences indicated in Dinkey Landscape restoration and long-term plan documentation. Output files were generated through 2050.

Priority Treatment:

Following the treatment and regrowth simulations of the no treatment and full landscape treatment scenarios in FVS and fire severity modeling in FlamMap the stands that experienced the greatest potential reduction in flame length due to treatment were prioritized for treatment simulations in FVS. The potential reduction in flame length per forest stand was found using the cell statistics tool in ArcMap to subtract each pixel conditional flame length value (the fire severity metric output from FlamMap) generated under the 300 SDI treatment scenario from the conditional flame length value generated under a no treatment scenario. The raster calculator tool was then used to multiply the reduction in conditional flame length by a probability of ignition – developed by Mann et al. 2016 – under two climate scenarios to find the potential reduction in fire severity per pixel. To find the per stand potential reduction in fire severity, the zonal statistics tool was used to find the average potential reduction in fire severity per public tree stand. The reductions mean potential reduction in fire severity was then separated into quantiles and the stands in the upper quantile of potential fire severity reduction were identified for prioritized fuel treatments. A sensitivity analysis of the percentage of landscape treated was also performed by decreasing the number of treated parcels in the prioritized treatment scenario to 15% (4,035 acres) of the landscape and 10% (2,690 acres) of the landscape.

FlamMap Fire Severity Modeling

FlamMap, a fire behavior model that uses fuel profiles generated by FVS to assess average fire behavior across multiple random fire simulations, was used to seed 1,000 random fires with a maximum burn time of 900 minutes for each year following simulated fuel treatments, such that fires were simulated in years 2018-2050. The FlamMap parameters of 1,000 random fires with a 900 minute maximum burn time were the same as those employed by Moghaddas et al. 2010. See Appendix 4, Item C for a comparison of fire severity results from FlamMap models using 1,000 simulated fires versus FlamMap models using 10,000 simulated fires.

FlamMap models the 1,000 random fire starts such that the fire spreads stochastically across the landscape using the inputs of wind speed and direction to produce conditional flame lengths for the landscape to model how simulated fuel treatments impact fire severity during any given year in the regrowth interval between fuel treatments. The Arcfuels package allows for the mapping of the conditional flame length outputs to produce a weighted average of conditional flame lengths per pixel across the randomized fire runs. These conditional flame lengths were then binned into six severity categories defined by Scott et al. 2013 to categorize the simulated fires by their severity for ease of interpretation between the scenarios (no treatment, full landscape treatment, and prioritized treatment).

FlamMap was used to model fire behavior under the no treatment scenario, the full landscape treatment scenarios – with thinning targets of SDI 260 and SDI 300 – and the prioritized treatment scenario, which treated only a subset of the landscape. Additionally, sensitivity analyses were performed explore the impacts of both moderate – 7 mph – and extreme wind speeds – 20 mph – on fire behavior (wind speeds were based off of values from Fire Family Plus).

Fire Severity Categorization

Fire severity is defined by the conditional flame length, with high severity fires categorized as conditional flame lengths of 8ft. or greater, medium severity fires as conditional flame lengths of 4ft.-8ft., and low severity fires defined as conditional flame lengths of 0ft.-4ft. These fire severity categories were determined by fire suppression cost (Buckley et al. 2014) and private parcel damage metrics associated with the conditional flame length ranges; metrics previously determined by a southern Sierra Nevada Mountains study by Thompson et al. 2016 (Figure 4-3). The percent property damage due to different fire severities will be used extensively in the cost-benefit analyses of private land fuel treatments in Section 5.

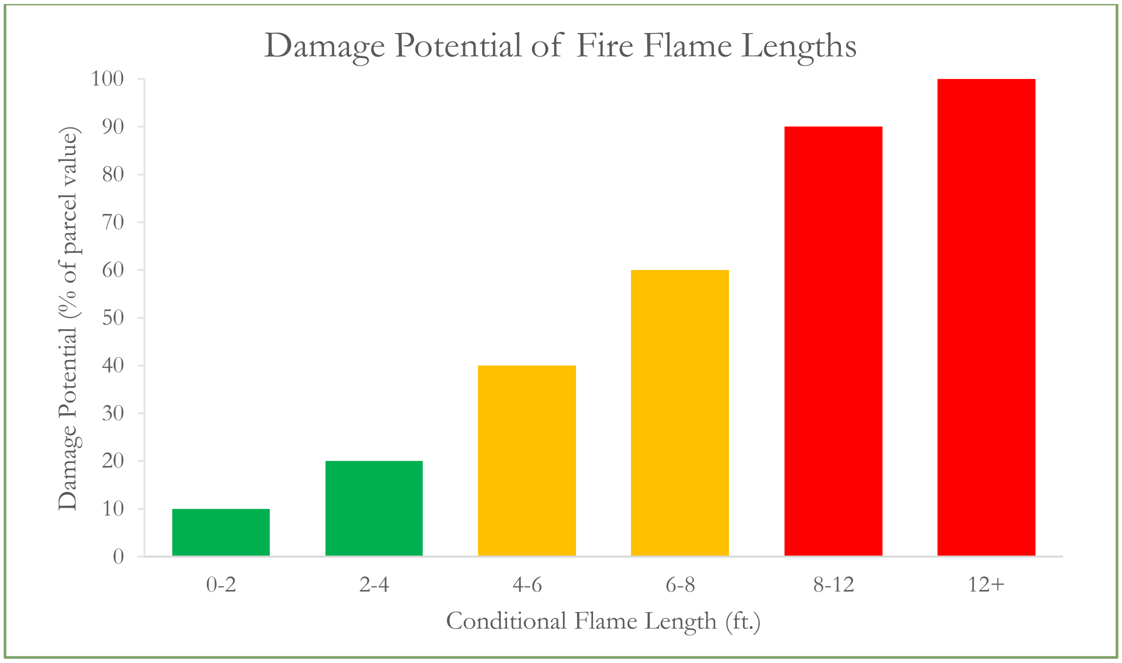


Figure 4-3. Conditional flame lengths grouped by fire severity (green indicates low severity fire, yellow severity, and red high severity fire) and graphed by the potential percent loss of private parcel value to moderate density human habitation the flame lengths can cause (data from Thompson et al. 2016).

Data Analysis

Conditional flame lengths across the treatment scenarios were analyzed in R. As the dataset for each scenario was very large, with almost 70,000 data points, there was a risk of over inflating the significance of statistical results with false positives. Therefore, for each treatment conditional flame length data was subset to a random sample of 2,000 pixels in which fires had spread in each year of the modeling to facilitate further analysis. The probability distribution of conditional flame length across the landscape were compared for each treatment scenario. T-tests were run to determine if reductions in flame length from the no treatment scenario to the prioritized treatment, SDI 260 treatment, and SDI 300 treatment were significantly greater than zero. T-tests were also used to determine if the conditional flame length distributions for successive years of a treatment cycle differed and shifted higher over time as regrowth occurred. Additionally, as there is concern amongst private landowners over the prevalence of large wood piles on the landscape, a t-test was used to determine if conditional flame lengths generated by slash piles from treatments during the all landscape treatment scenario differed from the conditional flame lengths generated under the no treatment scenario. An alpha level of 0.05 was used for all significance tests.

Crosswalk From Public Fire Severity Outputs to Private Fire Severity Outputs

Simulations of thinning treatments, fuel moves, and pile burning, and subsequent simulated fires were all performed using data from public lands. The stand-level data required as an input to FVS are not available for private lands due to the in-depth and extensive sampling techniques necessary in gathering this data and private landowners' general dislike of allowing public monitoring on their private lands. To crosswalk the fire severity results from the public to the private lands regression analysis was used to quantify the relationships between fire severity and defining vegetation and topographic landscape characteristics that are known to impact fire behavior and that are available for private lands. The regression analysis allowed for fire risk outputs generated for the public lands to be transmuted to a fire risk profile for private lands.

The defining characteristics that may impact fire behavior – characteristics with data that were available for both public and private lands – were determined via literature review and a census of available private lands data to be elevation, slope, aspect, dominant vegetation type, and NDVI. DEM layers sourced from USGS Landsat imagery were used to generate elevation, slope, and aspect rasters. An NDVI raster was created using Google Earth Engine and data from the Sentinel-2 satellite. Vegetation layers were sourced from CalVeg under the USFS. These five characteristics were identified on a pixel-by-pixel basis (30 meters by 30 meters) for the public parcels. An ordinal logistic regression was used to establish a relationship between the five characteristics and the conditional flame length outputs generated by the fire behavior model during the initial no treatment model scenario. The ordinal logistic regression was then applied to the values for the five characteristics gathered on a pixel-by-pixel basis from the private parcels to predict estimated conditional flame length values for private lands. Private parcels were paired with a comparable public stand by finding the closest numerical match between the predicted conditional flame length value for the private parcel and the model-generated conditional flame length value for the public forest stand. These pairings were then used to predict the conditional flame lengths for private parcels generated during all model runs (years and types of treatment) from the model outputs for public stands under those scenarios.

Fuel Treatment Placement Feasibility

Esri ArcMap (10.5.1) was used to explore what percentage of the private lands could be treated using each form of common vegetative management strategy – mechanical thinning and pile burning, hand thinning and pile burning, and prescribed burning. The primary topographical, ecological, and infrastructure constraints that impact fuel treatment feasibility are: slope, California spotted owl protected activity centers (PACs), proximity to streams, and distance to roads. The constraints follow USFS guidelines as written in the methodologies employed in academic papers by North et al. 2015 and through communication with USFS contacts.

Slope constrains the implementation of hand thinning and mechanical thinning, with slopes <50% feasible for treatment using both techniques, but with slopes greater than 35% being considerably more expensive and potentially more damaging to soils than slopes below 35% (North et al. 2015; Remucal et al. 2017; Skog and Barbour 2006). Prescribed burning can take place on any slope (A. Hernandez, personal communication, October 19, 2017). Fuel treatment constraints related to spotted owls PACs are also specific to hand and mechanical thinning. Both thinning treatments should buffer PACs by 152.4 meters (500 ft), whereas prescribed burns are not constrained (North et al. 2015; "Draft Interim Recommendations" 2015). The heavy machinery associated with mechanical thinning can degrade stream and riparian habitats, so mechanical thinning is restricted from streambanks. The recommended exclusion zones for mechanical treatments by streams are somewhat variable, but, in keeping with USFS guidelines, a small buffer of 30.48 meters (100 ft) was used (North et al. 2015). All treatments, however, are typically limited to implementation within 304.8 meters (1,000 ft) of a road (North et al. 2015; A. Hernandez, personal communication, October 19, 2017). For thinning treatments, treatment areas must be close to established roads to reduce the impact on soils during biomass removal (Agee and Skinner 2005). For prescribed burns, roads are used as fuel breaks and as access to monitor the burn (A. Hernandez, personal communication, October 19, 2017).

These identified constraints are accounted for in the mapping of feasible treatment locations. Treatments were assessed individually – mechanical treatment, hand thinning, and prescribed burning. A DEM layer was obtained from the USGS and used to apply the slope constraints to the treatments. Spotted owl PAC locations were obtained from the USDA and were buffered to exclude treatments within the buffered area. The streams layer, obtained from California Fish and Wildlife, was buffered to do the same. The roads layer that was supplied by the USFS was buffered, and, contrary to the stream and owl PAC buffers, only areas within the 304.8 meter buffer were made available for treatment.

The constraints were applied to the appropriate treatments to produce maps of lands available for prescribed burning, hand thinning, mechanical thinning, and low-cost mechanical thinning (mechanical thinning on slopes less than 50%). The mechanical treatment layers were further analyzed to select for contiguous tracts of 80937 m^2 (20 acres) or greater, which was indicated as the lowest bound of land area for which mechanical treatment is deemed to be cost-efficient (K. Duysen, personal communication, October 27, 2017). The land areas for each treatment were intersected with the private parcels on the landscape so that only treatments feasible on private lands are represented. The union tool was then used to combine the separate treatment layers into a singular layer.

The results of this analysis inform the percentage of the private parcel landscape that is available for treatment by each vegetative management strategy and the likely per acre cost of treatment to inform the prioritization of private parcels for treatment using Marxan.

Optimized Treatment Placement

The methodology below represents both a framework and an example of how the SRCD can decide where to place fuel treatments on the landscape given different optimization schemas that satisfy the forest management priorities of the SRCD, private landowners, or grant programs to which the SRCD intends to apply for funding. The private parcels on which fuel management and fire simulations were run were prioritized for treatment to achieve an optimized fuel treatment strategy that creates the greatest impact on chosen priority parameters at the least cost. This prioritization was performed in Marxan, a conservation planning tool designed to assist with the decision-making process in choosing reserve network locations. To optimize the placement of fuel treatments on the Dinkey Landscape, conservation targets were balanced against the cost of implementing fuel treatments and the potential fire risk reduction that could be achieved by implementing fuel treatments on the spatially distinct land parcels.

The following parameters were defined to run the analysis:

1. The spatially distinct private land parcel over which treatments would be optimized, referred to as the planning unit.
2. The cost of implementing vegetation management within each planning unit.
3. The desired amount of each conservation feature a land manager wants to preserve, known as the conservation target.

Planning Units

For private landowners, the property boundaries delineated by the County of Fresno were used as the Marxan planning units.

615 unique private parcel polygons were identified that represent the three private landowner communities found within the Dinkey Landscape: the Shaver Lake region in the northwest corner, Exchequer Heights, Providence, and Chamber Tract area in the center of the landscape, and the dispersed parcels in the southwest quadrant.

Conservation Features

Conservation features are measureable aspects of the landscape that Marxan will optimize fuel treatment placements to preserve. These conservation features are often identified in land or forest management plans. The relative importance of these conservation features can be adjusted by local stakeholders by changing the total amount of the conservation feature management that Marxan is coded to preserve, changing the placement of fuel treatments on the landscape.

The examples of prioritization schemas for fuel treatment placement presented in this report considered three measurable resources on the landscape. The first resource was the property value of a private parcel. Property values were calculated using the County of Fresno's land assessment values and averaged per community.

The second was the amount of land on a private parcel that falls within an identified California spotted owl Protected Activity Centers. The spotted owl conservation feature is important for prioritization because many forest and land management plans and grant programs for the southern Sierra Nevada address the protection of the endangered spotted owl.

The third conservation feature took into account the actual area that is feasible for treatment that exists within a given private parcel. This area was calculated using the methodology listed above in Section 4, Fuel Treatment Placement Feasibility and was used to modify the size of the planning unit. While not strictly a conservation feature, we included treatment feasibility to take into account the fact that not all private parcels have the same feasibility for implementation and will provide a metric that Marxan can use to weigh the feasibility value for treating a parcel. By including this metric as a conservation feature private parcels that are small with a majority of treatable land can be prioritized for treatment over private parcels that are large, but do not have a lot of feasibly treatable land, which would not happen if planning units had not been modified.

The relative values of these resources can be adjusted, and additional conservation features added, depending on management plan goals and requirements of acquired grants and proposals.

Computation of Costs

Costs in Marxan are used as a way to identify the most efficient planning solution. There are two category of costs that were taken into account for this model.

The first category of cost is the actual cost of implementing treatment. The treatment costs per planning unit were determined using existing MOUs that were signed by the SRCD with hand thinning contractors. Mechanical thinning costs were based on literature review of costs of mechanical thinning performed by contractors in the northern Sierra Nevada. These costs were multiplied by the number of acres that are physically feasible for fuel treatment implementation within each private parcel. However, if treatment costs were the only cost parameter included in the Marxan analysis the only parcels that would be optimized for treatment would be parcels whose costs for fuel treatment are low. Because the primary objective of fuel treatments is to reduce overall wildfire risk, a fire risk parameter needed to be included as a cost parameter to ensure that parcels with high fire risk reduction are optimized for treatment rather than just parcels with low treatment cost regardless of their potential fire severity.

Therefore, the second cost parameter considered in the Marxan analysis was the fire risk experienced by each private parcel. The results from the fire behavior modeling were used to determine the fire risk of each private parcel in the Dinkey Landscape. Fire risk was calculated by multiplying the conditional flame length produced by fire modeling by the ignition probability (from the models produced by Mann et al.

2016 and further described in Appendix 4, Item A), as described in Section 4, FlamMap Fire Severity Modelling.

The Marxan analysis works under the assumption that implementing fuel treatments in high fire risk areas results in relatively greater reductions of fire risk. By taking the complement of the fire risk metric (1 minus the fire risk) for each parcel on the landscape, the actual cost of fuel treatment is modified by the amount of fire risk reduction that could be produced by treatment on that parcel. Because Marxan optimizes for the greatest amount of a conservation feature that can preserved at the lowest cost, multiplying the complement of the fire risk by the treatment cost allows for parcels that have high potential fire risk and low implementation costs to be prioritized over parcels that just have low treatment costs.

Results

FVS Simulated Fuel Reduction Treatments

Under the no treatment scenario the number of trees per acre increased as FVS simulated regrowth until 25 years into the simulation. However, at year 2036, the number of trees per acre decreased and continued to do so until the model simulation ended in 2050. This decrease in trees per acre starting in 2036 was also found in both the full landscape treatment scenarios and the prioritized treatment scenario.

FlamMap Fire Severity Modeling

Mean reductions in conditional flame length were found to be significantly greater than zero for both the 260 SDI target (0.72 ± 1.19ft ($\mu\pm\sigma$), $t(1999) = 26.977$, $p < 0.001$) and the 300 SDI target (0.74 ± 1.21ft ($\mu\pm\sigma$), $t(1999) = 27.298$, $p < 0.001$), when compared to the no treatment scenario (Figure 4-4). The full landscape treatment thinned to the 260 SDI target was not found to be statistically different from the full landscape treatment thinned to the 300 SDI target (3.10 ± 0.68ft, 3.08 ± 0.67ft, respectively ($\mu\pm\sigma$), $t(3996.8) = -0.82635$, $p = 0.4087$), (Figure 4-5, Figure 4-6 Top Right). While fuel treatments did significantly reduce fire severity across the landscape, fire severity increased in some regions after treatment (Figure 4-4). This was in part because un-burnt slash piles, resultant from fuel treatments, significantly increased landscape fire severity until these piles were removed from the landscape through simulated pile burning. Additionally, due to FlamMap's stochastic seeding of fire starts, fire severity is also dependent on the number of years that have passed since treatment when a simulated fire intercepts a treated area, such that an area that experiences a fire later in a treatment cycle will have greater fire severities than one that has a fire earlier in a treatment cycle (Figure 4-10).

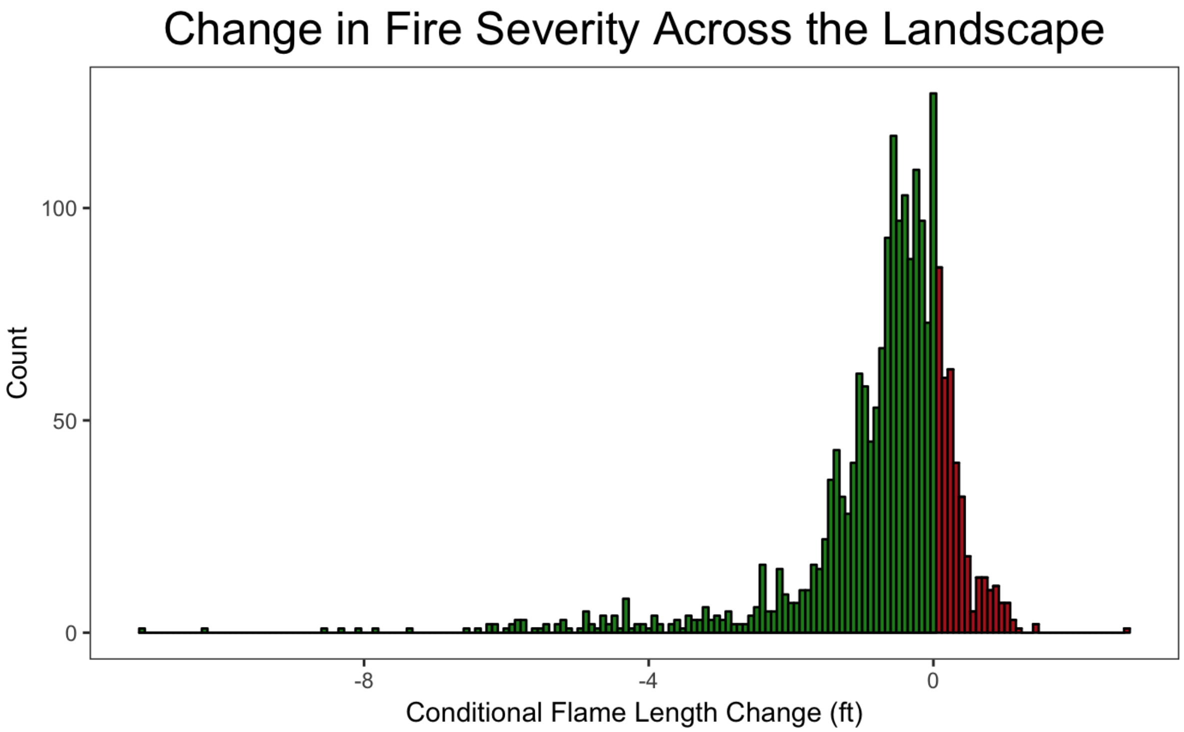


Figure 4-4. Flame length reductions in feet across the landscape, compared to No Treatment, when thinning to an SDI of 260. The green bars indicate reductions in fire severity and the red bars indicate increases in fire severity following treatment. Flame length reductions across the landscape were significantly greater than zero.

Prioritized Treatment Results

Under the prioritized treatments scenario, based on the upper quantile of potential fire severity reduction, 21% of the landscape was treated (equivalent to 5,650 acres of private lands). The mean conditional flame length from the prioritized treatment scenario (3.09 ± 0.86ft (μ±σ)) was found to be significantly less than the mean conditional flame length under a no treatment scenario ((3.82 ± 1.35ft (μ±σ), t(3406.9) = -20.267, $p < 0.001$), (Figure 4-6 Top Left, Figure 4-6 Bottom Left). Furthermore, even though the prioritized treatment treated a subset of the landscape, mean conditional flame lengths were not found to significantly differ from either the 260 SDI (t(3795.3) = -0.1948, p = 0.8456) or the 300 SDI full landscape treatments (t(3767.7) = 0.52709, p = 0.5982), (Figure 4-5, Figure -6 Top Left, Figure 4-6 Bottom Left).

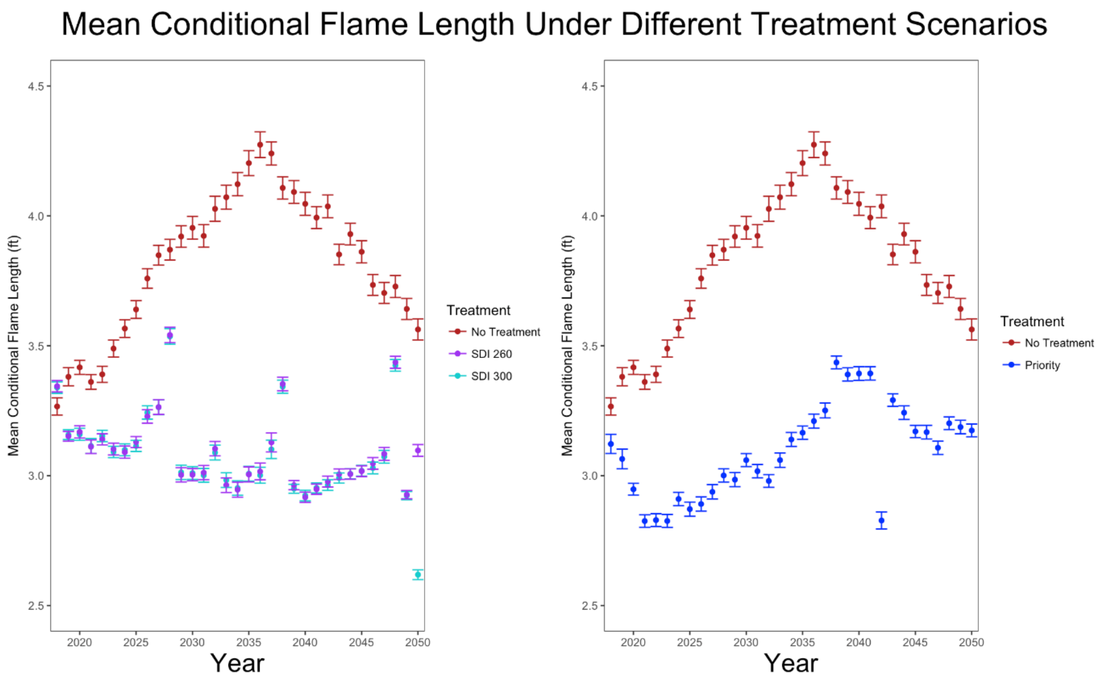


Figure 4-5. Mean conditional flame length (ft.) across the landscape over time for four treatment scenarios (No Treatment, SDI 260, SDI 300, and Priority). The entire landscape was treated for the SDI 260 and SDI 300 scenarios, whereas a prioritized subset covering 21% of the landscape was treated for the priority scenario. Error bars indicate standard error.

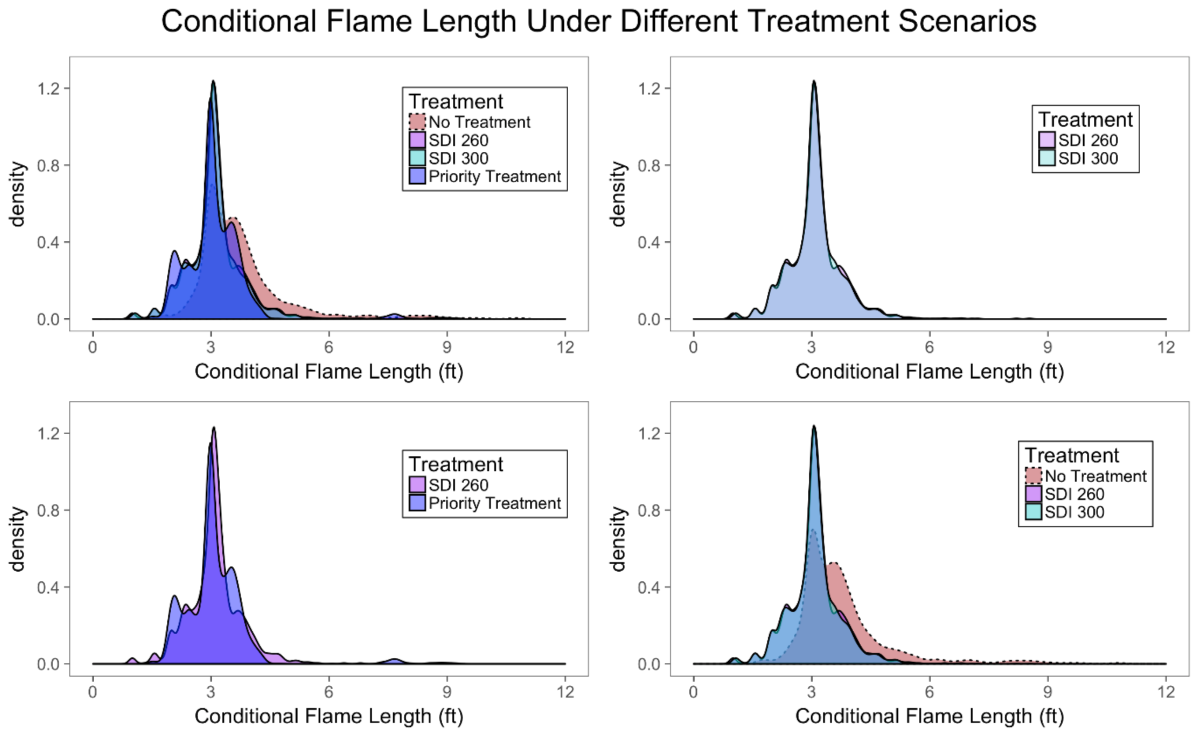


Figure 4-6. Relationship between treatment scenario and conditional flame length (ft.). There was no significant difference in conditional flame lengths between SDI 260, SDI 300, and Priority Treatments, while No Treatment had

significantly greater conditional flame lengths. Top Left) Conditional flame length probability density functions for four treatment scenarios (No Treatment, SDI 260, SDI 300, and Priority). All fuel treatment scenarios had significantly lower flame lengths than no treatment. Top Right) Conditional flame length probability density functions for SDI 260 and SDI 300 treatment scenarios. There was no significant difference between flame lengths for SDI 260 and SDI 300 treatment scenarios. Bottom Left) Conditional flame length probability density functions for SDI 260 and Priority treatment scenarios. While the Priority treatment only treated a subset of the landscape, mean flame length was not significantly different compared to SDI 260. Bottom Right) Conditional flame length probability density functions for No Treatment, SDI 260, and SDI 300 treatment scenarios.

The prioritized treatment simulated in this project was found to significantly decrease fire severity, as defined by the potential private parcel damage due to wildfire, across the private parcel landscape (Figure 4-7).

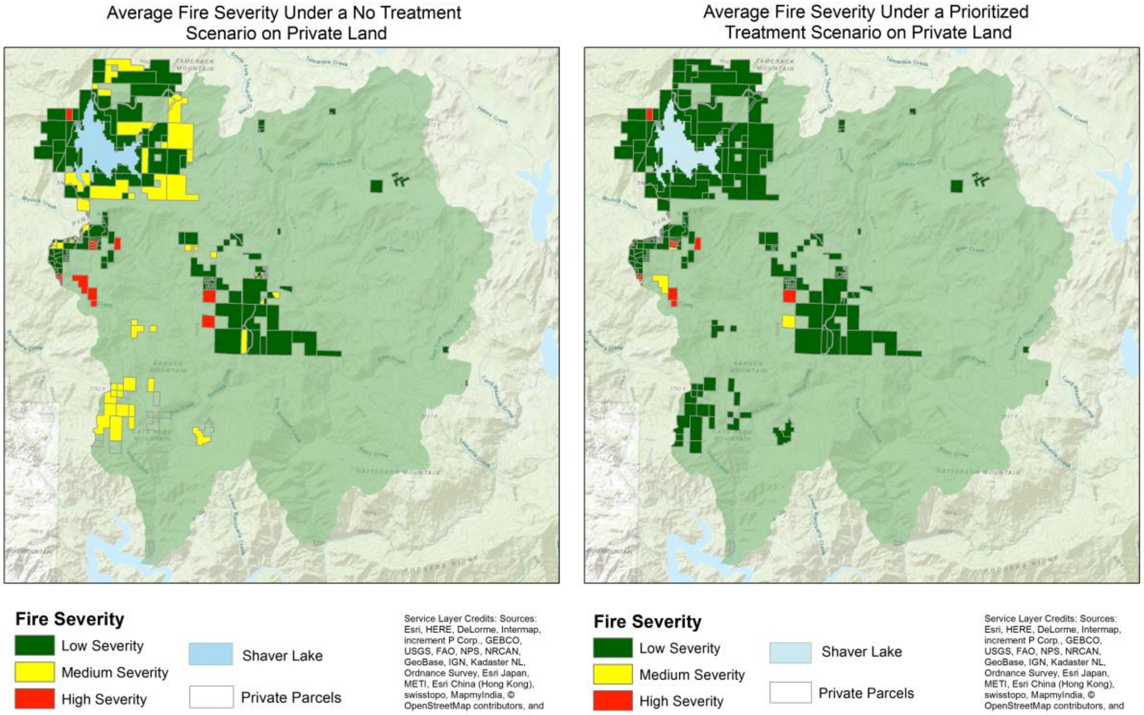


Figure 4-7. Averaged fire severity reduction across the private parcels landscape as a result of simulated prioritized fuel treatment and vegetation regrowth for 2018-2050.

The prioritized parcels equaling 21% of the landscape were derived from parcels that achieved an upper quantile of potential fire risk reduction, but do not, necessarily, represent the minimum threshold of the landscape that can be treated to achieve significant fire severity reductions. Results from fuel and fire simulations in which approximately 15% and 10% of the landscape were treated (4,035 acres and 2,690 acres respectively) show that treating these subsets of the landscape produces significantly lower fire severities than a no treatment scenario ($t(2870.8) = -27.432$, $p < 0.001$, and $t(2927) = -29.101$, $p < 0.001$). However, the distribution of conditional flame lengths from both the 15% and 10% treatments were also significantly different from the 21% treatment ($t(3883.1) = 4.2413$, $p < 0.001$, and $t(3835.6) = 7.0228$, $p < 0.001$). These results indicate that, although treating 15% or 10% of the landscape yields significant reductions in fire severity, these reductions are no longer similar to the reductions produced by a full-landscape treatment, so the minimum threshold for the amount of land that can be treated while maintaining the level of fire severity reduction potential of a full landscape treatment lies between 15% and 21% of the landscape (Figure 4-8).

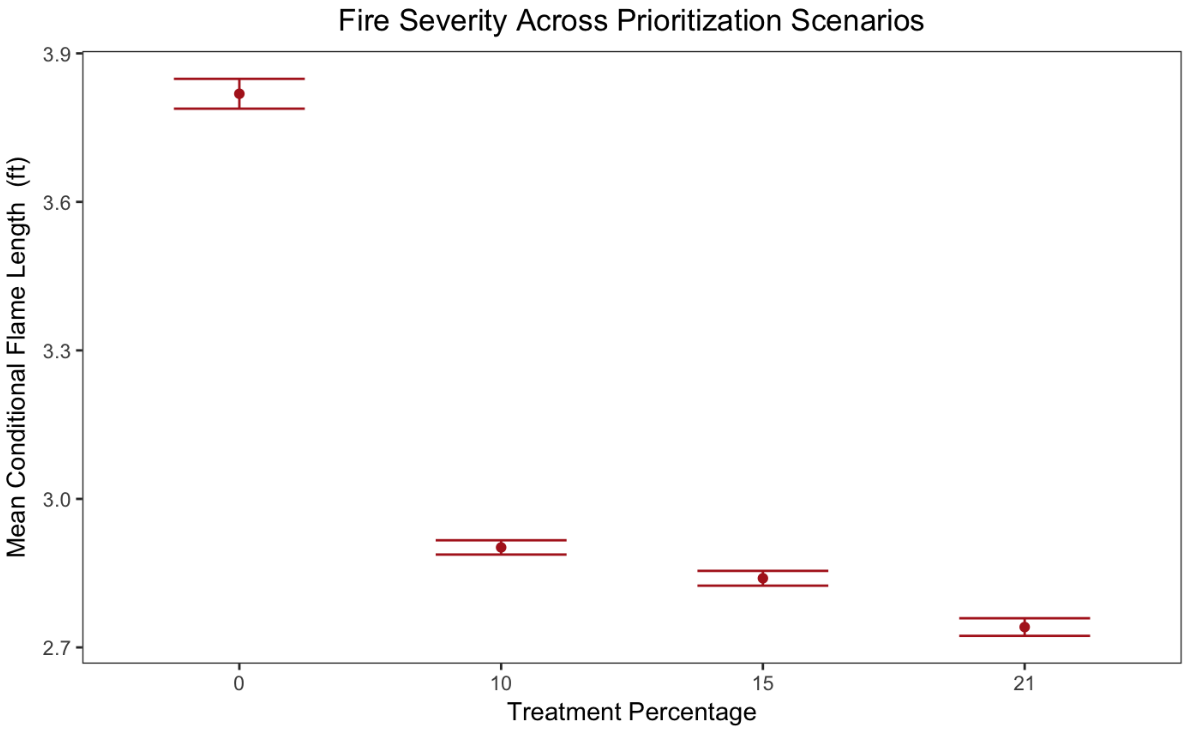


Figure 4-8. Tradeoff curve of the mean conditional flame length and the percentage of the private parcel landscape treated. If 21% of the landscape is treated, the distribution of mean conditional flame lengths is not significantly different compared to full landscape treatments, and the minimum threshold for achieving a similar conditional flame length to a full landscape treatment falls between 15% and 21% of the landscape. Both 15% and 10% landscape treatments achieve significantly lower conditional flame lengths than a 0% treatment scenario.

<u>Model Sensitivity Results</u>

Sensitivity analyses, which varied the wind speed during fire behavior modeling, show that the modeled wind conditions (10 mph) closely resembled results generated from moderate wind conditions (7 mph) with a sharp peak in conditional flame lengths around 3 feet with little rightward skew under the full landscape treatment scenarios. Conditional flame lengths for the modeled wind 300 SDI scenario (3.08 ± 0.67ft, (μ±σ)), did not vary significantly from the moderate wind 300 SDI scenario (3.09 ± 0.65ft, (μ±σ), (t(3994.4) = 0.50557, p = 0.613)). Similar results were observed when comparing a no treatment scenario with modeled wind conditions (3.82 ± 1.35ft, (μ±σ)) to a no treatment scenario with moderate wind conditions (3.87 ± 1.36ft, (μ±σ), t(3997.8) = 1.2094, p = 0.227)). However, under more extreme wind conditions (20 mph) fire behavior changed significantly, with probability density functions flattening and shifting towards higher flame lengths. Conditional flame lengths were significantly greater under the SDI 300 treatment scenario with extreme wind conditions (3.61 ± 0.90ft, (μ±σ)), than the 300 SDI scenario with modeled wind conditions (3.08 ± 0.67ft, (μ±σ)), (t(3702.5) = 21.314, p < 0.001)). Conditional flame lengths were also significantly greater under a no treatment scenario with extreme wind conditions (4.50 ±

1.26ft, (μ±σ)), than a no treatment scenario with modeled wind conditions (3.82 ± 1.35ft, (μ±σ)), (t(3978.3) = 16.665, p < 0.001)). Regardless of what wind assumptions were used, both the 300 SDI and 260 SDI full treatment scenarios consistently resulted in significantly smaller conditional flame lengths than those under a no treatment scenario (Figure 4-9).

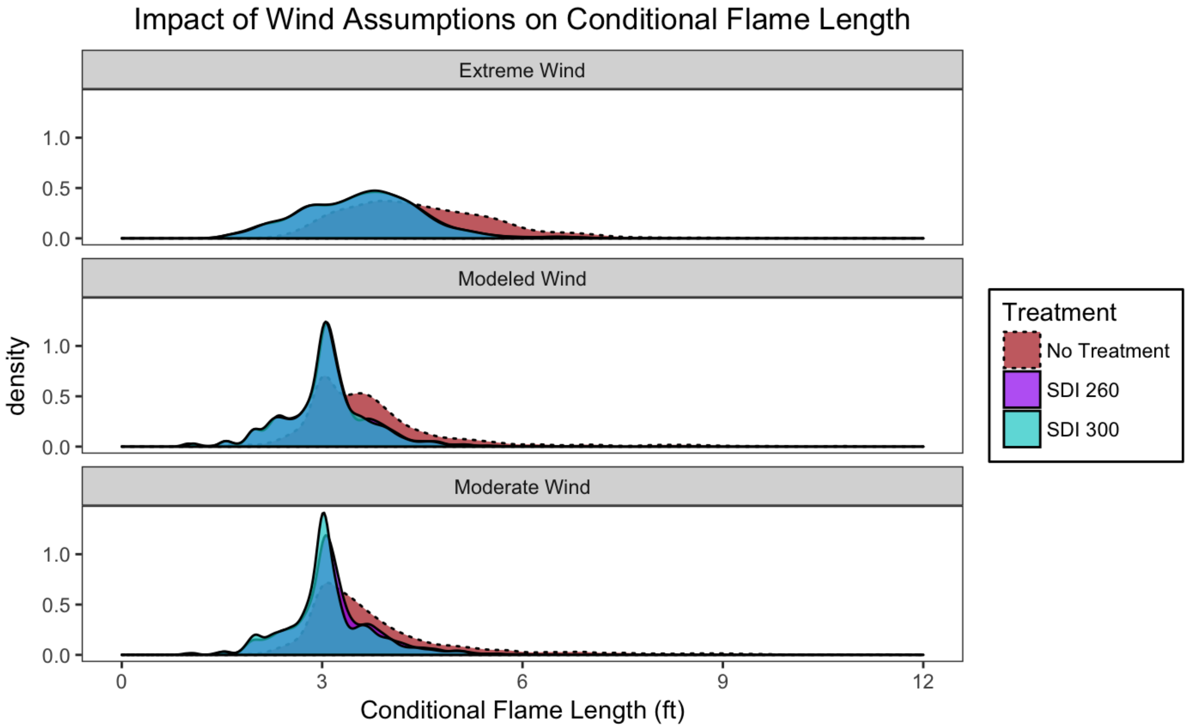


Figure 4-9. Probability density functions of conditional flame length (ft.) of three treatment scenarios (No Treatment, SDI 260, and SDI 300) under three different wind scenarios. The moderate wind scenario assumed wind conditions of 7 mph, the modeled wind scenario assumed wind conditions of 10 mph, and the extreme wind scenario assumed wind conditions of 20 mph. There was no significant difference in conditional flame lengths of treatments between modeled and moderate wind scenarios. Conditional flame lengths in extreme wind scenarios were significantly greater than those in modeled wind scenarios.

An analysis of the conditional flame lengths for the 260 SDI treatment across the years of the treatment cycles found that reductions in conditional flame lengths begin to decrease due to forest regrowth in the 8th year after treatment (Figure 4-10). The difference in conditional flame lengths across each treatment cycle when compared to the year that the fuel treatment was completed is not significantly greater than 0 until year 8 (t(1999) = 2.3454, p = 0.010). Unburnt slash piles also significantly increase flame length across the landscape. In the first year of treatment, when thinning occurs but slash piles are unburnt, mean flame lengths for both the SDI 300 scenario (3.34 ± 0.98ft, (μ±σ)) and the SDI 260 scenario (3.34 ± 0.99ft (μ±σ)) are significantly greater than the no treatment scenario (3.27 ± 1.48ft (μ±σ)), (t(3464.1) = 1.8312, p = 0.034; t(3491.8) = 1.958, p = 0.025; respectively), (Figure 4-4).

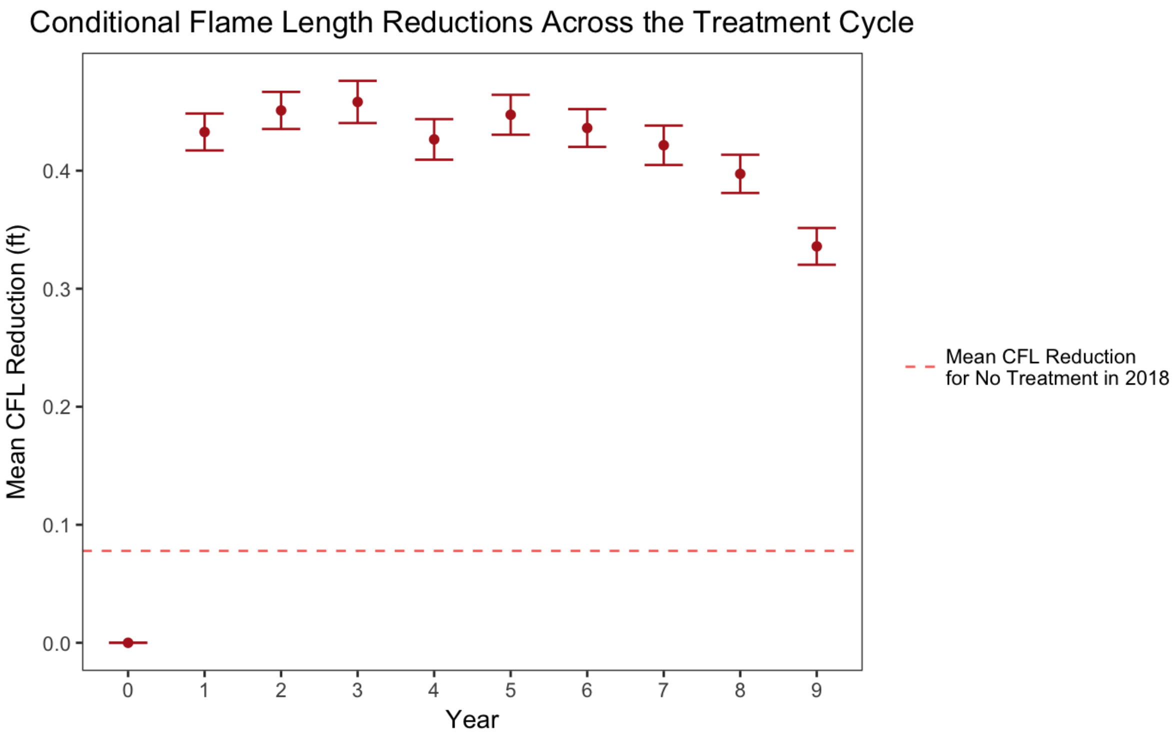


Figure 4-10. Mean reduction in conditional flame length across treatment cycles for the SDI 260 treatment compared to the year of treatment. Mean changes in conditional flame lengths were determined by subtracting flame lengths in each year of the treatment cycle from the first year of the treatment cycle, and then averaged across the three treatment cycles. Reductions in conditional flame length were not significantly less than year 1 (the year when piles have been burnt) until year 8. The red dotted line indicates the mean increase in flame length in the first year of no treatment compared to the first year of treatment due to the presence of slash piles on the landscape, which significantly increase fire severity until they are burned. Error bars indicate standard error.

Crosswalk From Public Fire Severity Outputs to Private Fire Severity Outputs

Ordinal logistic regression analysis was used to crosswalk the fire severity results generated from fire behavior modeling on public tree stand data to fire severity outputs for adjacent private parcels. The outputs of ordinal logistic regressions are probabilities binned by dependent variable category. Similar to the outputs from FlamMap, the ordinal logistic regression produced probabilities of conditional flame length category for each of the six severity categories based on the predictor variables. These probabilities were then used to determine conditional flame length. Conditional flame length was calculated by multiplying the severity bin probabilities by the mean conditional flame length of the bin and summing the products of each of the six bins to generate a singular flame length for a specific private parcel location. This methodology for calculating conditional flame length based on fire severity bin probabilities is the same methodology used by the fire behavior model FlamMap. Slope, elevation, aspect, dominant vegetative cover type, and NDVI were significant predictors of conditional flame length using an ordinal logistic regression. Lipsitz (LR statistic = 419.1, p-value < 0.001) and Hosmer-Lemeshow (X^2 (44) = 1577.4, p < 0.001) goodness of fit tests were performed to confirm good correlation between the predicted and observed values of conditional flame length. Cox-Snell and McFadden's Pseudo-R^2 tests were used to determine the regression's explanation of conditional flame length variability (Cox-Snell pseudo $R^2 = 0.099$ and McFadden pseudo $R^2 = 0.095$). Conditional flame lengths for public lands generated by FlamMap and those predicted by the ordinal logistic regression are represented in Figure 4-11.

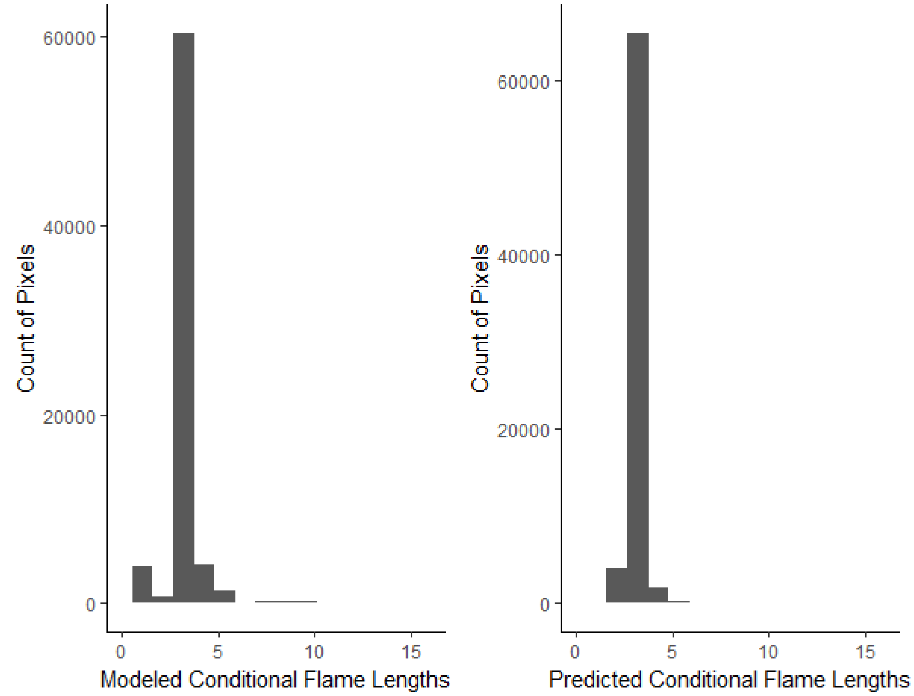


Figure 4-11. Results of counts of modeled conditional flame lengths for public lands versus the counts of conditional flame lengths for public lands predicted using the ordinal logistic regression.

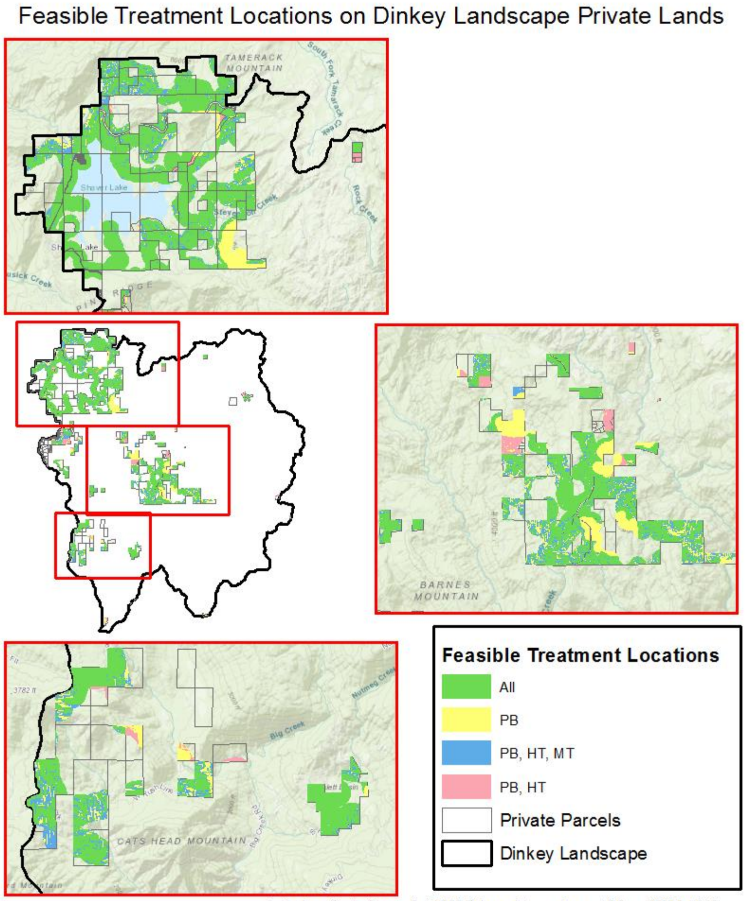
Predicted conditional flame lengths captured some of the variability in conditional flame length for small conditional flame lengths, and achieved a similar mean flame length to the conditional flame length outputs from FlamMap (mean of modeled conditional flame lengths = 3.19 ft.; mean of predicted conditional flame lengths = 3.17 ft.). Conditional flame length variability for the higher conditional flame lengths was lost using the ordinal logistic regression. A t-test comparison of a 2,000 pixel subsets of the distributions, modeled conditional flame lengths and ordinal logistic regression predicted conditional flame lengths, found that the distributions were not significantly different ($t(2172.1) = 1.6891$, $p < 0.09134$). The results of the comparison of the modeled and predicted conditional flame lengths demonstrated that the ordinal logistic regression was a sufficient predictor of conditional flame lengths to translate results from the public parcels to the private parcels for the purposes of this report, however future studies could greatly improve the fire severity analysis for private lands by improving this regression analysis or directly modeling fire behavior on private lands.

Fuel Treatment Placement Feasibility

Treatment feasibility maps show that 62.39% of private lands by land area can be treated by one of the four assessed treatment types. Prescribed burn, the treatment with the fewest physical and ecological constraints, is feasible across the largest landscape of the assessed treatments (Table 4-1, Figure 4-12). The current state of the forest, however, precludes the safe implementation of prescribed burning without first performing some form of fuel treatment. Therefore, the most extensive treatment type that can be employed immediately on the landscape is hand thinning, feasible on 54.36% of private land area.

Table 4-1. Area and percentage of private land that can undergo fuel treatments.

Treatment Type	Square Kilometers	Acres	% Private Lands
All Treatments	47.24	11672.18	43.40%
Prescribed Burn	67.90	16,778.64	62.39%
Hand Thinning	59.16	14,619.61	54.36%
Mechanical Thinning	56.45	13,950.04	51.88%
Mechanical Thinning Low Cost	47.26	11,677.88	43.43%



Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4-12. Treatment feasibility analysis across the Dinkey Landscape. The type of treatment (PB = Prescribed Burn, HT = Hand Thinning, MT = Mechanical Thinning, and All = Prescribed Burn, Hand Thinning, Mechanical Thinning, and Mechanical Thinning at low cost) that is feasible on private lands broken up by the three community areas of interest on the Dinkey Landscape.

Optimized Treatment Placement

Two examples were produced from the optimized treatment analysis performed in Marxan to help illustrate how fuel treatments placement can be optimized and adjusted using this planning tool. The first example optimized fuel treatment placement base to achieve treatment of 21% of the landscape (5,650 acres) at the lowest cost and greatest fire risk reduction potential (Figure 4-13). While this optimization run is limited by the information available on established roads on the Dinkey Landscape, which in turn limits the percentage of the landscape that is deemed feasible for treatment, the optimization provides a framework that can be improved with better knowledge of the landscape or adjusted given different parameters of conservation features for prioritization.

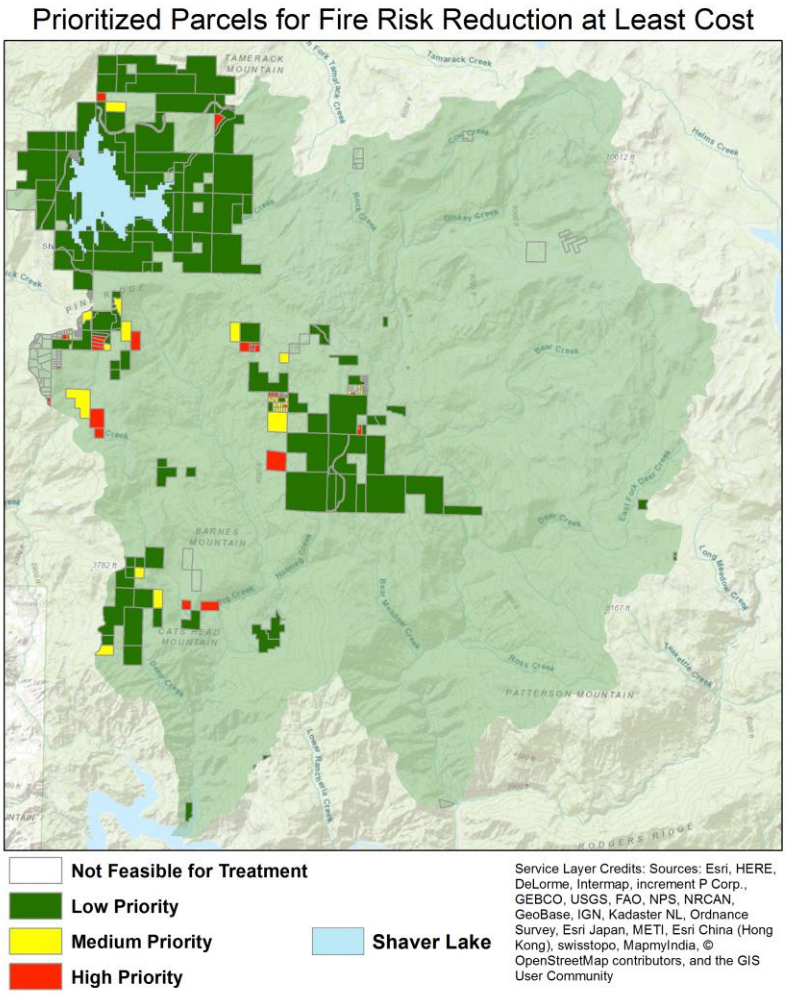


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Figure 4-13. Potential optimization schema for prioritizing fuel treatment placement on private lands if the primary goals of fuel reduction activities are to achieve the greatest reduction in fire risk at the least cost.

The second example of fuel treatment placement combines the conservation features of feasibly treatable acreage, acres of California spotted owl Protected Activity Centers, and land value. In this case, land value was considered an important conservation feature both as a proxy for targeting landowners who may have more financial capacity to invest in fuel treatments and because those landowners stand to lose the most value if a severe wildfire impacts their land under a no treatment scenario. In this optimization example, feasible area for treatment was the conservation feature given the most weight (i.e. the Marxan run will try to place fuel treatments in areas with the most land available for treatment first). Land value was the conservation feature with the second greatest weighted value in this optimization run, followed by California spotted owl Protected Activity Center area. Because land value was weighted so highly in this optimization of fuel treatment placement, the areas prioritized for fuel treatments were primarily in the Shaver Lake area, a community where land values tend to be higher than those of the rest of the landscape (Figure 4-14). In the future the SRCD would be able to change the weights assigned to each of the conservation features, or remove conservation features, depending on their priorities.

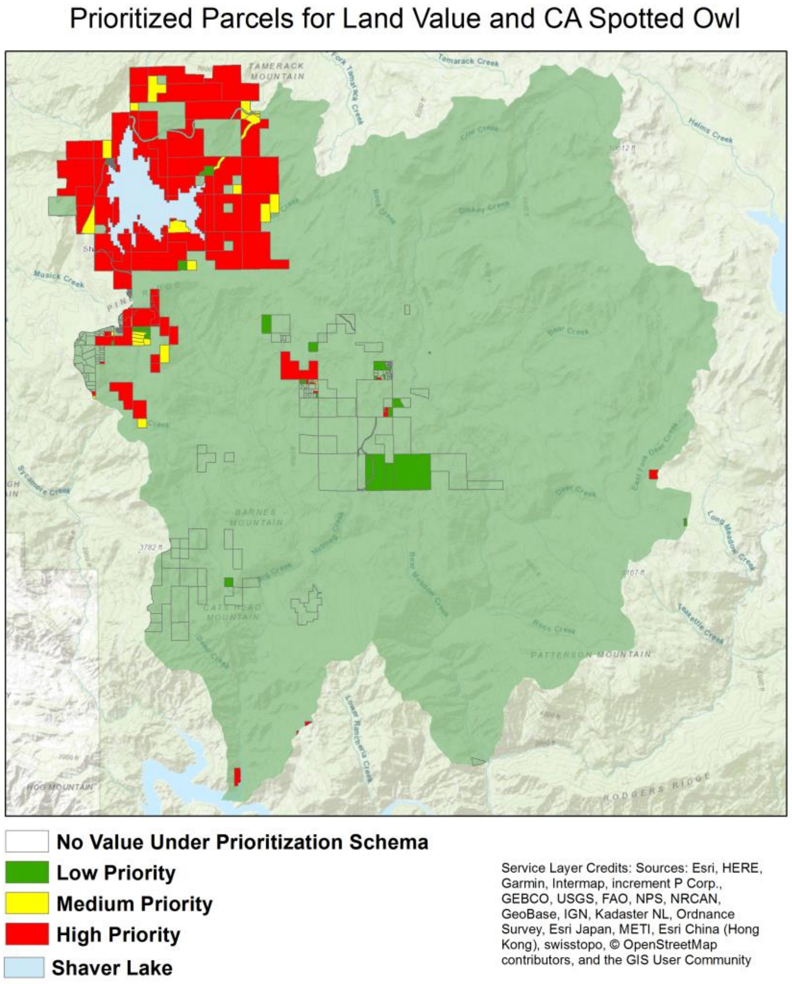

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Figure 4-14. Potential optimization schema for prioritizing fuel treatment placement on private lands if the primary goals of fuel reduction activities are to achieve the greatest reduction in fire risk for the least cost while targeting areas of high land value and California spotted owl habitat. The private parcels with no fill indicate parcels on which fuel treatments were never placed under the optimization schema due either to low land value and the absence of spotted owl Protected Activity Centers or because the land was not physically feasible for fuel treatments.

Discussion

Fuel Treatments Reduce Potential Fire Severity

Fuel simulations and fire behavior modeling illustrate that fuel reduction and vegetation management activities could have a significant impact on conditional flame lengths during a wildfire event. Conditional flame lengths are a measure of fire severity. Because fuel reductions were found to significantly reduce conditional flame lengths fuel treatments were shown to effectively reduce potential fire severity across the landscape. Results comparing conditional flame length produced by treatment to those produced under a no treatment scenario do indicate, however, that not every part of the private landscape will experience an overall decrease in conditional flame length for the 33 years of the fuel and fire behavior simulations (Figure 4-4). This finding is influenced by three major factors. The first factor is that the fire simulation model functions such that not every parcel experiences a fire in each of the 33 years of the simulations. This means that some of the conditional flame lengths are more heavily influenced by fires simulated in years when regrowth has already occurred post-thinning. In reality, a wildfire is likely to behave in a similar way, intercepting treated landscapes at different stages of regrowth post-treatment. The second factor is that the conditional flame lengths are heavily influenced by the first year of the treatment cycle when small woody debris is still present on the landscape prior to pile burning. If the years in which piles are present are removed, the number of increased conditional flame lengths compared to a no treatment scenario are reduced almost by half. However, the existence of woody debris piles on the simulated landscape is actually more representative of the fuel loads present on the actual landscape as private landowners find it difficult to remove woody debris post-thinning due to the prohibitive costs of transport or insufficient machinery or infrastructure to allow removal (S. Haze, personal communication, April 19, 2017). Finally, the impact of the decrease in trees per acres under the no treatment scenario for the later years of the simulations (2036-2050) may also be artificially lowering the conditional flame lengths comparative to treatment scenarios. The cause of this decrease in trees per acre under the no treatment scenario will be discussed later in the limitations portion of this section.

Piles of Woody Material Increase Potential Fire Severity

However, the results also demonstrate how critical it is to pair thinning treatments with large and small woody debris disposal. The modeled treatments included a fuel move, meaning that the woody debris greater than 12 inches in diameter was removed from the landscape – to a biomass plant or timber mill – and a pile burn of the small woody material was performed. In the Sierras, it is required that piles are left to cure for at least six weeks prior to burning to reduce smoke outputs (De Lasaux and Kocher 2006). The nature of FVS is such that treatments must be simulated all at one time or must take place the following year. Because of this feature of the model, simulated small woody debris piles were left on the landscape for a year prior to burning. This allowed for the analysis of the impact of those woody piles on fire severity. Even the simulated woody piles of small woody material – less than 12 inches in diameter – caused significant increases in fire severity relative to the fire severity experienced in the years following the simulated pile burn. This was a critical piece of analysis because private landowners in the Dinkey Landscape often have trouble removing woody debris from their land post-thinning because of the inaccessibility of the location of woody piles, the lag-time between thinning and burn days allowable for pile burning, or the high costs of transporting the material offsite. As a result, over 3,000 piles of large and small woody debris piles is currently present on private lands on the Dinkey Landscape; a number that is likely to increase with additional thinning unless the need for woody removal is emphasized and addressed.

The removal of woody debris post-thinning is critical because, in the model, maintaining the woody piles on the landscape in the first year of treatment nearly negated the impacts of the treatment itself. The simulated piles represent just a portion of the fuel load that results from thinning treatments, and, if the large and small woody biomass following treatment is not removed from the landscape, private landowners will see limited benefits from their thinning efforts.

Prioritized Fuel Treatment Placement is Effective

The results of the prioritized fuel treatment scenario show that, if fuel treatments are strategically placed, they can produce an effect similar to that gained by treating the entire landscape. This is a key finding in that it demonstrates that efforts to engage private landowners can be targeted and expenditures on fuel treatments can be minimized while still significantly reducing potential wildfire severity. For a region without much financial capital and an agency that relies on grants to implement on-the-ground projects, the ability to maximize the reduction in potential fire severity with limited time and funds is a critical. The lower bound of acreage on the landscape that can be treated and still achieve fire severity reductions similar to those produced by a full landscape treatment lies between 5,650 and 4,035 acres, or 15% and 21% of the private parcel landscape. However, while treating 15% or 10% of the landscape does not produce fire severity reductions on par with a full landscape treatment, the conditional flame lengths produced are significantly smaller than those produced under a no treatment scenario. As such, even if a prioritized treatment of 21% cannot be achieved there are still significant benefits generated by treating a small percentage of the landscape.

Fuel Treatments are Physically Feasible

Much of the private parcel landscape can be treated with some form of fuel reduction strategy. The largest percentage of land can be treated with prescribed fire because this method of fuel reduction has the fewest physical constraints. However, there are many safety and social constraints that impact prescribed burns, and the state of much of the landscape likely precludes the safe use of prescribed fire without pre-treating the land through forest thinning. The forest stands on the public lands were found to greatly exceed the healthy forest density range for mixed conifer forests. These forest stands, being that they are on public lands in the WUI, have experienced some level of fuel treatment in the recent past that likely exceeds that of the majority of adjacent private lands. As such, it is safe to assume that private lands may be just as densely forested as their public land counterparts. The USFS does not perform prescribed burning on WUI lands without first performing a pre-treatment fuel thin, so the same is recommended for private lands (A. Hernandez, personal communication, October 19, 2017). Prescribed burning should thus be used on the private parcel landscape only following a fuel treatment that first thins the forest stands. When these two vegetation management strategies are paired, it is the most effective and ecologically beneficial form of fuel management (Stephens et al. 2009; 2014). Prescribed burning also requires expertise in planning and executing the fuel strategy. This capacity is limited on the landscape to the USFS and the Cold Springs Rancheria of Mono Indians of California, which is building its capacity in performing traditional burns for forest restoration. Prescribed burning is unlikely to be the primary method for fuel treatment on the private parcels.

Aside from prescribed burning, hand-thinning is the treatment that is physically feasible for implementation across the largest percentage of private land, with hand-thinning able to be implemented on over 54% of the private landscape. This form of fuel treatment is sensitive to the ecological characteristics of the landscape, such as soil health, water quality, and critical species habitat, but it is a relatively inefficient fuel reduction strategy over large landscapes. Hand thinning is inefficient in the sense that the rate of thinning is exceedingly slow compared to mechanical thinning and the portion of the land that should be treated to produce a sizeable impact on landscape-level fire severity. The tradeoff curve of the number of acres that can achieve the same reduction in fire severity as a full landscape treatment found that this minimum threshold falls between 21% and 15% of the private parcel landscape, equating to between 5,650 acres and 4,035 acres. If hand thinning is use to achieve fuel treatment at this lower bound of acreage it would take approximately 77 years at the rate of 0.2 acres per day that hand crews are currently achieving on the landscape. The 77 year timeline is achieved if one handcrew is working year-round without weekends on fuel treatments. If the same parameters are used to assess mechanical fuel treatment timelines, the 5,650 acres would be treated in approximately 3 years.

Despite the feasibility of implementing treatments on the landscape based on the physical constraints of the fuel reduction methods themselves, the human and physical capacity of local fuel thinning contractors is limited. Many of the contractors in the region only have the capacity to perform thinning of fuels by hand. Few of the already limited number of local contracts have access to fuel thinning machinery such as feller-bunchers or cut-to-length mechanized harvesting systems. Neither does the financial capital currently exist for many of these local contractors to invest in such machinery. This capacity gap severely limits the capability of the community to achieve significant fuel reductions within a reasonable timeline.

Prioritization of Fuel Treatment Placement Can be Modified

The strategic placement of fuel treatments on private lands modeled through the optimization tool Marxan indicates how the prioritization ranking of private lands may change with what private landowners and the SRCD deem to be the important goals of the fuel treatments. The goals of fuel treatment – fire severity reduction, preserving high valued parcels, maintaining endangered species habitat, and carbon sequestration – can be adjusted according to private landowner priorities or the stipulations of the grants under which SRCD must operate.

Treatment Benefits Begin to Decay

Reductions in conditional flame length produced by thinning and pile burning fuel treatments begin to decline approximately eight years after the completion of the fuel treatment. While conditional flame remain lower than those under a no treatment scenario, conditional flame lengths do increase over the course of the 10-year treatment cycle after the eighth year of that cycle. Vegetation management needs to be maintained and repeated into the future in order to continue to realize benefits in the form of reduced fire severity. Therefore, if the capacity exists, land managers should repeat fuel treatments on lands if eight years have passed since it was last treated to maintain reduced fire severity.

Daily Weather Patterns Can Significantly Increase Fire Severity

Wind speed is a critical component of wildfire spread, intensity, and ease of suppression. The results of the sensitivity analysis which explored fire behavior under varied wind speed scenarios demonstrate that the 10 mph wind scenario – the wind conditions this study primarily used for analysis – are conservative. If wind conditions are reduced to moderate winds – 7 mph – fire behavior and severity were not significantly different from fire severity under the 10 mph winds used in the full analysis. However, if wind speeds are increased to a high wind speed of 20 mph fire severity under both the no treatment and full treatment scenarios is significantly greater than fire severity for those scenarios under 10 mph wind conditions. Under the severe wind conditions, fire severity for the full landscape fuel treatment scenario remain significantly lower than that under the no treatment scenario. Therefore, if wind conditions are severe with high wind speeds of 20 mph, the benefits of performing fuel treatments for landscape-scale fire severity could be even more pronounced.

Limitations

Successive Fire Years

This analysis of fire risk reduction potential is limited in that the models used for fuel and fire behavior modeling did not have the capacity to analyze the impact of successive or multiple fire years. Over the course of the projected 33 years – from 2018 to 2050 – it is possible that a wildfire will occur during two or more years. This analysis only looks at the impacts of fuel reductions on isolated fire years: a fire in one year or a fire in another. Therefore, this analysis gives an indication about the fire behavior of the first wildfire that occurs on the landscape from 2018 to 2050 under a no treatment or treatment scenario.

Reduced Trees per Acre Over Time

Under the no treatment scenario at year 2036 conditional flame lengths begin to decline drastically. This decline in conditional flame length is caused by a decreasing trend in trees per acre. The decreased trees per acre is a result of the interaction of the underlying mortality assumptions of FVS and the adapted regeneration kcp file created for this study, the combination of which drove trees per acre down in the later simulations of the no treatment scenario. The Western Sierra Nevada variant of FVS uses a mortality adjustment based on SDI. As forest stands approach the maximum SDI determined for the stand's mix of tree species, mortality increases beyond background levels to include the effects of density-dependent competition and associated mortality. This mortality favors shade in-tolerant trees, understory vegetation, and trees with low crown ratios. The mortality adjustment begins to significantly reduce the number of trees per acre from 2036-2050 in the fuel simulations so that the stands are primarily large, overstory, mature trees. This mortality effect was then paired with a custom regeneration kcp file that may have underestimated the number of trees that would be able to recruit in the forest stand. While the reduction in trees per acre seems extreme, logically it makes sense. As inter-tree competition increases with density mortality will increase. In such a competitive forest stand seedlings and saplings may have very little ability to recruit, especially in the dry regions of the southern Sierra Nevada. As such, a decline in the number of trees per acre is not illogical. However, this trend ignores the impacts of climate change, which may further affect not only the forest density but also the vegetation distribution in the area. The limitations of this study in regards to climate change considerations is further discussed below.

The reduced trees per acre, and subsequently reduced conditional flame lengths, impact not only projections of future conditions under a no treatment scenario, but also the relative benefits of fire severity reduction garnered through performing fuel treatments. If the reduced trees per acre under a no treatment scenario represents an actual future reality, then the simulations stand as an accurate representation of the reductions in fire severity that can be achieved with fuel treatments. If, in reality, one could expect for stand densities to plateau rather than peak and decline, the benefits of fuel treatments have been underestimated. If, instead, climate change will cause significant shifts in dominant vegetation cover the interpretation is complicated. Given that dominant vegetation on private parcels is expected to shift to less fire-resilient species by 2050 (this report Section 3, "Reforestation"; Appendix 4, Item E; McIntyre et al. 2015) the impacts of fuel treatments are likely still underestimated.

Mortality Adjustment

The vegetation modeling is limited in its predictive capacity by the data that was available for analysis. The data available for the public tree stands pre-dated the tree mortality event that swept through the southern Sierras beginning in 2015. A mortality adjustment, created by a USFS silviculturalist, was used to update the forest stands to reflect the potential impacts of the mortality, however, current data from stands impacted by the mortality event would serve as more robust data and likely increase the predictive power of FVS for this landscape.

Constant Environmental Conditions

A limitation of using FlamMap to model fire behavior is that FlamMap employs constant environmental conditions such as fuel moisture, wind speed, and wind direction during every fire simulation. Therefore, the modeled fire conditions are only reflective of potential fire behavior under those weather conditions. The fire behavior that was modeled necessarily ignores daily variation in weather and moisture conditions.

Crosswalk of Modeled Fire Behavior from Public to Private Lands

Vegetation and fire modeling was also limited by the absence of data compatible with those models for private lands. The ordinal logistic regression that was employed to predict modeled outputs of conditional flame lengths using topographical and vegetation characteristics that were available for both public and private lands (slope, aspect, elevation, dominant vegetation cover, and NDVI) significantly predicted modeled conditional flame lengths. However, the regression explained only a small percentage of the variability in the conditional flame lengths. As a result, much of the resolution of the variability in conditional flame lengths as a result of fuel treatment was lost in the transfer of modeled results to private lands. The conditions that impact fire behavior are varied and fire behavior models exist because fire behavior is not appropriately explained by regressions between landscape characteristics and fire severity. Additionally, the impact of fire spread on fire behavior and impact on select parcels, which is a part of the FlamMap fire behavior modeling, is lost during the crosswalk of fire behavior to the private lands.

To gain a more complete perspective on the potential impacts of fuel treatments on private lands on subsequent wildfire behavior, data that match with FVS and FlamMap inputs need to be gathered on private land. Because this process would be expensive to undertake and potentially intrusive to private landowners, fire behavior modeling could be repeated using a fire behavior model that can make use of currently available landscape and remotely sensed data for private lands. A fire behavior model that can explore fire behavior using these types of data, RHESSys, is nearing the point when fuel treatments may be simulated and subsequent fire behavior modeled.

Treatment Feasibility

The primary factor that is limiting the feasibility of treatment on the private parcel landscape is the distance of those lands to roads. All treatments are recommended to take place within 1,000 feet of an established road (A. Hernandez, personal communication, October 19, 2017). The roads layer used in this analysis was supplied by the USFS High Sierra District. If there are established roads known to the community or the landowner that were not included in the layer supplied by USFS, the amount of treated land has the potential to be significantly increased.

Prioritization

The prioritization methodology does not incorporate boundary effects – the impact of placing multiple treatments next to each other to further reduce fire severity and increase potential cost efficiency. The limitations of the crosswalk of conditional flame lengths from public forest stands to private parcels reduces our capacity to make predictions about the benefits of placing fuel treatments in close proximity. Regardless, the flexibility of the prioritization methodology does still demonstrate that communities with limited funding can use prioritization to target certain areas for fuel treatments and get much of the benefits that are realized under a full landscape treatment scenario at a significantly lower cost.

Climate Change Impacts on Vegetation Shifts

This analysis ignores the impact of climate change on vegetation species shifts. Future climate is included in this analysis only through the probabilities of fire ignition modeled under two different climate scenarios (PCM and GFDL) until 2050 (Mann et al. 2016). Dominant tree species habitat modeling, however, predicts upslope elevation shifts in habitat suitability by 2050 for the five key dominant forests covers on the Dinkey Landscape: mixed-conifer forest, ponderosa pine, white fir, black oak, and lower montane chaparral (McIntyre et al. 2015; Pile 2017; this report Appendix 4, Item E). This range shift would result in vegetation on the private parcels to transition from predominantly mixed-conifer forest cover to ponderosa pine, black oak, and chaparral cover, some of which have higher severity fire regimes than mixed-conifer forest (Balch et al. 2016). Mixed conifer and ponderosa pine forests, for example, are fire-resilient, whereas white fire, chaparral, and oak forests are not (Stephens et al. 2015). White fir, chaparral, and oak stands have a longer fire return interval than mixed conifer and ponderosa pine forests (35-100 years and 0-35 years respectively), but the ingrowth that occurs during the interval between fires in white fir, chaparral, and oak stands greatly increases fuel loading and the potential for higher severity fires than fires in mixed-conifer and ponderosa pine stands (Balch et al. 2006).

Climate change, with its potential to cause changes in precipitation, may drastically impact fire behavior regardless of vegetation shifts. Climate change has the potential to impact vegetation growth rates and productivity (Lenihan et al. 2003). Additionally, with expected increases in drought conditions and warmer temperatures, fire seasons are expanding in the southern Sierra Nevada Mountains (Williams et al. 2010; AghaKouchak et al. 2014; Westerling et al. 2006). Drought conditions and amplified inter-tree competition has been shown to increase mortality events and decrease fuel moisture of woody fuels; impacts which increase fire severity (Williams et al. 2010).

High severity stand-replacing fires also have the potential to cause shifted or novel species recruitment in the burn scar (North 2012). These predicted and potential changes in dominant vegetation assemblages have the capacity to alter the fire regime for the landscape, both in the landscape's fire resiliency and fire return interval. Depending on the SRCD's and the private landowners' goals in performing vegetative management activities, reforestation of desired species, informed by site-specific predicted shifts in vegetation, may be a considered action item following fuel reduction. Because this analysis was unable to capture the response of fire severity to climate change, future mortality events, or future stand replacing wildfire, the SRCD may want to consider engaging a group of researchers to expand upon this report's fire modeling to explore the impacts of these dynamic factors.

Disregard of Reforestation Efforts

The fire behavior modeling performed in this study ignores the potential for reforestation projects to supplement natural regeneration following fuel treatments. While this is not currently a widespread practice on private lands, a reforestation framework was recently drafted by the Dinkey Collaborative to guide reforestation efforts on public lands motivated in part by the threat of climate change causing shifts in vegetation. Previous reforestation efforts have been identified by the USFS as insufficient to maintain desirable fire-resilient species on the landscape. The inefficiency of public land reforestation efforts is due to the high levels of tree mortality three years after planting – up to 50% mortality – and the lack of forest disturbances under the current regime of fire suppression that provide opportunities for post-disturbance reforestation (Landram 2010). This demonstrates that conducting reforestation only following natural disturbance events slows the rate of forest recovery, and that, by neglecting to include private landowners in reforestation efforts forest management has been inconsistently implemented across private parcels and between public and private lands (Landram 2010).

If the SRCD or private landowners are sufficiently motivated to conduct reforestation on private lands, they may want to capitalize on reforestation efforts following fuel treatments. Since forest thinning acts as an artificial disturbance event, many of the same beneficial conditions for reforestation success exists, such as more access to sunlight and water and the release of existing vegetation from competition that would otherwise hinder growth (Landram 2010). Reforestation may assist in forest recovery and help maintain fire-resilient tree species that could help reduce risk exposure of private lands to high-severity fires. Reforestation efforts may be strategically implemented in areas of high predicted climate stress for fire-resilient species of interest (Appendix 4, Item E, Figure E-5).

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Appendix—4

Item A—Ignition Probability Assumptions

The empirical fire ignition model described in Mann et al. 2016 was developed to describe the probability of fire ignitions within California in 25-year increments under two different climate projections (Geophysical Fluid Laboratory A2 and Parallel Climate Model) and a business as usual human development growth scenario. The two climate models were chosen by Mann et al. as a way to bookend the predicted climate scenarios for California. ArcGIS and the Zonal Statistics as Table tool were used to identify the 25-year ignition probability for each tree stand and each private parcel. The input zonal raster was the Dinkey tree stands polygon layer, the zonal field was the Stand ID (ArcMap attribute table alias "SETTING_ID"). The input value raster was the raw Fire Probability Model (Mann et al. 2016). The average annual ignition probability for each stand was found by dividing the 25-year ignition probability by 25.

Item B—Tree Mortality Adjustment within FVS Model

Mortality Adjustment of Tree Stand Data

Double entries of tree stand information were deleted from the FVS database as their inclusion generated zero values for all of the variables associated with stands with double entries. For the most part, Dinkey Lidar observations were deleted in the cases wherein the duplicates were caused by multiple project observations. Dinkey Lidar data appeared to be less comprehensive than other project data (Dinkey Lidar data tended to have fewer plots and missing species composition information). However, in the Dinkey stands Dinkey Monitoring was removed in preference to Dinkey Lidar because the Dinkey Lidar data preserved additional site species information, although plot numbers were smaller. If Dinkey Lidar was not the additional project, then the project with the least number of plots was removed.

The tree mortality adjustment methodology used was based on that developed by Ramiro Rojas of the USFS. Ecosystem Disturbance and Recovery Tracker (eDaRT) data from 2014, 2015, and 2016 was obtained from USFS (2017 data was not in the same format, nor finished for the year and could not be used). The data was uploaded to ArcMap and the Zonal Statistics tool was used to obtain the maximum value of the magnitude of eDaRT change for each pixel over the years 2014-2016. The raster was then reclassified according to the coding associated with the eDaRT magnitude scale and "NoData" values (-1 and 1-19) were excluded to allow for the calculation of the average change across each tree stand using the tool Zonal Statistics as Table. This produced a weighted average of the magnitude of change to determine which USFS keyword file mortality adjustment should be used in FVS.

Tree stands with a weighted average disturbance magnitude less than 20 were coded with a "1," tree stands with a weighted average disturbance magnitude between 20 and 50 were coded with a "2" per the methodology provided by Ramiro Rojas (USFS) who created the keyword files (Table 4-B-1). No tree stands experienced a weighted average of disturbance with a magnitude greater than 50.

Table 4-B-1. Basal area change category (from Blue Canyon treatment descriptions 6-25-2017, Ramiro Rojas, USFS).

code	Basal Area Change	kcp file name
0	-10	NONE_
1	0	BET_UNF
2	0.3	BET_2050
3	0.4	BET_50100
4	0.5	BET_100
5	0.75	BET_100
6	TREATED WITH ENHANCE SURVIVAL	BET_SPEC

Public tree stands in the vicinity of the private parcels of interest were found to experience low levels of mortality (by magnitude weighted by area). A visual inspection of the magnitude and area of the landscape indicates that the WUI zone, which has been a focus for fuel treatments and vegetation management by the USFS, may have experienced a depressed impact of the mortality event that may not be reflected in all of the Dinkey private parcels of interest. An NDVI assessment of 2017 data, however, does not show a significant difference in cover due singularly to private or public boundaries (Appendix Item D).

The kcp files for use in FVS reduce basal area in the study stands based off a relationship created between the eDaRT data and basal area loss found through a ground-truthing survey performed by the USFS. The kcp files apply this basal area loss differently depending on tree species per the findings of that survey.

Data that is forthcoming from eDaRT (expected early 2018) will enhance the power of eDaRT to register disturbances.

Item C—Number of Random Fires Determination

Conditional flame lengths produced by FlamMap under a no treatment scenario with 1,000 randomly seeded fires were compared to those produced from a no treatment scenario with 10,000 randomly seeded. Running the model with 10,000 fires presented significant time constraints with each run requiring over 45 minutes processing time. While a paired t-test determined that there was significant difference between these two scenarios, this difference was significantly less than the difference between the conditional flame lengths of treatment and no treatment scenarios. Furthermore, model outputs for both scenarios produced more than 70,000 data points, and it is likely that any significant difference in conditional flame length between the 10,000 and 1,000 fires scenarios was due to working with such a large dataset. Because of this, it was determined that it was sufficient to use model runs that simulated 1,000 fires, as was done in previous studies (Moghaddas et al. 2010).

Item D—Justification for Using Public Lands Data for Private Land Management

Satellite imagery of the Dinkey Landscape from mid-summer (July, 2017) was obtained from the Sentinel-2 satellite and analyzed using Google Earth Engine. This satellite imagery produces twelve band images, including Red and Near Infrared at ten-meter resolution. The imagery was uploaded to Google Earth Engine and clipped to the tree stand polygons on public land and to the private parcel polygon layer. A normalized difference function was used to create two NDVI layers, one for private lands and one for public. Histograms were produced in Google Earth Engine to compare vegetation on public and private lands. No significant difference in NDVI was found as a result of the public-private boundary.

Item E—Forest Distribution Changes and Strategic Reforestation on the Dinkey Landscape

The Dinkey CFLRP recognizes their uncertainty as to climate effects on vegetation distribution in the region over long-term climate projections (Dinkey Collaborative Forest Landscape Restoration Program 2017). Therefore, understanding how reforestation efforts may be coupled with the beneficial impacts of forest thinning on private lands may be key to facilitating forest resiliency to future climate change (Reynolds et al. 2013). Evidence from other areas within the Sierra Nevada Mountains indicates that elevation shifts upslope for forest types such as Sierra mixed-conifer forest (McIntyre et al. 2015), and potential loss of more fire-resistant species such as ponderosa pine, may occur under current climate projections (McCullough et al. 2015). Analysis of historical forest structure found that historical conditions were characterized by reduced forest canopy, higher basal area, and greater heterogeneity compared to current conditions (Stephens et al. 2015). The period of fire suppression during the mid 20th-century aided the encroachment of shade-tolerant white and red firs from higher elevations, and chaparral from lower elevations, into historically mixed conifer and ponderosa habitat. This increased competition has led to the stressing and exclusion of more fire-resistant pine species, higher fuel loads, and potential future changes in vegetation type if large-scale and frequent outbreaks of bark beetle attacks continue (Pile 2017). In order to either preserve current vegetation distributions or adapt to future distributions under projected climate change, there is a need to prioritize areas of likely change.

Within the CFLRP reforestation framework, there is an expressed desire to improve the ability to anticipate future climate distributional changes of dominant forest types to optimize reforestation efforts in conjunction with fuel treatment (Dinkey Collaborative Forest Landscape Restoration Program 2017). Simulations of changes in habitat suitability for dominant forest types across the Dinkey Landscape were conducted and the full results and methodology detailed below. Key results show that current distribution of desirable forest cover types (Sierran mixed conifer, ponderosa pine) are likely to shift outside of their present ranges as they are displaced by lower montane chaparral (Figure 4-E-4). Given that chaparral is prone to higher-severity fire that could cause more damage on private lands (Skinner et al. 1996), prioritizing reforestation efforts with fuel thinning would be advantageous to private landowners wishing to retain or achieve lower-severity fire regimes characteristic of pine-dominated forests.

Methods

Maximum Entropy modeling software (Philips et al. 2017) was used to assess current (MaxEnt Version 2.0), and estimate future (Maxent Version 1.4), distribution for several key vegetation types that compose the dominant vegetation cover surrounding and comprising private landowner parcels in the WUI. Climate data was sourced from WorldClim and Basin Characterization Model (BCM), including future conditions based on the 5th assessment by the Intergovernmental Panel on Climate Change spanning four GCM climate projections. At its simplest, MaxEnt estimates relationships between recorded species presence observations and the environmental conditions found across study sites. The program begins by assuming even probability of distribution across a landscape, and then calculates new probabilities of co-occurrence between the recorded observations and environmental covariates. Much like logistic regression, this helps characterize key covariates for an average presence observation and determines all possible locations fitting the explanatory covariates across the region of interest. The standard output is a gradient of habitat suitability that can be analyzed using ArcGIS.

Due to resource constraints the USFS typically does not record individual presence data for plant species, except on specific project sites, preferring instead to monitor overall vegetation types by aerial survey. Observational inputs for MaxEnt were derived from the most recent LANDSAT aerial survey (USFS 2016), with California vegetation types pre-coded based on spectral band, ground-truthing, and historical knowledge (Nelson et al. 2015). Random points were seeded across the southern Sierra Nevada landscape, masked for each vegetation type, and georeferenced to simulate the necessary occurrence data inputs for MaxEnt.

The primary focus for this analysis is Sierran mixed-conifer forest (SAF Code 243), but the following forest cover groups were also modeled for comparison: ponderosa pine (SAF Code 245), white fir (SAF Code 211), red fir (SAF Code 207), hard chaparral (SAF Code 262), canyon live oak (SAF Code 249), and black oak (SAF Code 246). Using the CALVeg Existing Vegetation Layer (USFS 2016), which contains categorized grid cells from remote sensing surveys, all vegetation types within the Dinkey Landscape were converted from polygons to a raster of SAF Cover Types (dominant vegetation type > 80%), and then the total area by type was compared. Prioritization for inclusion in this study balanced both the total landscape area covered by each vegetation type, its proximity to private landowners, and neighboring vegetation types that are likely to invade or recede according to current literature. Examples include mixed-conifer replacement by white fir and pacific ponderosa replacement by oak and hard chaparral (McIntyre et al. 2015, McCullough et al. 2015). Red fir results were ultimately excluded from this report since its present range only occurs in the upper northwest elevations of the landscape, does not intersect with private parcels of interest, and under most climate projections became completely extirpated from our study region boundaries.

19 WorldClim bioclimatic variables, 9 Basin Characterization Model (BCM) climate-hydrological variables, fire ignition probabilities (Mann et al. 2016), and 4 topographical variables were tested as potential covariates. Collectively, these variables represent 30-year averages from 1980-2010 and 2040-2069. Using jackknife and area under the curve testing in MaxEnt, this list was narrowed down to only BCM and fire variables based on their performance in maximizing predictive capacity. This analysis agrees with existing literature, primarily concerning climate water deficit and evapotranspiration relationships, as they has been shown to have a significant role in predicting forest response to climate change (Lutz et al. 2010, McIntyre et al. 2015, McCullough et al. 2015). All datasets were projected to NAD 83 California Teale Albers and modeled across the entirety of the southern Sierra Nevada range so as to train the model across the fullest extent of forest cover presence, which establishes stronger statistical relationship with environmental conditions. This provides more realistic results that puts habitat suitability within the Dinkey Landscape into relative context with the broader Sierran range and reduces the risk of inflating suitability levels at the local level.

Since climate projections are inherently uncertain, four projections were used to represent a spectrum of potential climate stress, ranging from least to most extreme as follows: cool-wet (MPI rcp 4.5), cool-dry (MIROC rcp 4.5), warm-wet (CCSM rcp 8.5), and warm-dry (MIROC rcp 8.5). This is a strategy also employed by current literature (McCullough et al. 2015). RCP stands for representative concentration pathway, with 4.5 indicating global carbon emissions plateau by mid-century while 8.5 indicates a business as usual scenario, with emissions continuing to climb.

MaxEnt modeling was conducted across 15 training runs for each forest cover type, including subsampling of 25% for model testing, at up to 5000 iterations each. This process was re-run four times for each forest type to include each climate projection. ArcGIS was used to display outputs for comparison, as well as to create difference raster layers between future and present, with negative values indicating a loss in suitability and positive values indicating a gain. Since separate runs had to be conducted for each climate future, the scenarios were averaged using the Cell Statistics tool to create a composite average for each forest type. These were then reclassified into quantiles to identify the most at risk areas in need of reforestation, if the desire is to retain forest cover of interest, as well as potential areas for assisted migration, if the desire is to proactively adapt forest coverage to novel habitat suitability in response to increasing climate stress.

Results

There was high overlap between the present range of mixed conifer forest, as detected by aerial survey, and modeled output of potential distributional range (Figure 4-E-1). MaxEnt was able to successfully predict forest cover distribution using artificially generated presence data throughout the Sierra Nevadas as well as within the confined Dinkey Landscape study area. Areas of highest suitability of future species range (0.85 out of 1) were located in the interior bands of forest distribution, while areas of lowest suitability (approx. 0) were mapped for areas of likely absence, and thus low suitability.

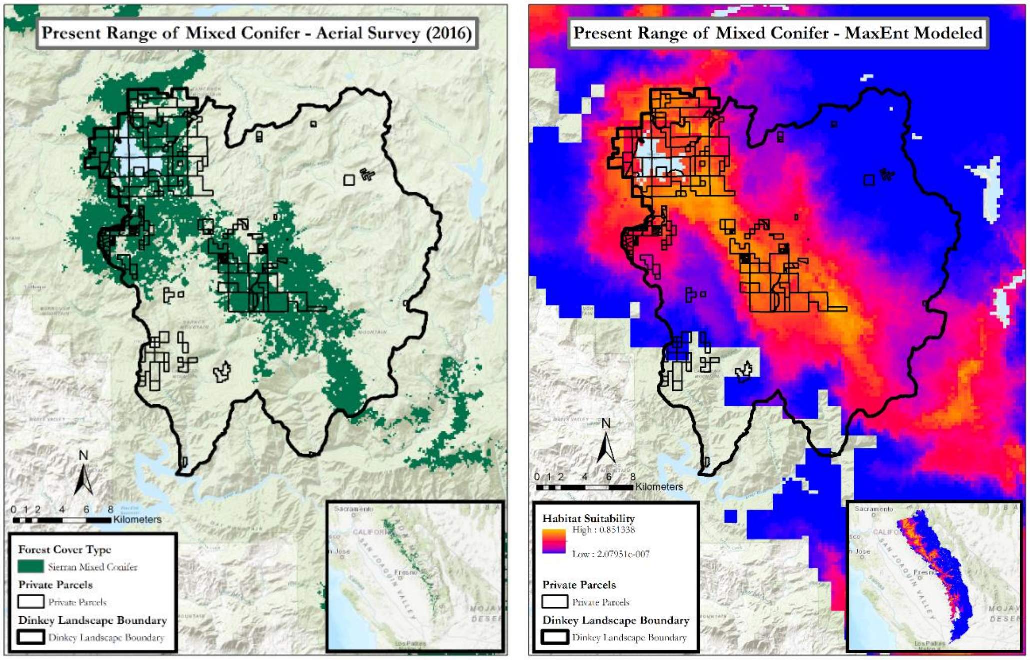

Figure 4-E-1. Present range of Sierran mixed conifer as determined by aerial survey (left) and predicted distribution based on presence points from throughout the southern Sierra Nevada range (right).

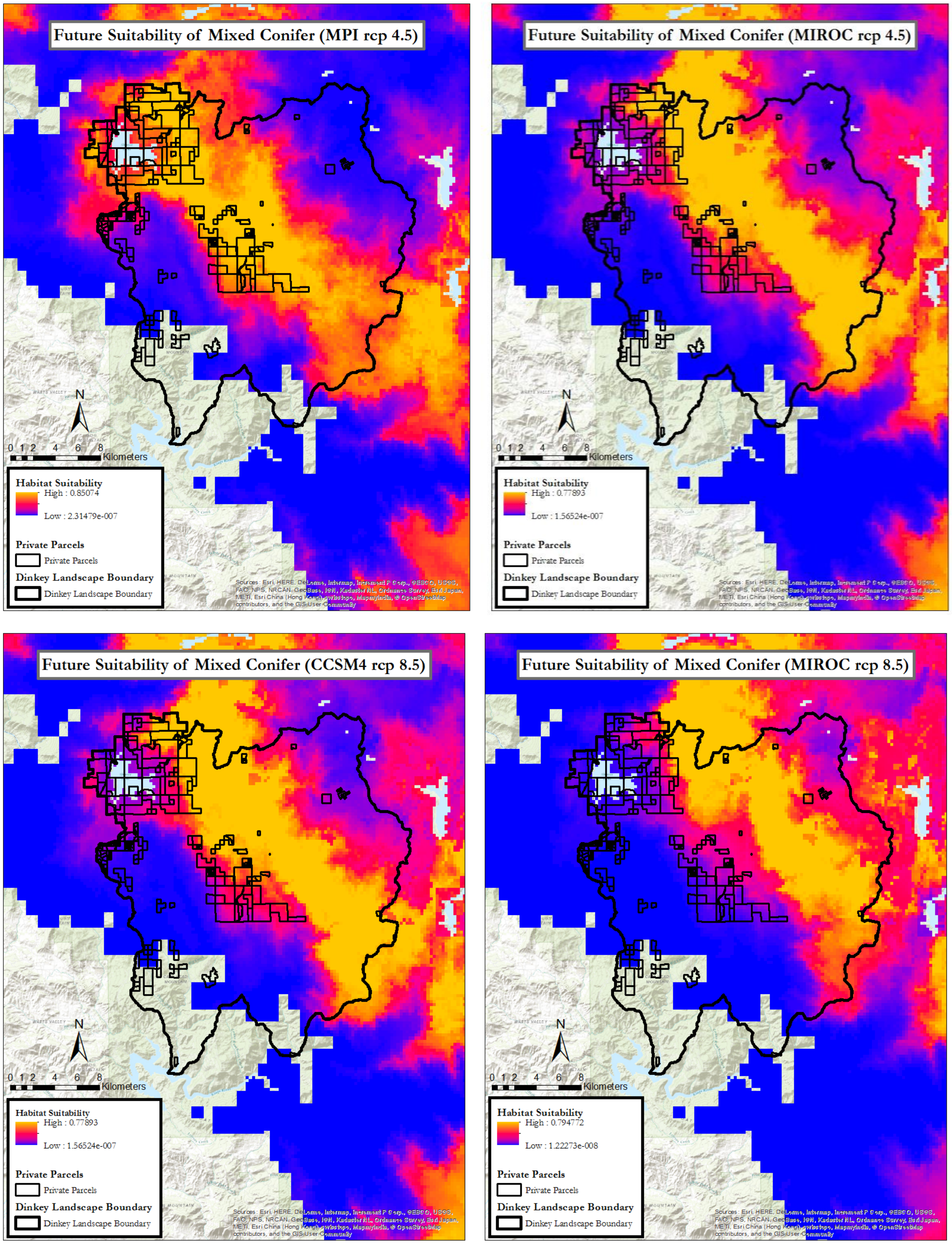

Figure 4-E-2. MaxEnt outputs for four climate projections of mixed conifer from left to right: cool-wet (MPI rcp 4.5), cool-dry (MIROC 4.5), warm-wet (CCSM4 rcp 8.5), warm-dry (MIROC rcp 8.5).

Results for mixed conifer forest across climate projections showed progressive shifts in forest distribution from present range toward higher elevation areas in the northeast part of the landscape by 2050 (Figure 4-E-2). Distributional shifts were less pronounced under cool-wet future conditions (MPI rcp 4.5), with some expansion of the highest regions of habitat suitability. However, this shift becomes more pronounced under more extreme conditions, such as the warm-dry projection (MIROC 8.5). Under all four scenarios, areas of highest habitat suitability actually expanded (within the Dinkey Landscape but outside of private parcel boundaries), but forest cover almost completely shifted out of its present distribution under the most extreme climate projection. Averaged results across future distribution preserve the strong northeast elevation shift in mixed conifer forest cover, as observed under the progressively extreme climate scenarios (Figure 4-E-3).

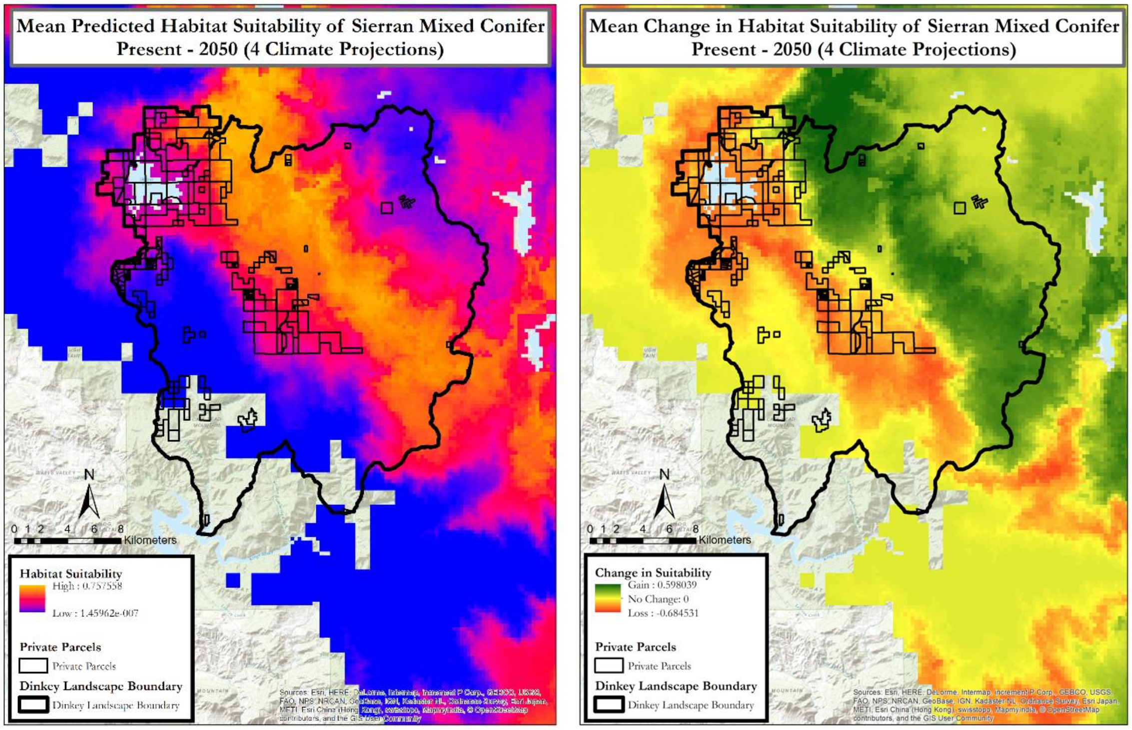

Figure 4-E-3. MaxEnt output of mean predicted future distribution of habitat suitability (left) and mean change in habitat suitability from present distribution, coded as gain vs loss (right).

Maximum suitable habitat decreased from an average present value 0.76 to 0.70 within the Dinkey, with 42% of the landscape experiencing a gain in suitable habitat and 47% experiencing a loss. Like mixed conifer, white fir, ponderosa, and oaks experienced decreases in the maximum habitat suitability across the landscape (Table 4-E-1). Black oak and white fir experienced the greatest loss in percent acreage of suitability, while canyon live oak and ponderosa experienced the greatest gain. The magnitude of highest suitability was less within Dinkey than elsewhere in the Sierras for present and future scenarios.

Table 4-E-1. Summary statistics from MaxEnt present and future distribution results for average test area under the curve (AUC), present and future highest suitability, greatest magnitude of gain and loss in suitability between present and future, and the percent of the landscape experiencing gain or loss of each forest type. Aerial surveys did not cover the entirety of the landscape, so proportions of landscape do not add up to 100%.

Forest Cover Type	Ave. Test AUC	Highest Present Suitability in Sierras	Highest Future Suitability in Sierras	Highest Present Suitability in Dinkey Only	Highest Future Suitability in Dinkey Only	Highest Gain	Gain of Landscape Acres	Highest Loss	Loss of Landscape Acres
Mixed Conifer	0.91	0.85	0.76	0.70	0.60	0.60	42%	-0.68	47%
White Fir	0.86	0.81	0.76	0.78	0.70	0.58	18%	-0.75	73%
Ponderosa	0.89	0.83	0.81	0.64	0.54	0.43	64%	-0.33	25%
Canyon Live Oak	0.87	0.87	0.85	0.79	0.73	0.66	70%	-0.48	19%
Black Oak	0.92	0.82	0.75	0.75	0.57	0.69	54%	-0.60	35%

As with mixed conifer, ponderosa pine, white fire, black oak, and lower montane chaparral, habitat suitability shifts with elevation (Figure 4-E-4**)**. The current range of white fir in the northeast quadrant of the landscape is projected to decrease by more than half by 2050. Ponderosa, in contrast, retains significant suitable coverage throughout the landscape, although it too shifts outside of its present range almost entirely. However, ponderosa is also a dominant species within mixed conifer forest, so these areas would likely become novel habitat for ponderosa pine forests, but not the species itself. Similar to ponderosa pine, black oaks also shift outside their present range almost entirely, but into a range where they currently exist as an interspersed and patchy tree species. Lower montane chaparral appears to be the cover type projected to be codominant with ponderosa pines across much of the private parcel landscape. This finding is hopeful in terms of retaining ponderosa pines on the landscape, but also worrisome given lower montane chaparral's higher-severity fire regime and encroaching proximity to private lands. Further, such a dramatic shift would likely result in cascade changes throughout the many other animal species presently located in the area that would need to adapt quickly enough to move to regions farther east and higher in elevation where preferred habitat is likely to migrate.

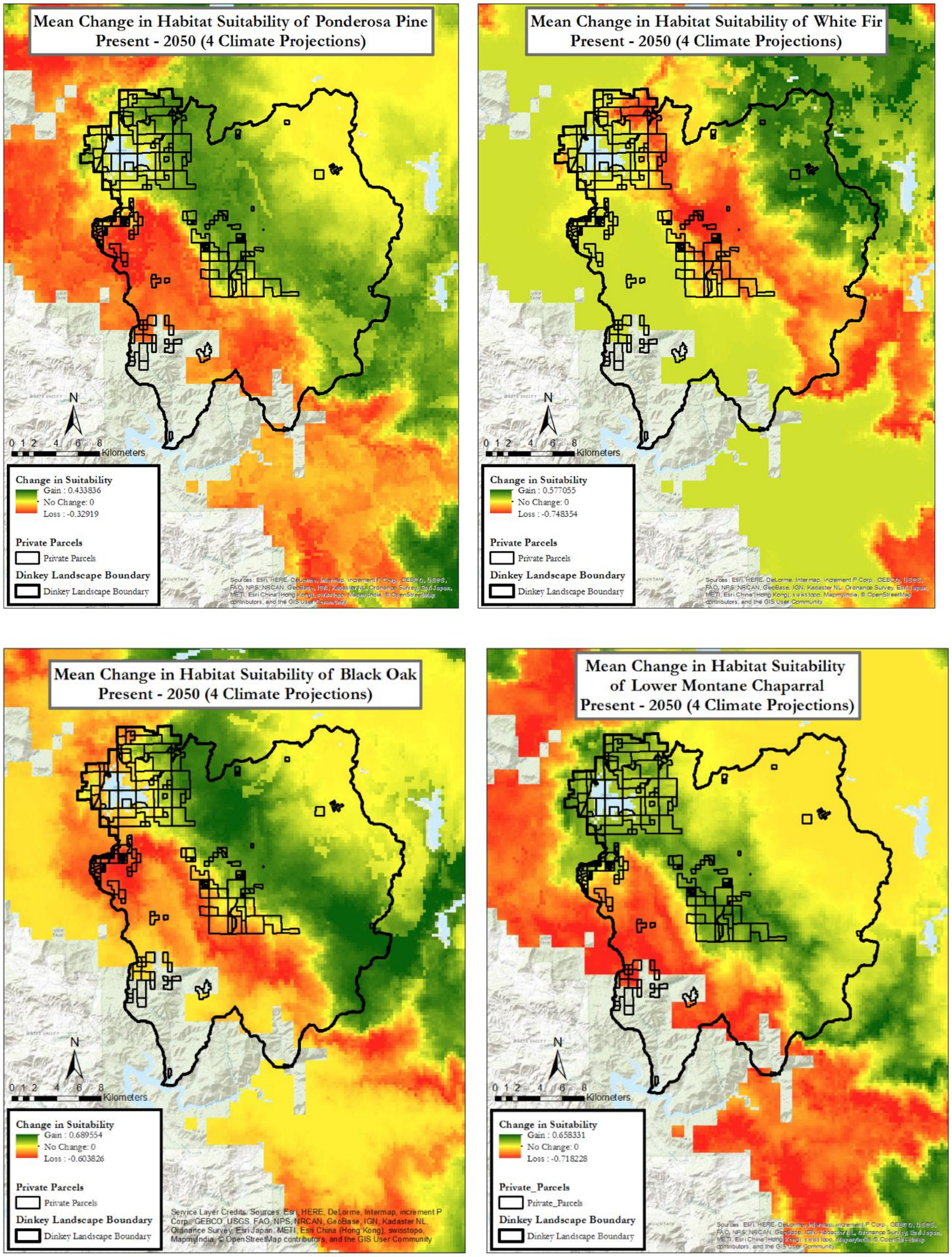

Figure 4-E-4: Mean change in habitat suitability for ponderosa pine (top left), white fire (top right), black oak (bottom left), and lower montane chaparral (bottom right).

Areas suitable for immediate mixed conifer reforestation within the current mixed conifer distribution on private lands were assessed by examining areas of projected levels of climate stress (i.e. habitat suitability loss) in 2050 (Figure 4-E-5). Highest ranked areas occur within the Shaver Lake and Exchequer regions.

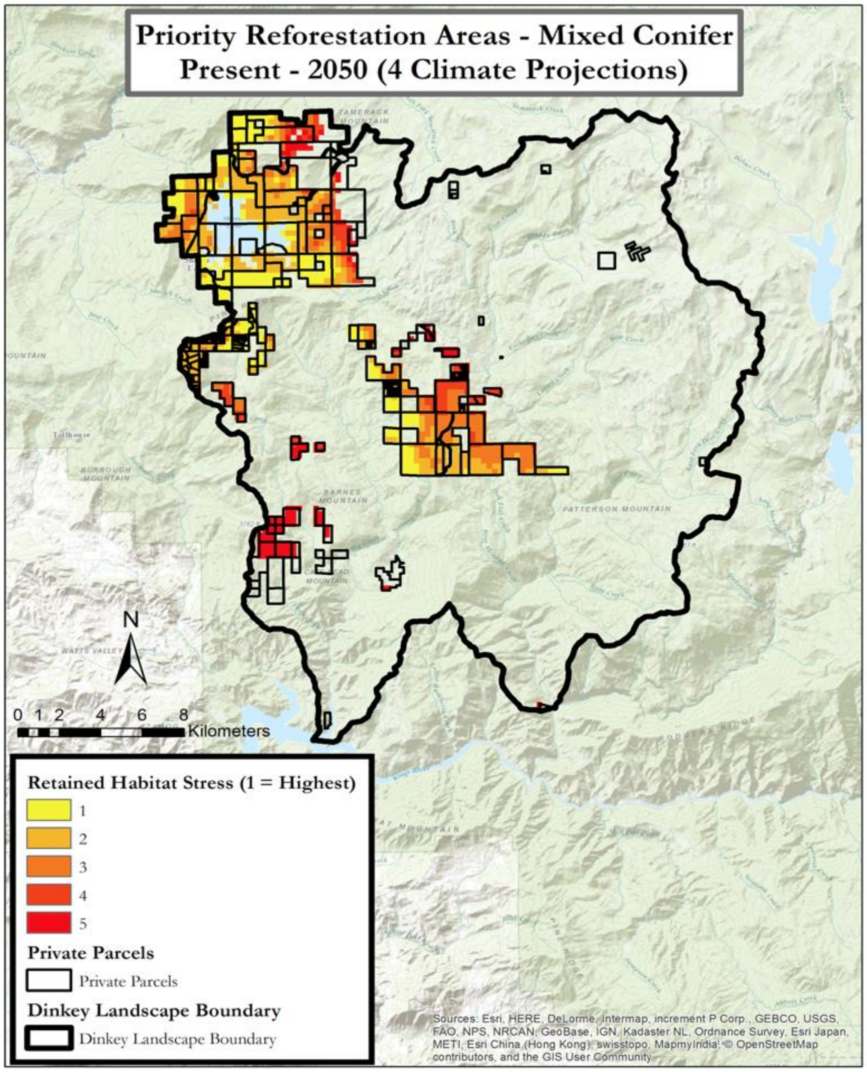

Figure 4-E-5. Potential reforestation areas of current forest cover distribution ranked by level of climate stress likely to occur by 2050.

Section 5—Fuel Treatment Cost-Benefit Analysis

Introduction

The recent fires in Napa, Sonoma, and Lake Counties, CA – the 2017 Tubbs Fire – and in Ventura and Santa Barbara Counties, CA – the 2017 Thomas Fire – have demonstrated how devastating catastrophic fires can be to lives and livelihoods. The costs associated with these high severity fires are astronomical. Fuel reduction methods and vegetative management strategies such as prescribed burning, hand thinning, and mechanical thinning, however, have been shown to have positive impacts on reducing fire severity (Moghaddas et al. 2010; Stephens et al. 2009; Fettig et al. 2006). This cost-benefit analysis aims to explore whether the benefits of reducing fire severity through fuel treatments exceed the costs of performing those fuel treatments.

This cost-benefit analysis explores the costs and benefits borne and accrued by three distinct stakeholders: Dinkey Landscape private landowners, the SRCD, and the High Sierra District of the USFS. In this analysis private landowners are represented as bearing the entirety of fuel treatment costs. In actuality, implementation of fuel treatments on the landscape may be paid for by a number of parties via personal investment or grant funding. This analysis simplifies the interpretation of the net present value (NPV) of investing in fuel reductions from the perspective of the private landowner by assigning the entirety of the costs of treatment to the landowner. The SRCD, as a representative of the private landowners, is also concerned with the costs and benefits attributed to that stakeholder. Therefore, for the cost-benefit analysis from the perspective of the SRCD the entity bears all the costs and accrues all the benefits attributed to private landowners in addition to some of the ecological benefits of fuel treatments which play into the entity's mandate. As this cost-benefit analysis is intended to inform the SRCD's grant application process, not representing the costs as borne by singular stakeholders (either the private landowners or the SRCD) provides the SRCD with more flexibility in their approach to applying for funding and utilizing this analysis as a support tool.

Summary of Results

Table 5-1. NPV per stakeholder per discount rate and climate scenario under a prioritized treatment scenario using hand thinning.

Stakeholder	7% Discount Rate		5% Discount Rate	
	GFDL Climate Scenario	PCM Climate Scenario	GFDL Climate Scenario	PCM Climate Scenario
Private Landowner	$111.76 million	$111.95 million	$136.21 million	$135.40 million
SRCD	$141.82 million	$148.00 million	$173.60 million	$183.03 million
USFS High Sierra District	$24.11 million	$24.11 million	$29.69 million	$29.69 million

Table 5-2. NPV per stakeholder per discount rate and climate scenario under a prioritized treatment scenario using mechanical thinning.

Stakeholder	7% Discount Rate		5% Discount Rate	
	GFDL Climate Scenario	PCM Climate Scenario	GFDL Climate Scenario	PCM Climate Scenario
Private Landowner	$243.16 million	$243.45 million	$288.58 million	$287.77 million
SRCD	$273.22 million	$279.40 million	$325.97 million	$335.40 million
USFS High Sierra District	$24.11 million	$24.11 million	$29.69 million	$29.69 million

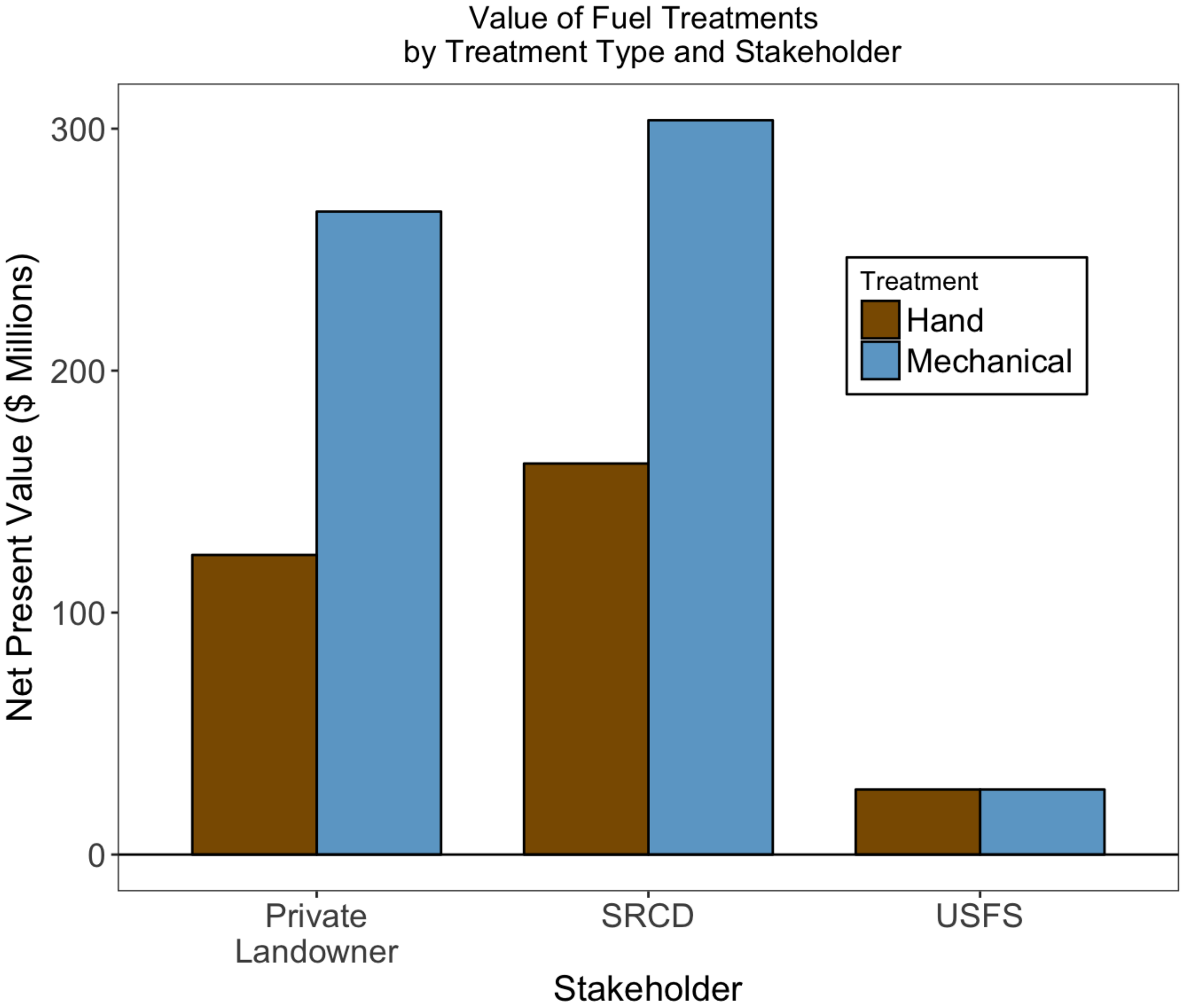

Figure 5-1. NPV of fuel treatments to private landowners, the Sierra Resource Conservation District and the United States Forest Service, for mechanical thinning and hand thinning. These values are averages across two climate projections (PCM and GFDL), and two different discount rates (5% and 7%).

Methodology and Results

Results from fire behavior modeling were used to inform this cost-benefit analysis. In this analysis, the wildfire impacts of the prioritized treatment schema developed through the fire behavior modelling were compared to the wildfire impacts of the no treatment scenario. The prioritized treatment simulated fuel reductions on 5,650 acres – 21% of the private parcel landscape – every 10 years from 2018-2050. A discount rate of 7%, the accepted discount rate from the U.S. Office of Management and Budget for private investments, will be used for the cost-benefit analysis. However, because funds for implementation may be supplemented or supplied by state and federal grants, costs and benefits were also assessed under a 5% discount rate, which provides a conservative measure for federal discount rates – as compared to the current 2% discount rates – as they begin to increase from their post-2008 lows (Federal Reserve 2017).

Costs to the Private Landowner

We quantified the direct costs of conducting fuel reductions under a prioritized treatment method. This treatment method includes thinning paired with pile burning of materials less than 12 inches DBH. Costs of the thinning treatments and piling of slash were determined by costs of services listed in memorandums of understanding (MOUs) between the SRCD and local contractors, as well as figures for mechanical thinning costs from previous work in the northern Sierra Nevada (Holl 2007). Treatment costs were assessed for a landscape thinned entirely by hand or entirely by mechanical thinning. Average costs for mechanical thinning and pile burning were determined to be \$2,750/acre (Holl 2007). Average costs for hand thinning and pile burning, based on the signed MOUs, are \$2,025/day. Using a hand thinning treatment project currently underway on the landscape, the rate of hand thinning is determined to be 0.2 acres/day (C. Ashley, personal communication, October 19th). Therefore, the per-acre cost of hand thinning and pile burning were determined to be \$7,375 per acre. The net present value (NPV) of the costs associated with four treatment cycles over 33-years under a prioritized treatment scenario (treating 5,650 acres) will be \$79.1 to\$92.6 million, using hand thinning, and a 7% or 5% discount rate, respectively. Treatments using mechanical thinning over the same area cost \$29.5 to \$34.5 million, using a 7% or 5% discount rate, respectively.

Indirect costs to land, air, and surface water quality for private landowners can be minimized with appropriate fuel treatments practices. Hand thinning has, arguably, the least impact on soil and water quality, however, the impacts of thinning machinery can be mitigated if thinning activities are properly planned with regard to current soil moisture, soil erosive potential, slope of treated lands, and future weather conditions. Impacts to water quality can be minimized by avoiding streams and channels - e.g. with buffers of 30.5 meters around waterways to exclude mechanical treatment (North et al. 2015). Pile burning in Fresno County is only permitted during identified burn days to minimize the impact on air quality (J. McBougald, personal communication, October 27, 2017).

Benefits to the Private Landowner

Avoided Cost of Private Property Damage from Catastrophic Fire

The fire behavior modeling performed in this study confirmed that thinning activities paired with the removal of large fuel from the landscape and pile burning of slash fuel results in a reduction in fire severity. As such, a primary benefit of fuel reduction activities is the avoided cost of catastrophic fire. The fire behavior model's outputs include a metric called "conditional flame length," which is the length of the flames in a wildfire one can expect given the *condition* that there is an ignition source. The conditional flame length is a measure of potential fire severity. Conditional flame lengths were placed into six bins based on the conditional flame length range (Figure 5-2). In this report, high severity fires are defined as simulated fires with conditional flame lengths of 8ft. or greater (bins 5 and 6), medium severity fires as fires of conditional flame lengths of 4ft.-8ft (bins 3 and 4)., and low severity fires defined as fires of conditional flame lengths of 0ft.-4ft (bins 1 and 2). These fire severity categories were determined by private parcel damage metrics associated with the conditional flame length ranges; metrics previously determined by a southern Sierra Nevada Mountains study by Thompson et al. 2016 (Figure 5-2).

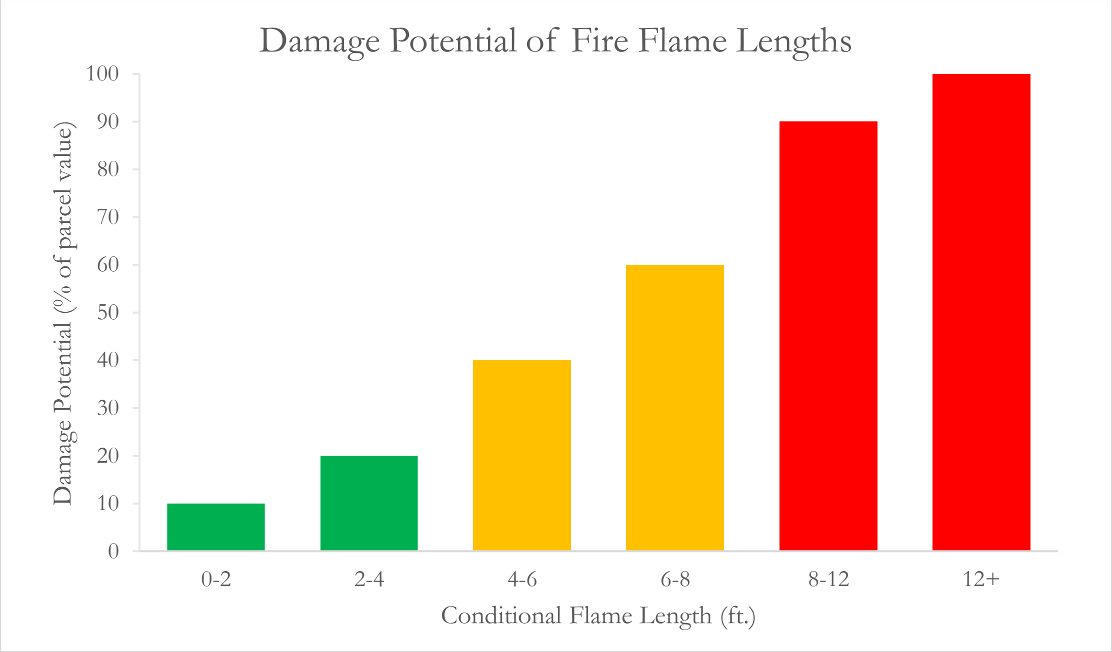

Figure 5-2. Conditional flame lengths grouped by fire severity (green indicates low severity fire, yellow medium severity, and red high severity fire) and graphed by the potential percent loss of private parcel value the flame lengths can cause (data from Thompson et al. 2016).

Because the results of the model assume that an ignition source exists, the probability of a fire occurring must be included in the benefits calculations to temper the results, as it would not be appropriate to assume that a wildfire burns every private parcels of the Dinkey Landscape every year. The probabilities of fire ignitions across the landscape, produced by Mann et al. 2016, provides the average annual probability of fire ignition under two climatic scenarios which are intended to bookend the projected climatic extremes for California: the Parallel Climate Model (CMIP3 PCM A2) and the Geophysical Fluid Dynamics Laboratory (GFDL A2) climate model.

Private parcels were sectioned into three community areas based on geographic and socio-economic conditions. There three community areas were the Shaver Lake area in the northwest, the Chambers Tract, Providence, and Exchequer Heights area in the center of the landscape, and the southwest area for the dispersed parcels in the southwest. Land and improvement values were provided for private parcels by the County of Fresno. Because of missing values, average land values per acre were calculated at the community-scale and applied to each parcel in the community area.

An average conditional flame length was calculated for each private parcel from the fire severity model outputs for each of the years modeled (2018-2050). The conditional flame length was then binned into one of the six corresponding fire severity bins. Each fire severity bin has an associated percent damage due to fire defined by Thompson et al. 2016. This percent loss in value was then applied to the appropriate parcels corresponding to the parcels' assessed fire severity bins.

The product of the probability of fire ignition on the landscape under the two different climate,the number of acres on private parcels in each of the six fire severity bins, the depreciation in the value of private associated with the six bins of fire severity, and the average land value per acre represents the economic damage resulting from fire..

DV = Percent loss in land value for severity levels 1-6
SA = Acres per fire severity level for severity levels 1-6
LV = Value of land per acre
P(I) = probability of ignition

$$D = \sum_{1}^{6}(SA * DV)) * (LV * P(I))$$

The difference between the NPV of damage under a no treatment scenario and the NPV of damage under the prioritized fuel treatment scenario yielded the cost avoidance benefit of treatment. When this benefit is assessed over the 33-years of fire behavior modeling, \$190.85-\$228.81 million in costs to private landowners are avoided by performing fuel treatments. The lower bound of this range is the cost avoidance under the GFDL climate model for ignition probability and a 7% discount rate, whereas the upper bound is represented by the cost avoidance under the same climate model scenario, but a 5% discount rate.

Revenue Generation and Avoided Treatment Cost

Mechanical thinning represents an opportunity for some landowners to profit directly from fuel treatments as well as avoid the upfront cost of treatment itself. This potential revenue comes from the local contractor for Sierra Forest Products (SFP), which may pay up to \$50/1,000 board-feet of quality timber harvested from forest thinning on private lands back to landowners on top of absorbing treatment costs (K. Duysen personal communication, October 23, 2017). However, there are several restrictions that constrain the applicability of this revenue generation for the Dinkey private parcel landscape. These restrictions are: a private parcel must be at least 20 contiguous acres and each acre must have, at minimum, 3,000 board-feet of merchantable wood for harvest (K. Duysen personal communication, October 23, 2017).

Given these restrictions, for the four treatment cycles simulated in this study only a portion of private parcels met the restrictions that would allow for Sierra Forest Products to treat their parcels and provide landowners with a margin for the wood removed. Out of the 615 private parcels, in the first treatment cycle 59 parcels met the requirements, in the second cycle 40 parcels met the requirements, in the third treatment cycle 37 parcels met the requirements, and in the fourth and final treatment cycle 104 parcels met the minimum requirements. There are two benefits of using Sierra Forest Products' services: the avoided cost to landowners of mechanical thinning plus potential revenue from removed merchantable wood. These benefits accrue to an NPV of \$81.8-\$94.3 million, with 5% and 7% discount rates applied respectively. While these simulated treatments are hypothetical and do not guarantee a set revenue to landowners, they do indicate a potential net positive gain in benefits as a result of forest thinning on private lands, with the possibility of generating revenue for private landowners through negotiated agreements with a professional contractor. Even if revenue were not included, and the benefit to private landowners were calculated based only on the avoided cost of treatment, benefits would still be substantial, ranging from \$64.4-\$76.6 million.

Before engaging in any contractual services, please note that if any of the wood removed during fuel treatments is intended to be sold for revenue or to offset the costs of treatment, a timber harvest document must first be filed with CalFire ("CalFire Answers Your Questions on Bark Beetle and Tree Mortality"

2016). When contracting with SFP, the timber harvest permit is handled by SFP (K. Duysen, personal communication, October 27, 2017).

Avoided Cost of Air Quality Effects on Private Landowner Health

Pollution resulting from smoke and ash particles, which are less than 10 microns in diameter (PM_{10}), has been identified as one of the leading atmospheric contaminants due to wildfire (Kusel et al. 2015). While both wildfire and natural forest processes regularly release small amounts of PM_{10} into the atmosphere, high-severity wildfire has the potential to release as much as three times the PM_{10} emissions of a wildfire on a treated landscape (USFS 2007). Lands whose fuels have been thinned produce significantly less PM_{10} in the event of wildfire than lands that have not been treated (USFS 2007). Fuel thinning would thus produce indirect benefits for private landowners in the form of avoided costs of degraded air quality in the event of a wildfire. Avoided costs of degraded air quality include: avoided health costs due to poor air quality, avoided loss in revenue from recreation and visitors, and avoided school and business closures as a result of poor air quality. Because the metric for quantifying the benefits of better air quality depends on population and the population of the private lands on the Dinkey Landscape is transient – with many second-home owners in Shaver Lake and part-time inhabitants of family land in the central and southwest parcels – this air quality benefit could not be assessed for private landowners, but was quantified for the SRCD cost-benefit analysis.

Costs to the SRCD

As a representative of the private landowners on the Dinkey Landscape, and the entity tasked with several wildfire mitigation responsibilities under the Fresno County Hazard Mitigation Plan (2009), the SRCD is concerned with the costs borne by their private landowner constituents. Under some funding strategies and management schemes detailed in Section 6, the SRCD may take on the entirety of costs associated with implementing fuel treatments. As such, in order to present a comprehensive cost-benefit analysis for the SRCD, the costs of fuel treatments, identical to those in the cost-benefit analysis for private landowners,is also considered a cost to the SRCD. The NPV of the costs associated with four treatment cycles over 33-years under a treatment scheme prioritized to produce the greatest reduction in fire severity will be 5,650 acres at $79.1-$92.6 million under hand treatment only and 7% and 5% discount rates respectively, and 5,650 acres acres at $29.5-$34.5 million under mechanical thinning only and 7% and 5% discount rates.

Benefits to the SRCD

Avoided Cost of Private Property Damage from Catastrophic Fire

Avoided property damage is the key benefit accrued to private landowners. Because the private landowners are key constituents to the SRCD and because this cost-benefit analysis also attributes the costs borne by private landowners to the SRCD as well, the private landowners' benefits should also be considered as part of the cost-benefit analysis of the SRCD.

Avoided Cost of Air Quality Effects on Public Health

Pollution resulting from smoke and ash particles, which are less than 10 microns in diameter (PM_{10}), has been identified as one of the leading atmospheric contaminants due to wildfire (Kusel et al. 2015). While both wildfire and natural forest processes regularly release PM_{10} into the atmosphere, a high-severity wildfire on an un-treated landscape has the potential to release as much as three times the PM_{10} emissions of a wildfire on a treated landscape (USFS 2007). The difference between the PM_{10} emissions released from wildfire on untreated (un-thinned) land as opposed to treated land has been estimated to be 0.421 tons/acre (USFS 2005). Regression analysis (Appendix, Item A) was used to explore the relationship between forest regrowth and years since treatment for each assessed treatment cycle to apply a decay rate of benefits to the reduced PM_{10} emission from treated lands. A 2008 USFS assessment used a willingness to pay (WTP) of \$4.95 to reduce each pound of PM_{10} (McPherson et al. 2008). This WTP was based on the population for Fresno County in 1995 (749,534), so the WTP used in this assessment was scaled by the proportion of the projected Fresno County population to the 1995 population using the current population (989,200) and a projected annual growth rate of 0.9% ("Fresno County Economic Forecast" 2016). Using calculated probability of ignitions for the private parcel landscape under the two assessed climate scenarios the NPV of the benefits to air quality produced by fuel treatments was calculated. Over a 33-year, discounted time period, the net present value of avoided PM_{10} emissions on public health accrues to between \$1.62 million and \$4.42 million with the GFDL climate model under a 7% discount rate representing the lower bound of the range and the PCM climate model with a 5% discount rate scenario representing the upper bound.

These figures are likely heavily underestimated as the assessed health impacts ignore the effects of other emissions associated with wildfire, namely $PM_{2.5}$ and ozone. Recent research has shown that the health effects of transient smoke plumes, and specifically, $PM_{2.5}$ can be drastic for the health and mortality of the elderly (Miller et al. 2017). Mixed-conifer landscapes with heavy fuel loading produce 0.357 tons/acre more $PM_{2.5}$ than thinned landscapes with more typical fuel loading (USFS 2005). Research has shown that wildfire smoke exposure, and associated increases of $PM_{2.5}$ concentrations by 2 $\mu g/m^3$, can increase deaths in elderly populations by approximately 0.5 extra deaths per million. Additionally, because even transient smoke exposure can significantly increase mortality, the scope of impacted regions expands beyond the communities in the immediate vicinities of the wildfire to communities within a radius of many hundreds of miles away depending upon the prevailing winds during the wildfire's life. Since severe wildfires burn for several weeks or months and may not be fully suppressed for up to a year, the health-related costs associated with severe wildfires may be extreme (Miller et al. 2017). Although wildfires in treated areas also produce smoke that could become widespread with similar impacts, wildfire in treated areas are easier to contain and produce smaller smoke volume so the length of time with which they burn may be reduced compared to severe wildfires, and thus they would produce fewer days of elevated smoke impacts for communities near and far (Miller et al. 2017; Safford et al. 2009, Buckley et al. 2014).

Increased Water Yield

The impact of fuel treatments and vegetative management on water yield has been a topic of emerging scientific discussion. On the one hand, research has demonstrated that if 40% of a watershed is treated by reducing forest canopy cover from 90% to 60%, or 90% to 30%, water yield can increase by 8% or 16%, respectively (Bales et al. 2011). More recent research, however, has shown that the water yield benefits of fuel treatments are highly dependent on the location and precipitation regime of those treated lands (Saska et al. 2017). The semiarid region of the southern Sierra Nevada is considered too water-limited to experience an increase in water yield from lands treated for fuel reduction. The water benefits that may be gained by thinning vegetation, and thereby decreasing evapotranspiration, are taken up by the remaining vegetation rather than being manifested as water yield increases for human consumption (Saska et al. 2017).

Carbon Sequestration and Greenhouse Gas Emissions Offsets

Forest carbon sequestration helps reduce overall atmospheric CO_2, a key greenhouse gas (GHG), by partially offsetting CO_2 emissions from human sources (Hurteau 2017). While this is not a 1:1 ratio, better quantifying forest sequestration potential, and the impacts of treatment on carbon storage, may be of interest to those wishing to become more involved with broader greenhouse gas reduction programs, including potential funding sources through grants. Forest thinning can result in improved landscape carbon sequestration compared to untreated sites, largely due to biomass growth in mature, remaining trees with larger basal area (Hurteau 2017). Onsite carbon initially drops due to thinning, but increases as the new forest density stabilizes through a combination of natural, lower-severity fire regimes and direct management control. The decision to not thin overgrown areas may thus result in a higher amount of carbon which could be lost to wildfire as combusted atmospheric CO_2 than would be lost from a treated landscape. The methodology that follows aims to mirror, in part, the approach developed by the California Air Resources Board (CARB) and used by CalFire for approving grant awards as part of the Greenhouse Gas Reduction Fund (CARB 2018). In its simplest form, GHG reductions due to fuel thinning are quantified by CARB as the difference in CO_2e (carbon dioxide equivalent as sequestered carbon) on non-treated vs treated land given an annual probability of fire occurrence. Unlike CARB, which characterizes final valuation in terms of proposal dollars requested/tonne of anticipated project GHG reduction, this study aims instead to estimate the value of the change in sequestered carbon as a whole. For more detailed methodology and equations for CARB's approach, please see "Quantification Methodology for the Department of Forestry & Fire Protection Forest Health Program: Fiscal Year 2017 - 2018" (CARB 2018).

The Carbon Report, an output database of FVS, provides estimates for modeled tons of carbon/acre on the landscape after running each treatment and regrowth simulation. Total above-ground standing carbon was used for this analysis, which includes live and dead wood from the canopy to the forest floor. The tons/acre for each private parcel counterpart on public lands (matched using the ordinal logistic regression) was multiplied by the anticipated watershed sub-HVRA-12 damage (Scott et al. 2013) given the conditional flame length (CFL) category, the burn probabilities under GFDL and PCM climate projections (Mann et al. 2016), and the parcel acreage, and then subtracted from the tons/acre per parcel to account for the change. Since low-severity fire can have a beneficial effect on improving carbon sequestration in larger, mature trees, this was captured in the HVRA's categorization of CFL categories 1 and 2 which use a growth, not damage, effect on carbon storage. This was repeated for each year from 2018 – 2050 and then summed to derive the cumulative parcels' total annual carbon storage for both no treatment and treatment scenarios. This value was then subtracted between no treatment and treatment years to derive the net change in sequestered carbon as a result of fuel reduction.

A benefit valuation can be applied in terms of dollars per metric tonne of CO_2e, the metric used in carbon trading markets. As of January 2018, the 5-day moving average trading price of CO_2e on the California cap-and-trade market was $15.28/tonne (California Carbon Dashboard 2018).

The estimated net-present value (NPV) of sequestered carbon (as CO_2e) as a result of treatment ranges from $4.33 million under a GFDL climate to $10.19 million under a PCM climate, each with a 7% discount rate applied. At a 5% discount rate, the NPV ranges from $5.67 million (GFDL) to $13.53 million (PCM). The lower valuation under a GFDL climate may be a result of the GFDL projection estimating higher precipitation patterns for this region approaching 2050, whereas the PCM projection estimates drier precipitation over the same horizon. The wetter conditions under GFDL would likely result in higher plant growth and higher fuel loads, and thus more carbon lost to wildfire (Mann et al. 2016). The positive treatment effect of fuel thinning on carbon storage, while evident in both climate scenarios, is amplified in drier conditions in which plant growth is more delayed and the loss to wildfire less.

The benefits accrued from carbon sequestration are quantified using only the market values for which SRCD may, in the future, be capable of obtaining through carbon credits under the California Cap and Trade Market. The monetary values for this cap-an-trade market do not, however, fully quantify the social costs of carbon. A study by the EPA (Technical Update 2016, p. 4), which did consider the social cost of carbon, provided a range of estimates for the value of sequestered carbon that ranged from below the current California market value to more than ten times its value. This range of values illustrates the variability and uncertainty of the social cost of carbon, and that the value of sequestered carbon produced by fuel treatments on the Dinkey Landscape may be undervalued in this assessment.

Water Quality Improvement

Wildfire mobilizes nitrogen and phosphorus in forest soils and because of the practice of fire suppression nutrients have accumulated to the level that a severe wildfire could have dramatic impacts on water quality (Miller et al. 2006). Severe wildfires also reduce soil porosity, leading to hillslope erosion and rapid runoff of precipitation, contributing to nutrient, ash, and sediment loading in surface waters (Neary et al. 2005). In the short-term severe wildfires have been found to degrade watershed condition by reducing water infiltration into soils, thereby reducing baseflow and storage between precipitation events (Neary et al. 2005). The Dinkey Landscape is part of a watershed identified by the Forests to Faucets USDA project as a watershed of high drinking water importanceThe project identified the forest as important to water supply and wildfire as a significant risk to that water supply. Although the benefits realized in improved water quality through the reduction of wildfire severity on the Dinkey Landscape private parcels are not easily quantifiable, they may be significant in the short-term following a wildfire event.

Benefits to the USFS

Avoided Cost of Fire Suppression

Over the last few decades wildfire suppression costs have increased as fire seasons have grown longer, and the frequency, severity, and size of fires have also increased. Fire suppression expenditures are projected to continue to increase to a ten-year average of $1.8 billion by 2025. This corresponds to a decrease of $700 million in non-fire program funding, including preventive fire measures (USFS 2015). Pre-emptive wildfire management efforts, such as fuel treatments =, can significantly reduce subsequent fire suppression expenditures. Fuel treatments alter burn probability, fire severity, and fire behavior. For example, in the Angora Fire near Lake Tahoe, high-intensity crown fires generally dropped to a surface fire within 150 feet after entering a treated area (Buckley et al. 2014). Fitch et al. (2013) estimated that fire suppression costs in treated areas are reduced by 60% compared to untreated areas, such that on treated lands, costs for fire suppression can range from $200 to $500 per acre, compared to $1000 to $1500 per acre on untreated lands (Fitch et al. 2013). The fire behavior modeling performed for the private parcels of the Dinkey Landscape confirmed that fuel treatments in this region reduce the severity of fire, which reduces potential fire suppression costs. When fuel treatments are implemented under the treatment method that prioritizes treatment on lands that experience the greatest potential in reduced fire severity, the avoided cost of fire suppression, given projected probabilities of fire ignition per year, amounts to an NPV of between $15,253 and $17,797, with the PCM model scenario with a 7% discount rate representing the lower benefit boundary and the GFDL climate model with a 5% discount rate representing the upper bound.

Avoided Cost of Insect Damage

Trees that are already stressed by prolonged and intense drought conditions are predisposed to higher infestation by insect pests and other pathogens, leading to overall higher tree mortality each year. The stand density levels that were modeled under the prioritized fuel treatment scenario produce forest stands that are more resilient to insect infestation than more densely stocked stands (North 2012). Since removal and processing of dead trees on the landscape is part of the annual operating budget for the USFS and Dinkey Collaborative, the thinned forests could provide an avoided cost of emergency response dead tree removal for the USFS. The costs associated with dead tree removal were realized by the USFS in response to the 2015 mortality event, whichresulted in an increase in treatment costs within the WUI (CFLRP Annual Reports 2011-2013, 2016-2017). Since no other mortality drivers, such as wildfire, were prevalent within the landscape, it can be assumed that the increase in treatment costs post-2015 are mostly attributable to increases in insect and pathogen infestation. By comparing the expenditures on hazardous fuel removal within the WUI from years 2011-2013 to those from 2016-2017, an increase in expenditures of $1,765,714.17/year was calculate. Over a 33-year discounted time period, the NPV of avoided cost of insect damage accrues to $24.1 million with a 7% discount rate and $29.67 million with a 5% discount rate.

Limitations

Static Cost Metrics

The costs of fuel treatments to either private landowners of the SRCD in these analyses were assumed to be static throughout the 33 years of the cost-benefit analysis. However, the price of contractor services may change in the future. It is possible that contractor services may increase in cost as demand increases or equipment, transportation, and labor costs increase. Alternatively, contractor services may decrease in cost as demand generates interest for new contractors to establish themselves, driving down the price of thinning services through competition. to reflect these possible changes in treatment costs, a sensitivity analysis was performed that increased costs by 5% each successive treatment cycle and another sensitivity analysis was performed that decreased costs by 5% each treatment cycle.

Under a 5% increase in price per treatment cycle, costs of treatment increased to $82 million-$97 million for hand thinning under 7% and 5% discount rates respectively. Mechanical thinning costs increased to $29 million-$36 million under 7% and 5% discount rates respectively. When costs were decreased by 5% each cycle costs of treatment decreased to $76 million-$88 million for hand thinning and to $29 million-$32 million with mechanical thinning under 7% and 5% discount rates respectively. While the magnitude of the NPVs for both private landowners and the SRCD responded to these changes in the cost of treatment, when compared to the NPVs of static costs of treatment, private landowner and the SRCD's NPVs remained positive for both treatment methods, climate projections, and discount rates.

Small changes in the costs of fuel treatments are thus unlikely to change whether private landowner or the SRCD's NPVs of investing in fuel treatments are positive or negative, but the changes do impact the magnitude of the NPVs. If costs of fuel treatments change drastically or more quickly, the cost-benefit analyses should be revisited.

Disregard of Potential Reforestation Projects

One cost that is not considered in the cost-benefit analyses is the cost of reforestation. Currently there are few reforestation efforts occurring on private lands on the Dinkey Landscape, however, the Dinkey Collaborative recently completed a reforestation framework for Dinkey public lands that may also be applicable to private lands. Since it has been found that pairing fuel treatments with post-treatment reforestation efforts aids in forest recovery and potential resilience to environmental stressors, reforestation may be an action considered for public lands that undergo fuel treatments in the future. Because reforestation was not the most immediate restoration concern for private lands on the Dinkey and because Dinkey reforestation objectives were not clearly defined until just recently, this report does not attempt to quantify the costs of benefits of reforestation in monetary terms. However, it is evident that actual implementation of reforestation projects on private lands may be more successful if private landowners execute them in partnership with the Sierra Resource Conservation District and USFS through the sharing of silvicultural expertise and coordination and alignment of reforestation activities across private parcels. This kind of partnership may be particularly relevant if private landowners wish to improve the amount of merchantable wood that could be harvested, along with fuel reduction to reduce fire risk, without depleting the abundance and diversity of fire-resistant species on the landscape.

Fire Severity Model Strength for Private Lands

This cost-benefit analysis is limited by the strength of our fire behavior modeling assumptions (Section 4, Limitations). Because of the large data gap for tree stands on private parcels, fire behavior modeling was performed on public tree stands in the Dinkey Landscape and crosswalked to the private parcels using an ordinal logistic regression. The regression had limited predictive capacity for conditional flame lengths on private parcels and lost the patterns of fire spread which are predicted in the fire behavior model. Currently a fire is only considered to impact a private parcel if the ignition source originates from that parcel, and the incapability of this analysis to consider fire spread likely causes potential fire damage to be underestimated. Since the cost-benefit analysis uses the crosswalked conditional flame lengths for private parcels, both the costs of treatment and the benefits of treatment are equally limited by this reduced predictive capacity.

Limitation Predicting Fire Severity Interactions with Ecosystem Benefits

Additionally, model capacity and time restrictions for analysis meant that some of the interactions and feedback loops that occur between realized benefits must go unexplored. The ignored interactions include the interaction between better suppression capability due to treated lands and the avoided cost of damage from wildfire and the interaction between catastrophic wildfire, avoided insect damage, and reduced heavy fuel loading.

The cost avoidance of damage from wildfire analysis assumes that the entire private parcel landscape burns in every analyzed wildfire according to the assessed probability of ignition. Fire suppression activity is ignored in this case. However, because fuel treatments increase the ease and efficiency of fire suppression, it is likely that, under a prioritized treatment scenario, more private parcels are saved from fire exposure than under a no treatment scenario Therefore, the avoided cost of damage due to wildfire may be underestimated because more efficient fire suppression under reduced fire severity conditions could save more land value than was estimated in the cost-benefit analysis which ignored this interaction, but may also be overestimated as the original assumption that an entire parcel burns during a wildfire is not necessarily true.

The forest vegetation simulations, which projected the vegetation fuel loads on which the fire behavior models are based, did not attempt to predict potential future bark-beetle induced mortality events. Without fuel thinning, the densities of the explored forest stands make those stands vulnerable to widespread mortality by bark beetle (North 2012). Future mortality events would create additional sources of heavy fuel loading that are likely to increase wildfire severity (A. Hernandez, personal communication, October 19, 2017). Therefore, under a no treatment scenario, costs due to damage from wildfire would be elevated compared to those calculated under this analysis, suggesting that the avoided cost of damage from wildfire produced through a prioritized treatment strategy is underestimated. However, multiple mortality events or catastrophic fires could reduce stand density significantly and may lead to the colonization of the burned landscape by a different assemblage of vegetation (North 2012). By not projecting future mortality events, a suite of complicated cascading events that impact fire severity and thus damage from fire are excluded from this analysis.

Additionally, this analysis considers the impacts of climate change on fire ignition probability, while ignoring its impacts on vegetation growth, productivity, and species assemblage. All three factors have the potential to increase fire severity. Because fuel treatments reduce inter-tree competition for limited resources, fuel treatments can increase favored (pines and oaks) forest species' resilience to environmental stressors. If fuel treatments do maintain desired fire-resilient tree species on the landscape, the benefits of fuel treatments presented in these cost-benefit analyses may be underestimated compared to the benefits of reductions in fire severity under changing climatic conditions. Future analyses of fire severity under different fuel treatment scenarios should incorporate climate change to explore the persistence of forest resilience to environmental stressors gained through fuel thinning and quantify how fuel treatments reduce fire severity under different climate futures.

Discussion

The cost-benefit analysis of performing fuel treatments on private lands demonstrates that, for the private landowner stakeholders, it is cost-effective for them to complete fuel treatments on their land even if they have to take on the entire burden of fuel treatment costs. Under both a hand thinning and a mechanical thinning scenario the costs of performing fuel treatments are greatly exceeded by the monetary benefits of those treatments that accrue to the private landowners. While this finding indicates that fuel treatments would be a good investment for private landowners, it does not reflect the inability of the private landowners to generate the funds necessary to cover the upfront costs of the treatments. Socio-economic studies for the communities associated with the Dinkey Landscape have shown that these communities are deficient in financial capital (Kusel et al. 2015). However, because private landowners would benefit so greatly from the implementation of fuel treatments on private lands, if they are supported in the up-front costs and physical implementation of the treatments through grants and reimbursement programs, many private landowners may be convinced to participate in fuel treatment cost-shares and programs. The SRCD (which bears the cost of treatment as a representative of the private landowner) and the USFS (which does not bear any costs under this analysis) also benefit greatly from fuel treatments under both mechanical and hand thinning treatment scenarios. Because these entities accrue the benefits of fuel treatment placement on private land private landowners should look to these entities for assistance – either financial or physical – in completing the fuel treatments.

The high upfront costs of completing fuel treatments on the assessed 5,560 acres of private lands may be lowered by treating less than 21% of the landscape. The tradeoff curve of treatment area versus fire severity reduction potential explored in Section 4 of this report shows that the lower bound of acreage that can be treated while still achieving the same fire severity reduction of a full landscape treatment lies between 21% and 15% of the landscape. However, the analysis also showed that treating a smaller percentage of the landscape – less than 15% – still produces significant reductions in fire severity when compared to a no treatment scenario. Therefore, even if grants, programs, and cost-shares cannot pay for the upfront costs of fuel treatments for 5,650 acres of the landscape, fewer acres of treatment will still produce significant benefits in reducing the risk of severe fire.

Regardless of the percentage of land to be treated, fuel treatments face both financial and feasibility barriers in their completion. This analysis demonstrates how expensive hand thinning is compared to mechanical thinning, with few quantifiable benefits separating the methods when the treatments are placed and completed correctly. Not only is hand thinning extremely expensive, but it is also far less efficient. Mechanical treatment crews are able to perform fuel reductions of approximately 5 acres per day (K. Duysen, personal communication, October 23, 2017). Current hand thinning operations, however, are able to perform fuel reductions on only 0.2 acres per day (C. Ashley, personal communication, October 19, 2017). It would take one hand thinning crew at least 200 days to perform fuel treatments over the entirety of just *one* private parcel of average size (42.9 acres). If the season for fuel reduction operations is assumed to be from April through November, a single job could take 214 days of a 244 day season if a crew were working every day of the season including weekends. For this reason, it is recommended that, capacity permitting, a strategic mixture of hand and mechanical thinning operations be undertaken for the fuel reduction actions on the private parcels of the Dinkey Landscape. The fuel treatment feasibility results (Section 4, Results) indicated that a strategic portfolio of treatments is feasible to be employed on the landscape, however, the current human and physical capacity for the communities associated with the Dinkey Landscape are limited in regards to fuel treatment strategies. There are limited local contractors that are primed to perform fuel treatments on the landscape and the majority of these contractors are currently limited to thinning fuels by hand thinning (S. Haze, personal communication, October 13, 2017;

J. Aldern, personal communication, December 6, 2017). This capacity gap severely limits the capability of the community to achieve significant fuel reductions within a reasonable timeline and without incurring astronomical costs.

The results of the fuel the revenue generation and avoided treatment costs indicates that select private land parcels may be able to perform fuel thinnings at a small profit. If there is capacity to identify and target these lands, these private landowners will likely be among the easiest landowners to convince to perform fuel treatments and performing treatments on these lands will not draw down any of the grant funding SRCD may receive to support fuel treatment implementation.

The cost-benefit analysis of performing prioritized fuel reductions on private lands on the Dinkey Landscape uncovers the long-term benefits that could be realized by the three primary stakeholders to this project: the private landowners, the SRCD, and the USFS. The benefits that accrue to all three stakeholders can be leveraged by the SRCD to expand their grant writing portfolio and the strength of their grant applications.

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Appendix—5

Item A—Decay Rate of PM_{10} Reduced Emission Benefits

The vegetation regrowth simulator (FVS), which produces the vegetation and fuel load profile on which the fire behavior modeling is performed, generates outputs of the total biomass remaining per stand after each treatment and each successive year of regrowth. A panel regression was employed to determine the rate at which the difference in biomass from year to year decreases until it approaches 0, meaning regrowth has reached equilibrium.

Tables 5-A-1: Entity fixed-effects panel regression results for change in biomass ($n_{t+1} - n_t$) for each cycle of optimized treatment. Estimated coefficients for year were used as proxies for benefit rate of decay for each cycle.

	Cycle 1 (2019 - 2027)				
Predictor	**Estimate**	**SE**	**t-value**	**p-value**	**Significance Level**
(Intercept)	2288.51	131.72	17.38	< 0.001	***
Year	**-1.13**	**0.07**	**-17.30**	**< 0.001**	*******
StandID051552BaldMtn0172	-3.89	1.50	-2.59	0.10	*
StandID051552BaldMtn0256	6.11	1.50	4.06	< 0.001	***
StandID051552BaldMtn1092	-1.00	1.50	-0.67	0.51	
StandID051552BaldMtn1094	-4.33	1.50	-2.88	0.0042	**
StandID051552BaldMtn1095	-6.67	1.50	-4.43	< 0.001	***
StandID051552BaldMtn1102	6.11	1.50	4.06	< 0.001	***
StandID051552BaldMtn1108	-7.00	1.50	-4.66	< 0.001	***
StandID051552BaldMtn1111	-6.44	1.50	-4.29	< 0.001	***
StandID051552BaldMtn1117	-3.78	1.50	-2.51	0.013	*
StandID051552BaldMtn1126	-5.78	1.50	-3.84	< 0.001	***
StandID051552BaldMtn1139	11.44	1.50	7.61	< 0.001	***
StandID051552BaldMtn1141	-12.67	1.50	-8.42	< 0.001	***
StandID051552Bear_fen0026	-17.89	1.50	-11.90	< 0.001	***
StandID051552Bear_fen0042	-14.56	1.50	-9.68	< 0.001	***
StandID051552Bear_fen0050	-2.33	1.50	-1.55	0.12	
StandID051552Bear_fen0443	-9.56	1.50	-6.36	< 0.001	***
StandID051552Bear_fen0712	-2.22	1.50	-1.48	0.14	
StandID051552Bear_fen0725	-11.22	1.50	-7.46	< 0.001	***
StandID051552Bear_fen0742	-6.11	1.50	-4.06	< 0.001	***
StandID051552Bear_fen0790	-6.56	1.50	-4.36	< 0.001	***
StandID051552Bear_fen0809	-5.44	1.50	-3.62	< 0.001	***
StandID051552Bear_fen0826	7.33	1.50	4.88	< 0.001	***
StandID051552Bear_fen0835	-16.44	1.50	-10.94	< 0.001	***
StandID051552Bear_fen0836	-11.89	1.50	-7.91	< 0.001	***
StandID051552Bear_fen0837	-12.89	1.50	-8.57	< 0.001	***
StandID051552Bear_fen0849	-13.78	1.50	-9.16	< 0.001	***
StandID051552Bear_fen1042	-13.22	1.50	-8.79	< 0.001	***
StandID051552Dinkey0125	-6.33	1.50	-4.21	< 0.001	***
StandID051552Dinkey0154	68.67	1.50	45.67	< 0.001	***
StandID051552EXCHEQUER0265	-3.00	1.50	-2.00	0.047	*
StandID051552EXCHEQUER0302	-6.56	1.50	-4.36	< 0.001	***
StandID051552EXCHEQUER0311	-0.78	1.50	-0.52	0.60	
StandID051552EXCHEQUER0337	-0.33	1.50	-0.22	0.82	
StandID051552EXCHEQUER0492	-10.44	1.50	-6.95	< 0.001	***
StandID051552EXCHEQUER0504	-3.44	1.50	-2.29	0.023	*
StandID051552EXCHEQUER0512	-6.22	1.50	-4.14	< 0.001	***
StandID051552EXCHEQUER0538	-7.11	1.50	-4.73	< 0.001	***
StandID051552EXCHEQUER0543	-7.89	1.50	-5.25	< 0.001	***
StandID051552EXCHEQUER0565	-2.78	1.50	-1.85	0.066	.

Residual standard error: 3.19 on 319 degrees of freedom

Multiple R-squared: 0.953, Adjusted R-squared: 0.9471

F-statistic: 161.6 on 40 and 319 DF, p-value: < 2.2e-16

	Cycle 2 (2029 - 2037)				
Predictor	**Estimate**	**SE**	**t-value**	**p-value**	**Significance Level**
(Intercept)	2527.37	120.98	20.89	< 0.001	***
Year	**-1.24**	**0.06**	**-20.78**	**< 0.001**	*******
StandID051552BaldMtn0172	4.78	1.37	3.48	< 0.001	***
StandID051552BaldMtn0256	3.56	1.37	2.59	0.010	*
StandID051552BaldMtn1092	-3.33	1.37	-2.43	0.016	*
StandID051552BaldMtn1094	-7.11	1.37	-5.18	< 0.001	***
StandID051552BaldMtn1095	-10.67	1.37	-7.76	< 0.001	***
StandID051552BaldMtn1102	3.89	1.37	2.83	0.0050	**
StandID051552BaldMtn1108	-8.44	1.37	-6.15	< 0.001	***
StandID051552BaldMtn1111	-3.78	1.37	-2.75	0.0063	**
StandID051552BaldMtn1117	-2.44	1.37	-1.78	0.076	.
StandID051552BaldMtn1126	-7.22	1.37	-5.26	< 0.001	***
StandID051552BaldMtn1139	18.33	1.37	13.34	< 0.001	***
StandID051552BaldMtn1141	-18.22	1.37	-13.26	< 0.001	***
StandID051552Bear_fen0026	-16.78	1.37	-12.21	< 0.001	***
StandID051552Bear_fen0042	-21.00	1.37	-15.28	< 0.001	***
StandID051552Bear_fen0050	1.00	1.37	0.73	0.48	
StandID051552Bear_fen0443	-17.56	1.37	-12.78	< 0.001	***
StandID051552Bear_fen0712	-4.11	1.37	-2.99	0.0030	**
StandID051552Bear_fen0725	-15.22	1.37	-11.08	< 0.001	***
StandID051552Bear_fen0742	-9.44	1.37	-6.87	< 0.001	***
StandID051552Bear_fen0790	-8.33	1.37	-6.06	< 0.001	***
StandID051552Bear_fen0809	-7.56	1.37	-5.50	< 0.001	***
StandID051552Bear_fen0826	1.78	1.37	1.29	0.20	
StandID051552Bear_fen0835	1.89	1.37	1.38	0.17	
StandID051552Bear_fen0836	-16.11	1.37	-11.72	< 0.001	***
StandID051552Bear_fen0837	-3.78	1.37	-2.75	0.0063	**
StandID051552Bear_fen0849	-3.00	1.37	-2.18	0.030	*
StandID051552Bear_fen1042	-17.44	1.37	-12.69	< 0.001	***
StandID051552Dinkey0125	-12.67	1.37	-9.22	< 0.001	***
StandID051552Dinkey0154	53.67	1.37	39.05	< 0.001	***
StandID051552EXCHEQUER0265	-5.78	1.37	-4.20	< 0.001	***
StandID051552EXCHEQUER0302	-6.00	1.37	-4.37	< 0.001	***
StandID051552EXCHEQUER0311	-0.89	1.37	-0.65	0.52	
StandID051552EXCHEQUER0337	-0.33	1.37	-0.24	0.81	
StandID051552EXCHEQUER0492	-15.67	1.37	-11.40	< 0.001	***
StandID051552EXCHEQUER0504	-5.44	1.37	-3.96	< 0.001	***
StandID051552EXCHEQUER0512	-6.67	1.37	-4.85	< 0.001	***
StandID051552EXCHEQUER0538	-8.22	1.37	-5.98	< 0.001	***
StandID051552EXCHEQUER0543	-8.78	1.37	-6.39	< 0.001	***
StandID051552EXCHEQUER0565	-6.56	1.37	-4.77	< 0.001	***

Residual standard error: 2.915 on 319 degrees of freedom

Multiple R-squared: 0.9541, Adjusted R-squared: 0.9483

F-statistic: 165.6 on 40 and 319 DF, p-value: < 2.2e-16

	Cycle 3 (2039 - 2047)				
Predictor	**Estimate**	**SE**	**t-value**	**p-value**	**Significance Level**
(Intercept)	3712.17	90.20	41.15	< 0.001	***
Year	**-1.81**	**0.04**	**-41.04**	**< 0.001**	*****
StandID051552BaldMtn0172	6.00	0.91	6.63	< 0.001	***
StandID051552BaldMtn0256	5.75	0.91	6.35	< 0.001	***
StandID051552BaldMtn1092	-1.63	0.91	-1.80	0.074	.
StandID051552BaldMtn1094	-5.13	0.91	-5.66	< 0.001	***
StandID051552BaldMtn1095	-10.75	0.91	-11.88	< 0.001	***
StandID051552BaldMtn1102	8.25	0.91	9.12	< 0.001	***
StandID051552BaldMtn1108	-0.63	0.91	-0.69	0.49	
StandID051552BaldMtn1111	-6.75	0.91	-7.46	< 0.001	***
StandID051552BaldMtn1117	-0.88	0.91	-0.97	0.33	
StandID051552BaldMtn1126	-7.00	0.91	-7.73	< 0.001	***
StandID051552BaldMtn1139	29.38	0.91	32.46	< 0.001	***
StandID051552BaldMtn1141	-18.25	0.91	-20.17	< 0.001	***
StandID051552Bear_fen0026	-17.75	0.91	-19.61	< 0.001	***
StandID051552Bear_fen0042	-18.25	0.91	-20.17	< 0.001	***
StandID051552Bear_fen0050	-2.75	0.91	-3.04	0.0026	**
StandID051552Bear_fen0443	-20.50	0.91	-22.65	< 0.001	***
StandID051552Bear_fen0712	-3.25	0.91	-3.59	< 0.001	***
StandID051552Bear_fen0725	-11.75	0.91	-12.98	< 0.001	***
StandID051552Bear_fen0742	-10.75	0.91	-11.88	< 0.001	***
StandID051552Bear_fen0790	-8.75	0.91	-9.67	< 0.001	***
StandID051552Bear_fen0809	-6.75	0.91	-7.46	< 0.001	***
StandID051552Bear_fen0826	11.25	0.91	12.43	< 0.001	***
StandID051552Bear_fen0835	-7.88	0.91	-8.70	< 0.001	***
StandID051552Bear_fen0836	-13.50	0.91	-14.92	< 0.001	***
StandID051552Bear_fen0837	-9.63	0.91	-10.64	< 0.001	***
StandID051552Bear_fen0849	-6.88	0.91	-7.60	< 0.001	***
StandID051552Bear_fen1042	-15.75	0.91	-17.40	< 0.001	***
StandID051552Dinkey0125	-12.25	0.91	-13.54	< 0.001	***
StandID051552Dinkey0154	35.25	0.91	38.95	< 0.001	***
StandID051552EXCHEQUER0265	-6.88	0.91	-7.60	< 0.001	***
StandID051552EXCHEQUER0302	-2.88	0.91	-3.18	0.0017	**
StandID051552EXCHEQUER0311	4.88	0.91	5.39	< 0.001	***
StandID051552EXCHEQUER0337	-0.63	0.91	-0.69	0.49	
StandID051552EXCHEQUER0492	-7.25	0.91	-8.01	< 0.001	***
StandID051552EXCHEQUER0504	4.88	0.91	5.39	< 0.001	***
StandID051552EXCHEQUER0512	-6.75	0.91	-7.46	< 0.001	***
StandID051552EXCHEQUER0538	-6.75	0.91	-7.46	< 0.001	***
StandID051552EXCHEQUER0543	1.00	0.91	1.11	0.27	
StandID051552EXCHEQUER0565	-7.25	0.91	-8.01	< 0.001	***

Residual standard error: 1.81 on 279 degrees of freedom

Multiple R-squared: 0.9801, Adjusted R-squared: 0.9772

F-statistic: 343.1 on 40 and 279 DF, p-value: < 2.2e-16

Section 6— Management Plans, Programs and Funding Opportunities

Applicable Existing Management Plans

The SRCD is a party to, and has a variety of responsibilities under, multiple management plans within Fresno County and the SRCD jurisdiction. Formulated by various local, state, and federal agencies, some plans provide recommended actions for land management while others are strictly regulatory. In devising this report, careful consideration was made to promote continuity with various plans' priorities, objectives, and goals with the intent align our recommended land and fuel management actions with those of other agencies priorities as well as the SRCDs'. Each applicable management plan is briefly described below.

Federal Reports and Plans

USFS GTR-220: An Ecosystem Management Strategy for Sierra Mixed-Conifer Forests (2009)

USFS GTR-220 is technical guidance report for land management strategies in the Sierra Nevada forests. The report is the culmination and synthesis of various research projects, academic journals articles, and management techniques currently applied by agencies. The report focuses on summarizing forest research completed at different scales and integrating those findings into suggestions for managing forest landscapes. While some of the land management suggestions made in this report are already in use by the USFS, GTR-220 is limited to an ecological scope and does not include management suggestions that include other management goals such as socioeconomic or water resource management goals. Although water resources are not discussed in detail, some of the management recommendations suggested in the report may benefit water quality and quantity for downstream users (North et al. 2009).

Sierra Nevada Forest Plan Amendment (2004)

The Sierra Nevada Forest Plan (SNFP) is the culmination of 10 years of regional planning with the USFS, tribal entities, the scientific community, and policy makers. Within the planning process, the plan has undergone intense review and appeal processes issuing Environmental Impact Statements (EIS), Supplemental EISs, which were finalized with a Record of Decision (ROD) in 2004. For the purposes of identifying the SNFP's goals, objectives, and desired landscape conditions, one can refer to the succinct ROD. The ROD presents broad management goals and strategies for five distinct problem areas. They are: (1) old forest ecosystems and associated species, (2) aquatic, riparian, and meadow ecosystems and associated species, (3) fire and fuels management, (4) noxious weeds, and (5) west side hardwood ecosystems. The ROD also describes further desired conditions for these identified issues and associated management objectives. Additionally, the ROD provides direction for specific project planning and analysis (USFS 2004).

Draft Revised Land Management Plan for the Sierra National Forest (2016)

Unlike the SNFP, the Draft Revised Land Management Plan for the Sierra National Forest (LMP-SNF) is a land management document specific to the parts of Fresno, Madera, and Mariposa counties located in the Sierra National Forest rather than the forests of the entire Sierra Nevada mountain range. The development of the LMP-SNF is required by the National Forest Management Act of 1976 (16 U.S.C. 1604) and is the second tier land management report of three distinct levels of planning processes for the National Forests at-large. The purpose of this report is to provide planning and decision making strategies to guide how the Sierra National Forest is managed. The LMP-SNF does not directly call for or compel action, authorize projects, or guarantee specific results. Rather the LMP-SNF was developed with the intent to identify long-term or overall desired future conditions and provide general direction for achieving those desired conditions. Congruent with this intent, projects may be proposed in response to demands by the public or to respond to forest plan objectives (USFS 2016).

State and Regional Reports and Plans

Little Hoover Commission—Fire on the Mountain: Rethinking Forest Management in the Sierra Nevada (2018)

Starting in 2017, the Little Hoover Commission began to evaluate the tree mortality event within the Sierra Nevada that, to date, has resulted in the death of 129 million trees. The commission explored the current and possible forms of coordination and collaboration among its state federal, local, agencies, and private and nonprofit organizations. After analyzing stressors contributing to declines in forest health in the Sierra Nevada and the policies the drive forest management practice, the commission delivered a set of recommendations that aims to promote investments intended to drive a strategy in which the state pays more for front-end forest management, and, eventually, pays less for crises and disasters (Little Hoover Commission 2018).

CA Department of Water Resources—Integrated Regional Water Management Plan Southern Sierra (2014)

The Integrated Regional Water Management Plan was prepared by the Regional Water Management Groups, a group comprised of a collection of agencies, stakeholders, and individuals who share a common interest in managing water resources in a specific hydrologic region. The Southern Sierra RWMG was developed to improve coordination and collaboration on regional water management in the Southern Sierra Region, and the completion of this IRWMP is a significant milestone for the RWMG. The Southern Sierra IRWMP documents regional and local data, issues, water-related objectives, resource management strategies, and collaborative efforts. The IRWMP was developed with significant input from RWMG members and other interested stakeholders (Southern Sierra Regional Water Management Group 2014).

An update to the IRWMP is expected in 2018.

Fresno County General Plan (2000)

The Fresno County General Plan is a comprehensive, long-term framework written for the protection of the county's agricultural, natural, and cultural resources and for development in the county. Designed to meet State general plan requirements, it outlines policies, standards, and programs and sets out plan proposals to guide day-to-day decisions concerning Fresno County's future. A general plan is a legal document that serves as a community's "blue print" or "constitution" for land use and development. State law requires every city and county in California to adopt a general plan that is comprehensive and long-term ("Fresno County General Plan" 2000).

Fresno County Multi-Hazard Mitigation Plan (2008)

Fresno County and 12 other entities prepared a local hazard mitigation plan to guide hazard mitigation planning that better protects the people and property of the County from the effects of hazard events. This plan demonstrates the community's commitment to reducing risks from hazards and serves as a tool to help decision makers direct mitigation activities and resources. This plan was also developed to make Fresno County and participating entities eligible for certain federal disaster assistance, specifically, the FEMA Hazard Mitigation Grant Program and Pre-

Disaster Mitigation Program (Fresno County 2008). The SRCD is the governing authority for multiple mitigation actions listed with the FCMHMP plan. (Table 6-1).

Table 6-1: SRCD jurisdictional mitigation actions defined in the Fresno County Multi-Hazard Mitigation Plan.

Hazard Type	Mitigation Action	Current Status
Multi-Hazard - 32	Strengthen Non-Native Noxious Weed Control Efforts	Low priority due to impacts from drought & tree mortality
Dam Failure - 2	Strengthen Dam Failure/Flood Planning, Coordination, and Training	Low priority due to impacts from drought & tree mortality
Drought -3	Create an Integrated Regional Water Management Plan for Eastern Fresno County	Completed 2014- Plan is being updated in 2017/2018
Drought -4	Conduct a Fractured Rock Groundwater Capacity Study for Eastern Fresno County	Completed 2012- The study was completed under funding from the CA Department of Water Resources. The report and its findings are available
Wildfire - 1	Improve Alternate Emergency Access Roads	This should be developed through Community Wildfire Protection Plans (CWPP) with Highway 168 FSC as an update and Oak to Timberline FireSafe Council as a new plan
Wildfire - 2	Conduct Community Fuel Break Construction and Maintenance on a Landscape Scale	Working with Sierra National Forest under new grant from CAL FIRE
Wildfire - 3	Create a Fuel Break Along Highway 168	This should be developed through Community Wildfire Protection Plans (CWPP) with Highway 168 FSC as an update and Oak to Timberline FireSafe Council as a new plan
Wildfire - 4	Implement a Neighborhood Chipping Program	Executed MOU with Fresno EOC's Local Conservation Corp to address approach using existing resources such as from Tulare County RCD & Sequoia FireSafe Council
Wildfire - 5	Conduct Prescribed Fires	Potential to have performed through Cold Springs Rancheria Prescribe Fire Team
Wildfire - 6	Establish a System of Fire Pumper/Tanker Fill Stations and Water Storage	This should be developed through Community Wildfire Protection Plans (CWPP) with Highway 168 FSC as an update and Oak to Timberline FireSafe Council as a new plan
Wildfire - 7	Implement a Public Fire Prevention, Survival, and Mitigation Education Program	This is being developed through Community Wildfire Protection Plans (CWPP) with Highway 168 FSC as an update and Oak to Timberline FireSafe Council as a new plan
Wildfire - 8	Update Highway 168 FireSafe Council's Community Wildfire Protection Plan thru CA FireSafe Council Funding	Initiated in October 2016 - Completion by September 2019
Wildfire - 9	Develop Wildfire Protection Plan with Oak to Timberline FireSafe Council thru CA FireSafe Council Funding	Initiated in October 2016 - Completion by September 2019
Wildfire - 10	Implement a biomass utilization and dispositioning program for excessive forest and rangeland vegetation	Initiated planning and design of Old Auberry Mill site
Wildfire - 11	Partner with U.S. Forest Service to reduce fire risk in Wildland Urban Interface (WUI)	Partnered with Sierra National Forest with project through March 2020 & to receive funding for processing equipment

Source: (Fresno County 2008)

Local Reports and Plans

Hwy 168 Community Wildfire Protection Plan (2003)

A Community Wildfire Protection Plan identifies and prioritizes areas needing hazardous fuel-reduction treatment and recommends the types and methods for that treatment on Federal and non-Federal land. These lands are chosen to protect one or more at-risk communities or pieces of essential infrastructure, and the plan recommends measures to reduce structure ignitability throughout the at-risk communities (Gallegos, n.d.).

Last revised in 2003, the objectives of the CWPP included: (1) Solicit stakeholders and community involvement in wildfire mitigation through public education and awareness projects. (2) Plan and implement fuel reduction programs on private and public land. (3) Escalate the "Defensible Space" program to include the watershed, wildlife, transportation, recreational, and commercial areas in the council's sphere of influence. (4) Support and promote prescribed burning to mimic natural fire cycles and create wildland ecosystems which are resistant to destructive wildfires (Gallegos, n.d.).

Currently, the SRCD has secured a grant to update the HWY 186 CWPP. This is expected to be finished in September 2018.

Dinkey Collaborative Landscape Restoration Strategy (2010)

The Dinkey Landscape Restoration Project (Dinkey CFLRP) is a localized management strategy unique to the Dinkey Landscape in the Southern Sierra Nevada. With the Collaborative Forest Landscape Restoration Program established by Congress under the *Title IV of the Omnibus Public Land Management Act of 2009*, the Dinkey CFLRP establishes a framework for linking the SNFP with projects that might initiate National Environmental Policy Act (NEPA). Through the promotion of various landscape restoration strategies such as prescribed fire, mechanical thinning, watershed improvements, and other restoration treatments, this project seeks to restore key features of diverse, fire adapted forests, including heterogeneity at multiple scales, reduced surface and ladder fuels, and terrestrial and aquatic habitats for sensitive wildlife species. The strategy fosters a landscape that is resilient to uncharacteristic wildfire, insect and disease, climate change, drought, invasive species, and air pollution. A major goal of this restoration strategy is to provide current and future habitat for sensitive wildlife species by fostering ecosystem resilience, resistance, and adaptation to future wildfires and accelerated climate change impacts. The Dinkey CFLRP uses PSW-GTR-220—An Ecosystem Strategy for Sierran Mixed Conifer Forests as a technical guide for developing projects types identified in the Dinkey CFLRP (Dinkey Project Planning Forum 2010).

Dinkey Landscape Restoration Project Reforestation Framework (2017)

When reforestation is proposed, this document identifies the major goals, desired conditions, and activities for the Dinkey CFLRP, including associated timelines. It focuses on where and how the members of the Dinkey Collaborative will advocate for the reforestation of stands in the process of ecological restoration. Scientific and technical issues associated with reforestation are addressed to the extent the Collaborative finds appropriate at this time. If the goals and desired future conditions of other interested parties, including those of private landowners, are similar to the ones outlined by the Dinkey CFLRP, the following Framework may provide guidance for reforestation activities on their lands (Dinkey Landscape Restoration Project 2017).

Sierra Institute Socioeconomic Monitoring Report (2017)

> The Sierra Institute Socioeconomic Monitoring Report was developed in concert with the Collaborative Forest Landscape Restoration Program to address the social and economic conditions of the local communities and establish a baseline understanding of financial, social, human, cultural, and physical capital. The report presents its findings in three distinct sections: (1) forest restoration effects on the local economy, (2) education and training and (3) community capacity. Information was obtained through census data and discussion with informants that included local contractors, local business owners, tribal representatives, grazing permittees, and USFS employees (Kusel et al. 2015).

Applicable Management Plans and Project Alignment

Significant elements of this project align with many components of the existing regional management plans that govern land use, wildfire management, and ecological resilience in the SRCD's jurisdiction. Appendix—6 details the various land management plan's polices, objectives, goals, desired conditions, and prescriptions and how elements of this project, including recommendations, considerations and methodologies, align with those management plan components. Through this evaluation, it was found that elements of this project directly or indirectly align with a total of 112 management plan polices, objectives, goals, desired conditions, and sought prescriptions. Of those 112 management plan components, 69 directly, and 43 indirectly align with various project elements. The purpose for detailing the alignment between the management plan components and elements apart of this project was to highlight that many of the recommendations and methods used in this project are similar to those highlighted by other agencies and other reports. Creating consensus amongst land managers and agencies promotes continuity in planning and implemented projects especially across jurisdictional boundaries. Being that the SRCD jurisdictional boundary encompasses a variety of other agencies, acknowledgement of their land management plans and strategies supports the potential for cross-agency collaboration and more uniform planning of projects on the landscape.

Table 6-1. Number of project elements in alignment with management plans

Management Plan	Management Plan Components **Indirectly** in Alignment with Project Elements	Management Plan Components **Directly** in Alignment with Project Elements
Sierra Nevada Forest Plan Amendment	8	11
USFS GTR-220	14	5
Draft Revised Land Management Plan of the Sierra National Forest	4	22
CA Department of Water Resources—Integrated Regional Water Management Plan Southern Sierra (2014)	0	6
Fresno County General Plan (2000)	15	10
Fresno County Multi-Hazard Mitigation Plan (2008)	1	11
HWY 168 Community Wildfire Protection Plan	1	4
Total	**43**	**69**

Private Landowner Land Management Program Opportunities

Obtaining assistance for private land management activities can be costly, complicated, and time consuming. To help alleviate some of the difficulty private landowners endure when trying to enact land management activities, a brief summary of land management cost-share programs available to private landowners is listed below. Some programs provide direct monetary incentives to private landowners, while other are cost-share programs that absorb partial costs of land management activities enacted by landowners.

Natural Resource Conservation Service Programs

Environmental Quality Incentives Programs (EQIP)

EQIP is a program operated by the NRCS, which offers technical and financial assistance to farmers and ranchers to employ conservation practices as qualified by the NRCS to address natural resource concerns. The purpose of EQIP is to promote agricultural production, forest management, and environmental quality as compatible goals. The purpose of the program is to optimize environmental benefits and to aid farmers and ranchers in reaching compliance with local, state, federal, and tribal environmental regulations.

Private landowners are encouraged to apply for the program year-round; however, there are cutoff dates to establish timelines for funding selections. To qualify for EQIP funding, a landowner must (1) develop a conservation plan, (2) submit an application, (3) meet program eligibility, and (4) approve their EQIP schedule of operation.

Applicable to the forestland management, especially as it pertains to reduction of hazardous fuel loading, are two specific NRCS EQIP funding pools. They are: (1) **Sierra Nevada Forestland EQIP Fund Pool** and (2) **Forest Tree Mortality EQIP Fund Pool.** These two funding pools are directed at supporting private, non-industrial forestland owners to mitigate wildfire risks in the face of the extensive tree mortality event.

Sierra Nevada Forestland Environmental Quality Incentives Programs (EQIP) Fund Pool

Program Goals

The Sierra Nevada EQIP fund pool has the following defined goals (1) promote healthy and productive forestlands, (2) reduce erosion, (3) enhance fish and wildlife habitat, (4) minimize impacts to water quality, and (5) reduce wildfire risks on non-industrial private forestlands (NRCS n.d.).

Land Use Eligibility

In addition to landowners in 12 other counties, private landowners within Fresno County are eligible for the technical and financial assistance that the program offers. Additionally, to achieve eligibility, landowners must demonstrate that their land falls into a loose categorization of specified land uses. The qualified land uses include (1) Forest, (2) Associated Agricultural Lands, (3) Grazed Lands, or (4) Wildlife. The land use type *Forests* is described as land of which the primary vegetation is tree cover and the use is primarily for production of wood products or non-timber forest products. *Associated Agricultural Lands* are described as lands associated with farms and ranches that are not purposefully managed for food, forage, or fiber and are typically associated with nearby production or conservation lands. This could include incidental areas, such as ditches and watercourses, riparian areas, field edges, seasonal and permanent wetlands, and other similar areas. *Grazed Lands* are described as land where grazing animals impact how land is managed. *Wildlife* is described as land where a private landowner applicant is actively managing for wildlife (NRCS n.d.).

Resource Concerns

The EQIP program targets a multitude of resource concerns with the purpose of mitigating the harmful impacts associated with poor land management. Resource Concerns are defined by the Sierra Nevada EQIP Fund Pool as (1) Soil Erosion, (2) Insufficient Water, (3) Water Quality Degradation, (4) Degraded Plant Conditions, (5) Inadequate Habitat for Fish and Wildlife, and (6) Livestock Production Limitation. Applicants of the EQIP program must address at least one of the resource concerns in order to receive EQIP assistance.

While many of the resource concerns can be addressed with various forms of vegetative management, private landowners on forestlands are most likely to be most concerned with *Resource Concern #6—Degraded Plant Condition*. Plant condition degradation can drive stress, disease, and insect damage, which can change the structure and composition of vegetation on private landowner property. The Sierra Nevada EQIP Fund Pool explicitly identifies three types of *Degraded Plant Conditions* that it aims to mitigate with designed conservation measures. These three types of degraded plant conditions are (1) Inadequate Structure and Composition, (2) Excessive Plant Pest Pressure, and (3) Wildfire Hazard, Excess Biomass Accumulation. Most applicable to private landowners concerns about wildfire risks would be Wildfire Hazard, Excess Biomass Accumulation. The Sierra Nevada EQIP Fund Pool describes this as accumulated plant residue (biomass) that creates wildfire hazards that pose risks to human safety, structures, plants, animals, and air resources. The program recognizes that wildfire can be a beneficial part of the natural ecosystem, but uncontrolled or 'wild' fire poses a threat to life, health, and property (NRCS n.d.).

Conservation Measures

In a private landowner's development of a Conservation Action Plan (CAP), a necessary component of the EQIP application, a private landowner must identify the conservation measures that will be employed on their land. Conservation measures are identified with a practice code, a practice name, practice units, and the lifespan of the employment of the conservation measure. Additionally, each conservation measure with planned financial assistance must be included in the EQIP Schedule of Operations; another element required within the initial application (NRCS n.d.).

Conservation measures pertinent to wildfire risk reduction associated with the Sierra Nevada EQIP Fund Pool are listed in Table 6-2.

Funds Available from Sierra Nevada EQIP Fund Pool to Private Landowners

Funds available to the private landowners vary from site to site as density of forest, brush and other factors can determine the price and type of treatment utilized. Table 6-2 identifies cost-share rates supplied by the NRCS based on listed conservation practices. It should be noted that a more comprehensive list of pricing specific to certain 'landscape scenarios' is posted on the NRCS EQIP website, which would give a private landowner a more realistic idea for budgeting if they planned on participating in the program. Moreover, costs incurred by the private landowner will be dependent, in part, on the contracting service they hire. While the NRCS can provide a list of contractors, they cannot preferentially recommend any of those contractors (NRCS n.d.).

Forest Tree Mortality EQIP Fund Pool

The Forest Tree Mortality EQIP Fund Pool was established to provide immediate resource protection in drought-affected conifer forestlands where elevated tree mortality resultant from forest insect infestations has occurred or where it is imminent for future occurrence (NRCS n.d.).

Program Goals

The primary concerns of the program are to manage fire hazards resulting from dead tree fuel loading, manage pest control to reduce the spread of insect induced mortality, and to manage degraded forests to limit the loss of existing trees.

Benefits hoped to be gained through working towards these overarching goals are the reduction of catastrophic wildfires, reduction of harmful insect spread, reduction in threats to critical public safety infrastructure via falling trees, increased carbon sequestration, increased commercial timber values for private landowners, and improvement of aesthetic value and wildlife habitat (NRCS n.d.).

Land Use Eligibility

In addition to private landowners in 12 other counties, private landowners within Fresno County are eligible for the technical and financial assistance that the program offers. The land use eligibility for this fund pool is somewhat flexible. Eligible lands must fit in with, but do not need to exactly match, the following categories (1) *Forests* and (2) *Associated Agricultural Lands*. The land use type *Forests* is described as land of which the primary vegetation is tree cover and its use is primarily for production of wood products or non-timber forest products. *Associated Agricultural Lands* are described by lands associated with farms and ranches that are not purposefully managed for food, forage, or fiber and typically associated with nearby production or conservation lands (NRCS n.d.).

Resource Concerns

Particular to the Forest Tree Mortality Fund Pool, applicants hoping to receive financial or technical assistance must address *Degraded Plant Condition* resource concerns as defined by the program.

Degraded Plant Condition is further qualified by three resource concerns. They are (1) Inadequate Structure and Composition, (2) Excessive Plant Pressure, and (3) Wildfire Hazard, Excess Biomass Accumulation. Inadequate Structure and Composition are defined as plant communities that have insufficient diversity, density, distribution patterns, and three-dimensional structure necessary to achieve ecological functions of management objectives. Excessive Plant Pest Pressure is defined as any plant damage caused by animals, noxious weed, insects, bacteria, viruses, or any other abiotic factors that would promote damage from pests such as heat, drought, wind, or cold. Wildfire Hazard, Excessive Biomass Accumulation is defined as accumulated plant residue (biomass) that creates wildfire hazards that pose risks to human safety, structures, plants, animals, and air resources. The definition also recognizes wildfire can be a beneficial part of the natural ecosystem, whereas uncontrolled or 'wild' fire poses a threat to life, health, and property (NRCS n.d.).

Conservations measures associated with the Forest Tree Mortality EQIP Fund Pool are listed in the table below (Table 6-3).

Table 6-2. Most commonly used NRCS EQIP Fund Pool conservation practices.

NRCS Forest Tree Mortality EQIP Fund Pool Conservation Practices				
Practice Code	Conservation Practice	Practice units	Lifespan (years)	Cost Share Rates (Cost/Practice Unit)
314	Brush Management	Acres	10	Site Specific
315	Herbaceous Weed Control	Acres	5	~$ 100
342	Critical Area Planting	Acres	10	~$ 230
383	Fuel Break	Acres	10	~$ 1800
384	Woody Residue Treatment	Acres	10	~$ 370
394	Fire Break	Feet	5	~$ 0.40
472	Access Control	Acres	10	~$ 85
484	Mulching	Acres	1	~$ 300
490	Tree and Shrub Preparation -Mechanical Thinning	Acres		~$ 600
500	Obstruction Removal	Acres	10	~$ 2300
560	Access Road	Feet	10	~$ 6
578	Stream Crossing	No	10	~$ 500
580	Streambank and Shoreline Protection	Feet	20	Site Specific
612	Tree and Shrub Establishment	Acres	15	~$ 500
654	Road/Trail/Landing Closure and Treatment	Feet		~$ 10
655	Forest Trails and Landing	Feet	5	~$ 3
660	Tree and Shrub Pruning	Acres	10	~$ 300
666	Forest Stand Improvement	Acres	10	Site Specific

Source: (NRCS 2018).

Funds Available from Sierra Nevada EQIP Fund Pool to Private Landowners

Funds available to the private landowners vary from site to site as density of forest, brush, and other factors can determine the price and type of treatment utilized. Table 6-2 identifies cost share rates supplied by the NRCS based on listed conservation practices. It should be noted that a more comprehensive list of pricing specific to certain 'landscape scenarios' is posted on the NRCS EQIP website, which would give a private landowner a more realistic reference for budgeting if they planned on participating in the program. Moreover, costs incurred by the private landowner will be dependent, in part, on the contracting service they hire. While the NRCS can provide a list of contractors, they cannot preferentially recommend any of those contractors.

Healthy Forest Reserve Program (HFRP)

The HFRP is a voluntary program that private landowners participate in with the purpose of restoring and enhancing forest health in return for regulatory exemptions from Endangered Species Act of 1973—Section 4,. Private landowners receive cost-share payments for program conservation measures employed and direct payments in exchange for conservation easements on their land. Landowners can choose between 10-year, 30-year, or permanent easement agreements with the NRCS to receive varying forms of payouts, cost-share ratios, and levels of environmental regulation exemptions.

Program Goals

The HFRP goals as stated by the statutory requirements are to (1) promote the recovery of threatened and endangered species, (2) promote biodiversity, and (3) enhance carbon sequestration (NRCS 2014).

Applicant Eligibility

Only privately owned forestlands and tribal lands are eligible for enrollment. Eligible private land may include riparian areas along stream or other waterways, wetlands (including existing and degraded wetlands), or land adjacent to restored forestlands, whose inclusion would contribute significantly to the practical administration of the easement area. Privately owned land that is not eligible for the HFRP are those lands already subject to an easement or deed restriction that provides protection of wildlife habitat, or those lands where restoration practices would be impractical due to on-site or off-site conditions. Applicants must demonstrate that conservation actions on their lands would restore, enhance, or otherwise measurably (1) increase the likelihood of recovery of species listed as endangered or threatened under Section 4 of the ESA or (2) improve the well-being of species that are not listed as endangered or threatened under Section 4 of the ESA but are candidate species, state-listed species, or species of special concern. Additionally, applicants must provide proof of ownership, or an operator/tenant must provide written concurrence from the landowner of tenancy for the period of the HRFP restoration agreement (NRCS 2014).

Program Structure

There exist three options for private landowner enrollment in the Healthy Forest Reserve Program, each differing from one another based on duration of agreed upon HFRP contract. The 10-year, 30-year, and permanent easement contracts offer varying degrees of financial compensation. Under each easement scenario, the applicant and NRCS jointly develop a Habitat Restoration Plan. This plan must include the restoration practices or measures necessary to protect, restore, and enhance habitat for species listed under the ESA—Section 4 or other species defined as a candidate, state-listed species, or species of special concern. The program offers entitlement to technical assistance for the applicant to ensure compliance with the jointly agreed upon Habitat Conservation Plan and understanding of the terms and conditions of easement contract. The program has the capacity to accept up to two-million acres of easements nationwide under contractual agreements (NRCS 2014).

Private Landowner Benefits

Permanent Contracts—Applicants seeking to enroll in a permanent easement agreement under the HFRP would receive no less than 75% and no more than 100% of the fair market value of the land encumbered by the easement. Additionally, the HFRP would provide complete compensation for the actual costs of the approved conservation practices carried out on the land.

30-year Contracts—Applicants seeking to enroll in a 30-year easement agreement under the HFRP would receive up to 75% of the fair market value of their land encumbered by the easement. Additionally, the applicant would receive financial compensation for up to 75% of costs associated with approved conservation practices or 75% of the average cost of approved practices.

10-year Contracts—Applicants seeking to enroll in a 10-year cost-share agreement under the HFRP would receive up to 50% financial compensation for the approved conservation measures or 50% of the average costs of approved practices.

All contracts—When conservation activities on land enrolled in the HFRP result in a net benefit for listed, candidate, or other species, the legislation provides that the landowners will receive safe harbor or similar assurances and protection under the ESA—Section 7 or Section 10(a)(1). If additional necessary measures are identified after the HFPR restoration plan has been agreed too, additional cost-share assistance will be given to the applicant to enact those conservation actions (NRCS 2014).

Table 6-3. Most commonly used NRCS HFRP conservation practices.

NRCS HFRP Most Frequently Used Forestry Practices	
Practice Code	Conservation Practice
338	Prescribed Burning
381	Silvo-Pasture
391	Riparian Forest Buffer
394	Fire Break
409	Forestry System (Prescribed Forestry)
472	Access Control (Use Exclusion)
490	Tree and Shrub Preparation -Mechanical Thinning
612	Tree and Shrub Establishment
644	Wetland Wildlife Habitat Management
645	Upland Wildlife Habitat Management
655	Forest Trails and Landing
657	Wetland Development or Restoration
659	Wetland Enhancement
660	Tree and Shrub Pruning
666	Forest Stand Improvement

Cal Fire Forest Improvement Programs

The Cal Fire Forest Improvement Program (CFIP) is a forestry incentive program that offers financial and technical assistance to private landowners to perform various land management activities that promote the public and private investment in, and improved management of, California forestlands and resources. Such activities include assisting private landowners in developing management plans, performing site preparation, tree planting, thinning, pruning, follow-up monitoring, land conservation, and improvement to wildlife habitat (Cal Fire 2018).

Program Goals

The CFIP aims to (1) ensure adequate timber supplies, applicable employment, and other economic benefits and (2) protect, maintain, and enhance forestlands for present and future generations.

Applicant Eligibility

There are no major eligibility requirements, besides that which requires a landowner to possess at least 20 acres of land. Landowners are encouraged to contact their local Cal Fire unit to seek assistance in the application process. Applications are reviewed by the local Cal Fire office and subsequently sent to the Sacramento headquarters for further review. Upon review, the Sacramento office will contact the landowner to develop a standard CFIP agreement. Applications may be submitted on a rolling basis (Cal Fire 2018).

Funding

The program includes a 10-25% cost-share by private landowners with a match cost share of 75-90% by the program for various land management activities. Funding goals are flexible through time based on the current CFIP funding source. Currently, there are two sources of funding for CFIP, they are: (1) Timber Regulation and Forest Restoration Fund that contributed $3,450,000 dollars in the 2018 fiscal year and (2) High Speed Rail Authority that contributed $2,400,000 in the 2017 fiscal year. While funds from the Timber Regulation and Forest Restoration fund are more flexible in how a landowner could employ them, CFIP funds contributed by the High Speed Rail Authority are to be used strictly for Reforestation Projects to offset carbon impacts. There are additional per acre maximum costs that the funds can cover (Cal Fire 2018).

Cost-Share Structure

Table 6-4. Cal Fire CFIP cost-share rates for different management actions.

Cal Fire CFIP Cost Share Rates			
Practice	**CFIP Cap Rate**	**90% Cost Share**	**75% Cost Share**
Management Plan High (New)	$5000 + $3.00/acre 1st 160 acres $2.50/acre each additional acre to 1000	$4500 + $2.70/acre 1st 160 acres $2.25/acre each additional acre to 1000	$3750+ $2.25/acre 1st 160 acres $1.88/acre each additional acre to 1000
Management Plan Revised/Low (Mini)	$1750 + $1.40/acre	$1575 + $1.26/acre	$1313 + $1.05/acre
RPF Supervision	$150/acre 1st 20 acres $75/acre each additional acre	$135/acre 1st 20 acres $67.50/acre each additional acre	$112.50/acre 1st 20 acres $56.25/acre each additional acre
Site Prep			
Light	$298/acre	$269/acre	$224/acre
Moderate	$425/acre	$383/acre	$319/acre
Heavy	$680/acre	$612/acre	$510/acre
Tree Planting			
Average	$192/acre	$173/acre	$144/acre
Moderate	$298/acre	$269/acre	$224/acre
Difficult	$468/acre	$421/acre	$351/acre
Tree Shelters	$298/acre	$269/acre	$224/acre
Pre-Commercial Thinning			
Light	$298/acre	$269/acre	$224/acre
Moderate	$383/acre	$345/acre	$288/acre
Heavy	$595/acre	$536/acre	$447/acre
Pruning	$170 for 50 trees/acre $298 for 100 trees/acre $383 for 150 trees/acre	$153 for 50 trees/acre $269 for 100 trees/acre $345 for 150 trees/acre	$128 for 50 trees/acre $224 for 100 trees/acre $288 for 150 trees/acre
Release			
Light	$213/acre	$192/acre	$160/acre
Moderate	$340/acre	$306/acre	$255/acre
Heavy	$595/acre	$536/acre	$447/acre
Follow-up/Slash Disposal			
Light	$213/acre	$192/acre	$160/acre
Moderate	$468/acre	$421/acre	$351/acre
Heavy	$765/acre	$689/acre	$574/acre

Source: (Cal Fire 2018).

SRCD Land Management Funding Opportunities

USFS Western Wildland Urban Interface Grant Program—CA Fire Safe Council (WWUI)

- **Funds:** Up to $300,000.
- **Match:** 50% match required from non-federal source, Cal Fire support make proposals more competitive.
- **Intended Use of Funds:** Hazardous fuel reduction and maintenance projects within WUI. Community Wildfire Protection Plans and other planning/assessment documents. Wildfire prevention and mitigation education and outreach for private landowners and community members.
- **Program Goals:** Fire risk reduction activities to benefit at-risk residents, restore and maintain resilient landscapes, and create fire-adapted communities.

Title II—Secure Rural Schools and Community Self-Determination Act of 2000

- **Funds:** No set amount.
- **Match**: No match required, however a match does add to the proposal score.
- **Use of Funds:** Improve maintenance of existing infrastructure. Implement stewardship objectives that enhance forest health. Restore and improve land health and water quality.
- **Program Goals:** Enhancement of schools, roads, and forest projects that aim to improve cooperative relationships.
- **Other Information:** At least 50% of Title II funds must be used for road maintenance, decommissioning, or obliteration; or restoration of streams and watersheds.

FEMA Pre Disaster Mitigation Grant Funding

- **Funds:** No set amount.
- **Match**: 25% match required. 10% match for impoverished communities.
- **Intended Use of Funds:** Pre-disaster Mitigation Projects and Planning. Defensible space measures. Hazardous fuel reduction.
- **Program Goals:** Projects must be directed towards the protection of homes, neighborhoods, structures, or infrastructure.
- **Other Information:** Wildfire mitigation activities are allowable but must express conformance with the Local Hazard Mitigation Plan (Fresno County Multi-Hazard Mitigation Plan). Projects must have gone through NEPA prior to funding. Projects must be within the WUI. Prescribed burning is not allowed.

Cal Fire Green House Gas Reduction Fund Grants—Forest Health Program

- **Funds:** No set amount.
- **Match:** No match required.
- **Use of Funds:** Forest fuels reduction, pest management, reforestation, biomass utilization, and research (though research may not be a primary use of the funds).
- **Eligible Costs:** Funds may be used for salaries and wages, employee benefits, external contracts (technical support), travel, supplies, equipment, and indirect costs
- **Program Goals:** Reduce GHGs, protect upper watersheds where the state's water supply originates, promote long-term storage of carbon in forest trees and soils, minimize loss of carbon storage from large/intense wildfires, and further the goals of the California Global Warming Solutions Act of 2006 (AB 32).
- **Other Information:** Application requires many technical activities such as carbon accounting and FVS modeling depending on proposed activities.

Integrated Water Resources Management Plan Grants

- **Funds:** Dependent on solicitation of activities.
- **Match**: 50% match but can be reduced for impoverished communities.
- **Use of Funds:** Projects that reduce the risk of wildfire or improve water supply reliability.
- **Program Goals:** Same goals as stated in the IWRM plan (2004).
- **Other Information:** IRWM grants are now funded through Proposition 1. In order to be approved, the proposed grant activity must be included in the IRWM Plan.

Wells Fargo and NFWF Resilient Communities Program

- **Funds:** $200,000-$500,000.
- **Match:** No match required.
- **Use of Funds:** Activities that promote program goals listed below.
- **Program Goals:** Forest conservation, fuels management, habitat restoration, and conservation easements for healthy forest ecosystems.
- **Other Information:** Funds may not be used to support ongoing efforts to comply with legal requirements, including permit conditions or mitigation and settlement agreements. However, grant funds may be used to support projects that enhance or improve upon existing baseline compliance efforts.

Identification of Gaps in Human and Financial Capital

Financial Capital

The communities in and around the Dinkey Landscape that are at risk of damage from severe wildfire are limited by a lack of financial capital for investment in fuel reduction treatments. Socio-economic studies on communities associated with the landscape, though not necessarily inside the boundaries of the landscape, have found that the communities of Auberry and Cold Springs Rancheria exhibit household incomes below the $61,400 median household income for California. The annual household income for Shaver Lake, however, is well above California's median household income at $75,350 (Kusel et al. 2015). While the Shaver Lake community appears to have the greatest financial capacity on the Dinkey Landscape to investment in private land fuel treatments, residents of Shaver Lake have been shown to lack social and cultural capital: a lack of social cohesion that results in a low level of willingness of community members to work together to achieve community goals. This is believed to be the result of a majority of Shaver Lake residents being part-time or seasonal residents (Kusel et al. 2015). Regardless of residents' willingness to investment in projects that enhance community well-being, the cost-benefit analysis of private landowner investment in private land fuel treatments (this report, Section 5**)** illustrates that it would be in an individual landowner's best interest to investment in fuel reduction. The cost-benefit analysis, however, also shows how high the up-front costs of those investments are at between $2,750 and $7,375 per acre of treatment. The combination of the high up-front costs of treatment and the overall small amount of financial capital that is currently available for community projects on Dinkey private lands indicates that, without external financial assistance and implementation support, large-scale and impactful fuel treatment projects are unlikely to occur.

Human Capital

Beyond financial constraints, one of the primary capacity gaps that exists for the communities associated with the Dinkey Landscape that impede the completion of fuel treatments is a lack of local contractors for performing fuel treatments. Currently there is one contractor in the region that can undertake mechanical thinning projects – Sierra Forest Products – and, because they are primarily a timber company, their fuel treatment operations are constrained by a minimum requirement of merchantable wood that needs to be available for harvest per acre on a plot of land requiring treatment (K. Duysen, personal communication, October 27, 2017). Because Sierra Forest Products is constrained by this requirement, among others, their ability to operate as a contractor for private land fuel treatment projects is limited. Additionally, only three local hand thinning crews are currently available for fuel treatment work on private lands. Because of the slow rate of fuel treatments performed by hand thinning operations, the existence of only three crews also severely limits the amount of private land that can be treated for hazardous fuels reduction in a single year.

However, many of the communities associated with the Dinkey Landscape have suffered from a lack of local employment opportunities with many locals holding seasonal, part-time, or intermittent jobs. Limited employment opportunities have led to the out-migration of young adults from the area, though unemployment rates remain high in Auberry at 8.6% and Terra Bella at 31.6% (Kusel et al. 2015). If the financial capital available for fuel treatments on the Dinkey Landscape is increased through public grants or funding programs, increased demand for fuel treatments could create opportunities for local employment, especially from those communities like Auberry, Terra Bella, and Cold Springs Rancheria whose populations still have a substantial percentage of young individuals.

Equipment and Processing Capital

To complete fuel treatments on Dinkey Landscape private lands in an efficient manner, there likely needs to be an increase in fuel treatment contractors with the ability to thin parcels mechanically. However, the equipment to perform mechanical thinning is prohibitively expensive, with new thinning machinery, such as a feller buncher, costing approximately $500,000 (K. Duysen, personal communication, October 23, 2017). Given the current low demand for fuel treatments and the slim profit margins on hand thinning projects, it is unlikely that enough capital could be generated by hand thinning contractors to invest in thinning machinery without loans or grants that support their investment.

Not only is the region lacking in thinning equipment, effective fuel treatments on the landscape are limited by the ability to process woody debris and slash post-treatment. The lumber mill closest to the Dinkey Landscape is more than 200 miles away, but is almost entirely dependent on wood products removed from the Sierra National Forest and Dinkey Landscape (Kusel et al. 2015). Although the presence of the mill and the treatment work performed by Sierra Forest Products has helped Dinkey Landscape private landowners and the USFS stretch their treatment funds by maintaining bid competition for thinning contracts, precluding a non-local firm from gaining unilateral control of the bargaining process, the Terra Bella mill only processes merchantable wood (Kusel et al. 2015). Slash wood and non-merchantable timber tend to remain unprocessed on the landscape because, even though there is a biomass plant near the City of Fresno, the transportation costs for slash and non-merchantable wood are much higher than the nominal payment contractors could receive for the woody biomass (C. Quijano, personal communication, November 8, 2017).

However, recently the SRCD was awarded funds through Proposition 1 for the Pre-Development and Acquisition Planning for a Biomass Utilization Campus at the former Auberry Mill Site. The former mill site is a 65-acre parcel situated near highway 168 and is about 25 northeast of Fresno at the entry of the High Sierra Ranger District. Over the next year, this project will complete the pre-development planning, due diligence, and regulatory requirements for the SRCD to acquire and develop an integrated biomass campus on the Auberry Mill site. The eventual development of a biomass campus on this site will provide a receptacle for non-merchantable biomass for the communities of Auberry and Prather, the High Sierra Ranger District, and other private forest landowners on the Dinkey Landscape (Sierra Nevada Conservancy, 2018).

Short Term Approach for Fuel Reduction of Private Lands

The following section is presented in a two-tier approach to building a short-term plan for employing vegetation management and fuel treatments on private lands. First, a funding approach subsection offers a strategic approach to garnering funds to employ various management techniques based on the qualifications for that money source. Second, a planning and implementation approach subsection offers various planning strategies to maximize the amount of treatable private lands based on the limitation of treatment types available, financial and human capital, and formation of potential partnerships. The subsection continues and identifies geographic locations that should be prioritized for treatment, what the role of the SRCD might be in partnerships with various agencies and identifies other avenues to pursue to employ fuel management programs.

Funding Approach

Developing a strategic funding approach will be key to obtaining funds for fuel reduction treatments on private lands. This funding approach outlines potential grants that could be packaged to achieve desired levels of fuel treatment funds and goals for those respective grants.

Grant Packaging

The following grant packages were identified and developed in accordance with eligible costs of various actions, funding ranges and financial match requirements, and the applicability of fire modeling and cost-benefit analysis results from Section 4 and Section 5 of this report. Part of the reason for pairing grants together as such, is that combining multiple grants together make grant applications more competitive within the applicant pool as it demonstrates that multiple agencies or foundation support the overall goal that the grant applicant is attempting to accomplish. Key considerations to the following criteria were made specifically to optimize funding potential.

Match requirements: For grant applicants to be eligible for particular grant funds, some grants require matches. Match requirements could constitute different funding sources and/or financial minimums. For instance, some grant funds from federal governments require that the funding match be from a non-federal source. Further, some grants just require that a certain percentage of funds be provided through a financial match. For the developed grant packages, matching requirements were one of the factors that dictated the pairing of grants.

Local Agency Input: Advice from various agency personnel was critical in determining which grants would be best suited for fuel management goal completion under the SRCD and which grant packages were the most feasible and beneficial to SRCD goals.

Funds Available: As fuel reductions in private lands is a landscape scale problem and this project modeled the impacts of fuel treatments on fire severity at the landscape scale, grants that could provide enough funds to make a considerable impact were prioritized in this recommendation of grant packaging. Grants that offered smaller amounts of funding rewards were ignored, however, this approach does not undervalue smaller grants and encourages the SRCD to apply to them when appropriate.

Eligible Costs: Each grant has different goals and associated eligible costs. This determines what kind of activities can be done with the money from these grants. Each of the grants identified has a unique composition of actions that can be performed on the landscape as well as their own unique cost structure for administration and planning activities. Considerations of what could be done with monies received was reflected when developing the grant packages.

Grants our research supports: Aspects of our methodology, results, and findings are in alignment with the eligible costs, grant application methodologies, and grant goals. Grants packages were developed with this alignment in mind.

Applicability to management plans: In the case of some grants, grant applicant eligibility is contingent on the existence of certain local land management plans. Moreover, grant goals and eligible costs that were supported by federal, state and local management plans goals, policies, objectives, and desired conditions were considered when developing the grant packages.

Grant Package A

The *U.S.F.S Western Wildland Urban Interface* grant (WWUI) and *Cal Fire Forest Health Program* (FHP) grant were packaged together for many reasons. The WWUI grant is allocated by the USFS and supplies monies for projects that enhance protection of communities located within the WUI. The funds acquired through this grant can be used for actions such as hazardous fuel reduction, equipment purchases, and education and outreach. These eligible actions directly support the encouragement and implementation of fuel treatments on private lands. Further, applicants applying for this grant are considered more competitive if they also have financial support from Cal Fire. This is the reasoning behind coupling the WWUI grant with the Cal Fire FHP grant. Additionally, the WWUI grant is more competitive if it addresses landscape scale restoration, which this project supports. Finally, the WWUI grant is more competitive for applicants that have not received prior funding, which the SRCD has not. The Cal Fire FHP grant also focuses on forest fuel reductions and other direct land management activities. The FHP grant also specifically requires technical analysis using FVS modeling or carbon accounting. The vegetation and fire modeling completed for this report employed the FVS model so that the results of fuel and fire modeling in Section 4 could be used in the grant application to fulfill this technical requirement. Finally, the FHP does not have any match requirements, but because the WWUI grant does has a 1:1 non-federal match requirement, the FHP would qualify as a matching funding source for the WWUI grant.

Grant Package B

The *FEMA Pre-Disaster Mitigation* (FEMA) grant and *Title II—Secure Rural Schools and Community Self-Determination Act of 2000* (Title II) grant were packaged together as the FEMA grant requires a 25% match and the Title II grant was established as a viable matching source that met similar goals to the FEMA grant. Applicant eligibility for the FEMA grant is contingent on the geographic area presently included in a Multi Hazards Mitigation Plan. The Dinkey landscape, because it is included in the *Fresno County Multi-Hazard Mitigation Plan,* meets this requirement for the FEMA grant. Moreover, the SRCD is identified in the Multi-Hazard Mitigation Plan as the jurisdictional agency for multiple mitigation actions listed therein. This supports the application of the SRCD for the FEMA grant as it is already formally committed to completing actions that the FEMA grant identifies as eligible costs for grant recipients. The Title II grant, however, provides funds for on the ground fuel treatment activities and education and outreach, both of which are recommended actions the SRCD should undertake to achieve the fire severity reductions discussed in Section 4. Finally, costs eligible under Title II include those mitigation actions the SRCD is jurisdictionally responsible for in the *Fresno County Multi-Hazard Mitigation Plan.*

Grant Package C

The *Department of Water Resources Integrated Water Management* (IRWM) grant and the *National Fish and Wildlife Foundation/Wells Fargo Community Resilience* (NFWF) grant were packaged together as the IRWM requires a 50% match and the NFWF grant has the funding capacity to match it with a significant contribution ($200,000 = lower bound of funding range). The IRWM grants are now funded through Proposition 1 grants and must support the goals and objectives written in the local DWR IRWM plan. The local IRWM plan mentions reducing fire risks as an objective to improve watershed and environmental resource management. Therefore, eligible costs for the grant could include activities that reduce fire risk by placing strategic fuel breaks, conducting fuel treatments and forest restoration, and thinning underbrush. Additionally, the NFWF grant considers forest conservation, fuels management, habitat restoration, and conservation easements for healthy forest ecosystems as eligible costs for funds received through the grant. Both the goals and eligible costs of the NFWF grant pair agreeably with IRWM grant, as both promote community resiliency on a landscape scale.

Table 6-5. Grant packages applicable to SRCD efforts to support the implementation of fuel treatments on private lands.

Grant Package	Grant	Funding Range & Match Requirements	Examples of Amount of Money Distributed in Past Projects
A	U.S. Forest Service Western Wildland Urban Interface Grants – CA Fire Safe Council	Up to $300,000. 1:1 nonfederal match required.	$86,000—Average Receipt in 2013
	Cal Fire Forest Health Program Grant	No Set Amount	$5,000,000—USFS $406,600—USFS $864,780—USFS
B	Federal Emergency Management Agency Pre-Disaster Mitigation Funding	No set amount. 25% match required	$4,000,000 dollar max for mitigation actions—Past project funding receipts not listed
	Secure Rural Schools and Community Self Determination Act of 2000 (Title II)	No set amount. No Match Required, however improves application score	$200,000—Sierra County Fire Safe & Watershed Council
C	Department of Water Resources Integrated Regional Water Management (IRWM) Grants	Depends on solicitation. General match requirement is 50%	$488,320—Yosemite-Sequoia Resource Conservation and Development Council $496,000-Tuolumne Utilities District
	National Fish and Wildlife Foundation + Wells Fargo Resilient Communities Grant	$200,000- $500,000 No Match	$207,500—California Trout $305,000—Terra Fuego Resource Foundation

Planning and Implementation Approach

To assess the potential beneficial impacts associated with the receipt of some or all identified grant packages, Case Scenarios were put together to demonstrate the potential actions that could be employed if the identified grant packages were acquired by the SRCD. These case scenarios, while indeed speculative, offer insight to the capacity of the SRCD to employ various actions to reduce hazardous fuels on the landscape. The scenarios also highlight the disparity between the amount of acreage of fuel treatments whose impact on fire severity reduction were assessed in this report (Section 4, Results) and what is actually feasible to treat on the landscape given financial and community capacity constraints. The following section provides three scenarios: best, intermediate, and worst. In each case, an amount of funds per grant package is assumed to be received by the SRCD based on past grant allocations to similar projects. With these assumed funds and the costs eligible under each respective grant, several recommended actions for the SRCD are highlighted to help further their fuel reduction goals. These recommendations recognize that grant applications involve a lot of time and effort, so a timeline was created to loosely schedule grant applications and acquisition of grant funds. A timeline of 5-years is assumed for funding acquisition in each case scenario. This timeline is coordinated with fire severity findings from this report (Section 4, Results) as fuel treatment cycles are recommended for completion every seven to ten years. The schedule of fund acquisition and recommendations for actions does not attempt to make recommendations beyond a 10-year timeline because grant opportunities and associated funding are constantly changing and, as a result, future grant recommendations would be too speculative to be useful.

Included in this section is an analysis of how many acres of private land could be treated under each case scenario. While each grant package offers a multitude of recommendations that should be considered, the treatable acres analysis only takes two of these recommendations into consideration: (1) the SRCD directly pays for treatment on private lands and (2) the SRCD covers the difference in costs that private landowners incur as participants of NRCS and Cal Fire cost-share programs. This analysis offers three scenarios of fuel treatment scale which dramatically differ in outcomes of treated acres. It must, however, be recognized that multiple assumptions about the amount of funds received by the SRCD through each grant package and the exact cost of fuel treatments were used to generate these scenarios. The significant costs associated with 'boots on the ground' treatments is highlighted by each of these scenarios, and will hopefully motivate grant committees to acknowledge and distribute increased finances to the SRCD for the purpose of treating private lands in the Southern Sierra Nevada Mountains.

Planning Considerations with Funds Acquired via Grant Package—A

Funding Package: U.S.F.S Western Wildland Urban Interface Grant + Cal Fire Forest Health Program Grant

Consider:

- Using WWUI funds to host forums to engage private landowners with the benefits of treating their lands to reduce hazardous fuels and reforesting with fire-resilient species and to connect private landowners with a NRCS representative.
- Allocating Cal Fire funds for to reimburse private landowners participating in the EQUIP program for fuel treatment costs not covered through the cost-share.
- Increasing community and labor capital through purchasing equipment.

  - Equipment can be owned by SRCD and rented out to contractors to increase contractor capabilities and generate revenue for SRCD.
  - Equipment can be donated to community at-large or individual contractors to improve fuel treatment scale, capability, and debris processing.

- Developing a cost-share program for private landowners through the SRCD informed by the findings of this project and constrained by the limitations of the grant eligible costs.

Planning Considerations with Funds Acquired via Grant Package—B

Funding package: FEMA Pre-Disaster Mitigation Grant + Title II Secure Rural Schools and Community Self-Determination Act of 2000 Grant

Consider:

- Developing a cost-share program for private landowners through the SRCD informed by the findings of this project and constrained by the limitations of the grant eligible costs.

- Hosting forums to engage private landowners with the benefits of reducing hazardous fuels and reforesting with fire-resilient species and to connect private landowners with a NRCS representative.

Planning Considerations with Funds Acquired via Grant Package—C

Funding package: Department of Water Resources Integrated Water Management Grants + National Fish and Wildlife Foundation/Wells Fargo Community Resilience Grant

Consider:

- Building a relationship with the NRCS representative to best allocate EQIP funds matched or unmatched with water resources funds to maximize impact by supplying match funds for EQIP in appropriate or necessary situations.

- Hosting forums to engage private landowners with the benefits of reducing hazardous fuels and reforesting with fire-resilient species and to connect private landowners with a NRCS representative.

- Developing a cost-share program for private landowners through the SRCD informed by the findings of this project and constrained by the limitations of the grant eligible costs.

Planning Considerations with No Grants Obtained

Consider:

- Educating private landowners on the benefits of reducing hazardous fuels on private lands through the Bren-developed online app.

- Engaging private landowners with the EQIP program and representative.

- Advocating for application to the Community Planning Assistance for Wildfire (CPAW) program through Headwaters Economics for the Shaver Lake community.

- Continuing relationship building with contractors for fuel treatments to provide private landowners with lists of applicable local contractors or to inform contractor decisions in the event of a successful grant application that can be used for fuel reductions.

- Continuing to engage with the Dinkey Collaborative and the USFS to direct attention towards the information and capacity gaps between catastrophic fire preventative capacity on public and private lands.

- Staying apprised of state and federal agency funding and grant opportunities that require local engagement or the support of a local entity, which can then be leveraged to support work on private lands.

Treatable Acres under Limited Funding Scenarios

Introduction:

Given that benefits of fuel treatments on private lands in the Dinkey Landscape accrue to private landowners, the SRCD, and the USFS (this report, Section 5, Summary of Results); maximizing those benefits will rely on how thinning projects are implemented in time, space, and by which method. The placement of fuel treatments will dictate the costs and subsequently the amount of acreage that can be treated. As such, to understand the action potential of the SRCD to employ fuel treatments on private lands, an assessment of how many acres could be treated given the type of treatment and the amount of funds available for treatment is presented below.

Methodology/Results:

To analyze how much acreage could be treated, a theoretical funding range for each case scenario was established. To do this, past receipts for similar projects funded by the identified grants were evaluated to calculate a baseline for funds available under each grant package for future fuel reduction treatments. This information listed in Table 6-5 is based off similar projects that received varying degrees of funding from the identified grants. After the funding range was established for each grant package, a median value in that range was chosen as the 'Assumed Financial Capacity.' A median value was chosen for this analysis so as to not severely overestimate or underestimate the potential for receiving similar funding. Table 6-6 shows the theoretical range from funding opportunities labeled as 'Potential Financial Capacity' and the assumed funds for treatment under 'Assumed Financial Capacity'. The best-case scenario assumes that the SRCD would receive all three identified grant packages, the intermediate-case scenario assumed that the SRCD would receive any one of the identified grant packages, and the worst-case scenario assumes that no grant funding would be received.

After funding ranges were set, the amount of acreage that could be treated was tested under two different spending methods. The first spending method accounts for a spending scenario in which the SRCD pays for the full costs of treatment on private lands. This would cost the SRCD $2,750/acre to perform mechanical thinning, and $7,375/acre to perform hand thinning (Section 5, Results and Methodology). The second spending method explored treatable acres under a scenario in which the SRCD contributed the difference in costs to the private landowners they would incur when participating in the NRCS EQIP or Cal Fire CFIP programs. Because the EQIP and CFIP programs offer cost-share rates of ~600/acre and

536/acre respectively, the remaining cost the SCRCD would incur would be $2,150/acres and $2,214/acre respectively to perform mechanical thinning. Further, because grant money acquired from an agency often cannot be used to supplement other assistance programs run by the same agency , money that was acquired through any federal funds was not included as a part of NRCS EQIP cost analysis and funds acquired through Cal Fire were not used for the Cal Fire CFIP costs analysis. For all scenarios, 10% of the assumed funds were allocated to administration costs that the SRCD would incur for planning respective projects.

The target for thinning activities was based on the minimum threshold of acres that need to be treated on private lands to achieve a reduction in fire severity similar to that of a full landscape treatment (Section 4, Results).

Table 6-6. Assumed funding under the best, intermediate and worst case funding scenarios.

Action Capacity in Different Funding Case Scenarios Via Direct SRCD Payment of Treatment			
Funding Case Scenario	Grant Packages	Potential Financial Capacity ($)	Assumed Financial Capacity ($)
Best Case Scenario	A + B + C	600,000-2,200,000	1,350,000
Intermediate Scenario	A	300,000-1,000,000	600,000
	B	100,000-600,000	350,000
	C	200,000-600,000	400,000
Worst Case Scenario	No Grants Obtained	0	0

Table 6-7. Treatable acres under the best, intermediate and worst case funding scenarios with SRCD supplying the full costs of treatment for private landowners.

Action Capacity in Different Funding Case Scenarios Via Direct SRCD Payment of Treatment					
Funding Case Scenario	Grant Packages	Potential Financial Capacity ($)	Assumed Financial Capacity ($)	Potential Action Capacity (Acres) Mechanical | Hand Thinning	Deficit from Target (Acres) Mechanical | Hand Thinning
Best Case Scenario	A + B + C	600,000-2,200,000	1,350,000	506 | 165	4,494 | 4,835
Intermediate Scenario	A	300,000-1,000,000	600,000	196 | 73	4,804 | 4,927
	B	100,000-600,000	350,000	142 | 43	4,858 | 4,975
	C	200,000-600,000	400,000	167 | 49	4,833 | 4,951
Worst Case Scenario	No Grants Obtained	0	0	0	5,000

Table 6-8. Treatable acres under the best, intermediate and worst case funding scenarios with SRCD supplying the difference in cost of treatment for private landowners enrolled in other cost-share programs.

Action Capacity in Different Funding Case Scenarios with Cost-Share Programs							
Funding Case Scenario	Grant Packages	Potential Financial Capacity ($)	Assumed Financial Capacity ($)	NRCS Cost-Share Program		Cal Fire Cost-Share	
				Potential Action Capacity (Acres)	Deficit from Target (Acres)	Potential Action Capacity (Acres)	Deficit from Target (Acres)
Best Case Scenario	A + B + C	600,000-2,200,000	1,350,000	519	4,481	522	4,478
Intermediate Scenario	A	300,000-1,000,000	600,000	227	4,773	217	4,783
	B	100,000-600,000	350,000	125	4,875	142	4,858
	C	200,000-600,000	400,000	167	4,833	163	4,837
Worst Case Scenario	No Grants Obtained	0	0	0	5,000	0	5,000

Discussion:

The amount of treatable acres under each funding package does not change much under the two spending method available to the SRCD – whether they cover the entire costs of fuel treatment or they cover the cost of fuel treatment not covered by existing cost-share programs. The reason for this similarity between spending methods is the result of grant restrictions for federal and Cal Fire grants that limit the amount of money that can be used to cover the costs of fuel treatment not covered in cost-share programs. As a result, the maximum amount of acres that can be treated under either spending method is approximately 500 acres (Table 6-7). This 500 acres is only achievable under a best case funding scenario and using mechanical treatment. Hand treatment results in a maximum of only 165 treatable acres (Table 6-7).

Through conversations with agency representatives, it came to light that, currently, there is relatively low participation in the existing cost-share programs because landowners still cannot afford even the reduced costs of treatment (R. Evans February 12, 2018). It is believed that, if the SRCD were to reimburse the private landowner with more money to reduce their treatment costs, participation could be improved. Further, with the coupling of funds from other agencies, the price of treatment is effectively reduced, which results in slightly more acres being able to be treated (Table 6-8).

While 500 acres is a substantial amount of land for treatment, fire behavior modeling performed in this study found that the minimum amount of land that needs to be treated to achieve a reduction in fire severity similar to that of a full landscape treatment is about 21% of the landscape (Section 4, Results). This roughly equates to 5,000 acres of treatment. The difference between the amount of acres that would create significant landscape scale fire severity reductions and the amount of land that could be treated even under the best case funding scenario highlights a disparity in the amount of public funding available for impactful fuel treatment activities. The SRCD must seek re-occurring funding to continue to increase their fuel treatment impact through time.

That being said, smaller scale fuel treatment projects may still create significant reductions in fire severity for individual parcels and for the landscape as a whole, when compared with a no treatment scenario (Section 4, Results).

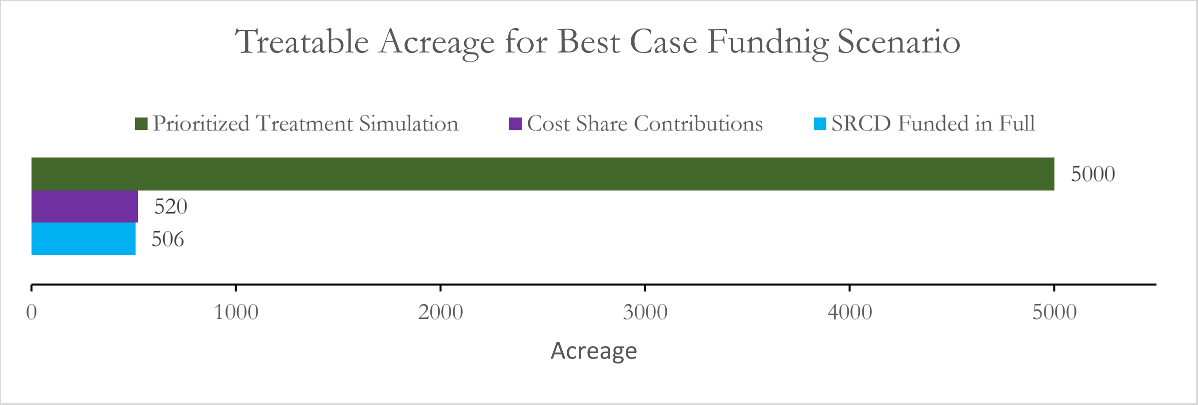
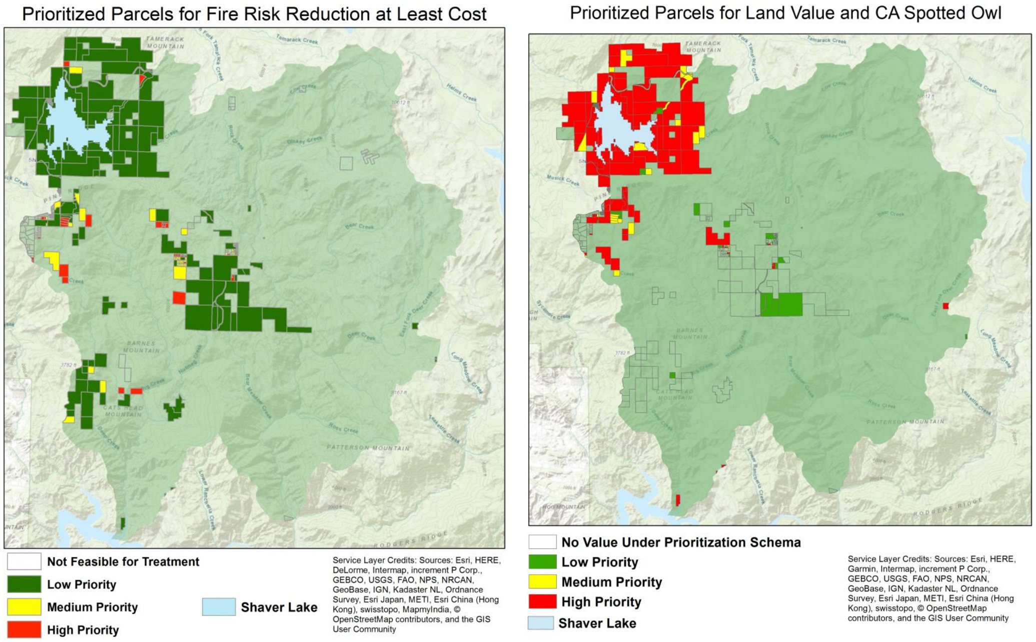


Figure 6-1. Assumed treatable acres under best-case funding scenario.

Prioritization of Parcel Treatment

Prioritizing parcels for treatment by location is a way for the SRCD to increase their ability to reach fire reduction and conservation goals within the constraints imposed by limited funding and human capital. As discussed in Section 4, using an optimization tool such as Marxan can be helpful in identifying locations for treatment based on weighted factors. These factors can include conservation targets such as – fire severity reduction, preserving high valued parcels, maintaining endangered species habitat, and maximizing carbon sequestration. Depending on the goals of the SRCD or the grant funding it has acquired , a Marxan analysis could be performed to identify parcels for treatment that would best achieve specified conservation goals. .

Figure 6-2 provides two examples that demonstrate Marxan can be used to identify parcels' fuel treatment priority based on different weighted conservation targets. While these examples are demonstrative, the SRCD should hire a private consultant if they are interested in targeting a Marxan analysis to their conservation goals based on the eligible costs of grants.


Prioritized Parcels for Fire Risk Reduction at Least Cost

Prioritized Parcels for Land Value and CA Spotted Owl

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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Figure 6-2. Examples of different treatment placement priority based on weighted values of conservation measures and costs.

Partnership Building

Developing partnerships with federal, state, and local agencies as well as other non-profits and private institutions can help offset the costs of fuel treatments directly incurred by both the SRCD and private landowners. Many of these entities have goals similar to the SRCD for fuel reductions across the landscape, and by dovetailing agency interest with those of the SRCD, there is a greater potential to increase the amount of acreage for treatment or the persistence of treatment through time. The SRCD should explore the possibility of partnership development with agencies that employ cost-share programs to private landowners, as this would effectively reduce costs for the SRCD to employ treatments and reduce costs for private landowners enrolled in those programs. Specifically, as it pertains to potential cost-share program partners, the SRCD should look into collaborating with the Cal Fire and the NRCS. In January 2018, the NRCS EQIP programs received $7.5 million to fund land management actions by private landowners enrolled in cost-share programs. This source of funding comes at an opportune time for the SRCD and establishing a partnership with NRCS could benefit both institutions.

Additionally, the non-profit organization *Headwater Economics*, based out of Bozeman, MT, offers a multitude of wildfire planning and mitigation services through their CPAW program. The SRCD should explore the possibility of coordinating with *Headwaters Economics* to understand the feasibility of utilizing their services to benefit the Dinkey Landscape, specifically the Shave Lake community. Applicants chosen to participate in the CPAW program bear no costs for enrollment and only have to meet with CPAW staff on a limited basis. The CPAW program's hands-off approach allows minimal labor required by local agencies, which allows local jurisdictions to remain focused on other tasks within the community. CPAW aligns their recommendations with other fire risk mitigation efforts such as Community Wildfire Protection Plans and Multi-hazard Mitigation Plans to increase continuity between management plans and policies. Currently Mammoth Lakes, CA is receiving wildfire planning and mitigation support through the CPAW program.

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Appendix—6

Item A—Management Plans and Project Alignment Matrices

Table 6-A-1. Sierra Nevada Forest Plan Amendment Goal Alignment Matrix

Sierra Nevada Forest Plan Amendment (2004)			
Goal	**Description**	**Alignment**	**Discussion**
Species Viability	Maintain and restore habitat to support viable populations of native and desired non-native plant, invertebrate, and vertebrate riparian-dependent species. Prevent new introductions of invasive species. Where invasive species are adversely affecting the viability of native species, work cooperatively with appropriate State and Federal wildlife agencies to reduce impacts to native populations.	Indirect	Section 4, Fuel Treatment Feasibility, takes into account that species of concern can be weighted in a geospatial Marxan analysis as considerations for placement of treatment on landscape
Plant and Animal Community Diversity	Maintain and restore the species composition and structural diversity of plant and animal communities in riparian areas, wetlands, and meadows to provide desired habitats and ecological functions.	Direct	Section 3, Reforestation, talks about a changing forest structure due to climate and how reforestation may look under as according to the Dinkey Reforestation Framework
Watershed Condition	Maintain and restore soils with favorable infiltration characteristics and diverse vegetative cover to absorb and filter precipitation and to sustain favorable conditions of stream flows.	Indirect	Section 3, Fuel Management Strategies, talks about the watershed scale benefit of performing fuel management across the landscape
Streamflow Patterns and Sediment Regimes	Maintain and restore in-stream flows sufficient to sustain desired conditions of riparian, aquatic, wetland, and meadow habitats and keep sediment regimes as close as possible to those with which aquatic and riparian biota evolved	Indirect	Section 3, Drivers and Stressors of Altered Forest Health and Increased Catastrophic Fire Risk, mentions streamflow diminishment in un-thinned forests
Riparian Conservation Objective #4	Ensure that management activities, including fuels reduction actions, within RCAs and CARs enhance or maintain physical and biological characteristics associated with aquatic- and riparian-dependent species.	Indirect	Section 3, Fuel Management Strategies, talks about the watershed scale benefit of performing fuel management across the landscape

Sierra Nevada Forest Plan Amendment (2004)			
Goal	**Description**	**Alignment**	**Discussion**
Fire and Fuel Management Goal-1	Treat fuels in a manner that significantly reduces wildland fire intensity and rate of spread, thereby contributing to more effective fire suppression and fewer acres burned.	Direct	Section 4, Results, demonstrates this with results from vegetation and fire modeling
Fire and Fuel Management Goal-2	Treat hazardous fuels in a cost-efficient manner to maximize program effectiveness.	Direct	Section 5, Discussion, mentions how lower costs can be achieved and by which methods
Fire and Fuel Management Goal-3	Actively restore fire-adapted ecosystems by making demonstrated progress in moving acres out of unnaturally dense conditions.	Direct	Section 6, Funding, Planning and Implementation Approach, addresses the need to do this on private lands
Fire and Fuel Management Goal-4	Strategically place treatment areas across landscapes to interrupt potential fire spread.	Direct	Section 6, Prioritization of Treatment Placement, mentions how outsourcing a private consultant to do further Marxan analysis could achieve treatment placement goals
Fire and Fuel Management Goal-5	Remove sufficient material in treatment areas to cause a fire to burn at lower intensities and slower rates of spread compared to untreated areas.	Direct	Section 4, Results, demonstrates this fire behavior modeling
Fire and Fuel Management Goal-6	Consider cost-efficiency in designing treatments to maximize the number of acres that can be treated under a limited budget.	Direct	Section 6, Treatable Acres Under Limited Funding Scenarios, explores how this might be achieved by SRCD
Hardwood Ecosystems Goal-1	Establish and maintain a diversity of structural and seral conditions in landscapes in proportions that are ecologically sustainable at the watershed scale.	Indirect	Section 3, Fuel Management Strategies, talks about the watershed scale ecological benefit of performing fuel management across the landscape
Hardwood Ecosystems Goal-2	Establish and maintain sufficient regeneration and recruitment of young hardwood trees over time to replace mortality of older trees.	Indirect	Section 3, Reforestation, talks about a changing forest structure due to climate and how reforestation may look under as according to the Dinkey Reforestation Framework

Sierra Nevada Forest Plan Amendment (2004)			
Goal	**Description**	**Alignment**	**Discussion**
Hardwood Ecosystems Goal-3	Establish and maintain sufficient quality and quantity of hardwood ecosystems to provide important habitat elements for wildlife and native plant species.	Indirect	Section 3, Reforestation, talks about a changing forest structure due to climate and how reforestation occur according to the Dinkey Reforestation Framework
WUI Defense Zone-Desired Condition #1	Maintain stands in defense zones that are fairly open and dominated primarily by larger, fire tolerant trees.	Direct	Section 6, Funding Approach, advocates for the acquisition of FEMA pre-disaster mitigation grant that focuses on WUI protection fuel treatments
WUI Defense Zone-Desired Condition #2	Encourage surface and ladder fuel conditions are such that crown fire ignition is highly unlikely.	Direct	Section 4, FVS Simulated Fuel Reduction Treatments, removes these types of fuels as a part of the simulated fuel treatments
WUI Defense Zone-Desired Condition #3	Encourage openness and discontinuity of crown fuels, both horizontally and vertically, that would result in very low probability of sustained crown fire.	Direct	Section 4, FVS Simulated Fuel Reduction Treatments, removes these types of fuels as a part of the simulated fuel treatments to promote this type of forest structure
WUI Threat Zone-Desired Conditions #1	Produce fuel conditions such that lame lengths at the head of the fire are less than 4 feet.	Direct	Section 4, Results, demonstrates this fire behavior outcome
WUI Threat Zone-Desired Conditions #2	Produce fuel conditions such that the rate of spread at the head of the fire is reduced to at least 50 percent of pre-treatment levels.	Indirect	Section 4, Results, fire modeling shows that fuel treatments reduce fire severity and spread
WUI Threat Zone-Desired Conditions #3	Treat fuels so hazards to firefighters are reduced by managing snag levels in locations likely to be used for control of prescribed fire and fire suppression consistent with safe practices guidelines.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, removes these types of fuels as a part of the simulated fuel treatments but does not due so explicitly to safety guidelines
WUI Threat Zone-Desired Conditions #5	Reduce tree density to a level consistent with the site's ability to sustain forest health during drought conditions.	Indirect	Section 3, Drivers and Stressors of Altered Forest Health and Increased Catastrophic Fire Risk, mentions how drought has affected un-thinned forests and how that might change with thinning

Table 6-A-2. GTR 220 Alignment Matrix

USFS GTR-220 (2009)			
Plan Finding	**Description**	**Alignment**	**Discussion**
Mechanical fuels management	When stands cannot be burned, reducing fuels to moderate fire behavior is still a key priority because wildfire is likely to burn the area eventually. A few of the ecological benefits of fire are achieved with mechanical fuel reduction, but thinning is not an effective substitute for fire in affecting ecosystem processes. Reducing surface fuels is as important as reducing ladder fuels.	Direct	Section 6, Planning and Implementation Approach, addresses the necessity to mechanically thin the forests even with limited funds as benefits may still be incurred by the localized area during wildfire
Limit use of crown separation in fuel treatments:	Sparingly apply canopy bulk density reduction and increased tree crown separation only in key strategic zones. More research is needed, but current models suggest its effects on reducing crown fire spread are limited, and the regular leave-tree spacing does not mimic tree patterns in active-fire-regime forests.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, removes these types of fuels as a part of the simulated fuel treatments to promote this type of forest structure, however, crown separation was not directly addressed
The ecological importance of fire	Prescribed fire can help reduce surface fuels and restore some of the ecological processes with which mixed-conifer forests have evolved.	Indirect	Section 3, Fuel Management Strategies, talks about the benefits of performing prescribed burning, however, prescribed burning was never modeled
Treatments focused on affecting fire behavior	Efforts to restore pre-European forest conditions are likely to fail in the face of climate change and also do not provide flexible prescriptions that adapt to different site conditions. Focus treatments on affecting potential fire behavior by manipulating fuel conditions, thereby allowing forests to equilibrate to fire under modern conditions and increasing forest heterogeneity.	Direct	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments to pre-European composition densities as thinning targets

USFS GTR-220 (2009)			
Plan Finding	**Description**	**Alignment**	**Discussion**
Retention of suitable structures for wildlife nest, den, and rest sites	Trees providing suitable structure for wildlife include large trees and trees with broken tops, cavities, platforms, and other formations that create structure for nests and dens. These structures typically occur in the oldest trees. Develop and adopt a process for identifying, and thus protecting, such trees for use by inventory and prescription-marking crews.	Indirect	The SRCD should take this into account when performing or planning fuel treatments. This report mention the benefits to wildlife habitat throughout as a result of fuel treatments
Stand-level treatments for sensitive wildlife	Areas of dense forest and relatively high canopy cover are required by California spotted owls, fishers, and other species. Identify and manage areas where, historically, fire would have burned less frequently or at lower severity owing to cooler microclimate and moister soil and fuel conditions for the higher stem and canopy densities that they can support.	Direct	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments on at stand levels. Actualizing this modeled scenario will rely on the SRCD implementation strategy
Large trees and snags	Given their current deficit in mixed-conifer forest and the time necessary for their renewal, protect most large trees and snags from harvest and inadvertent loss owing to prescribed fire.	Indirect	The SRCD should take this into account when performing or planning fuel treatments. This report mention the benefits to wildlife habitat throughout as a result of fuel treatments
Landscape-level treatments for prey of sensitive wildlife	In the absence of better information, habitat for the prey of owls and fishers may best be met by mimicking the variable forest conditions that would be produced by frequent fire. Reductions in stem density and canopy cover would emulate the stand structure produced by local potential fire behavior, varying by a site's slope, aspect, and slope position.	Indirect	The SRCD should take this into account when performing or planning fuel treatments. This report mention the benefits to wildlife habitat throughout as a result of fuel treatments

USFS GTR-220 (2009)			
Plan Finding	**Description**	**Alignment**	**Discussion**
Retain hardwoods and defect trees and promote shrub patches	Hardwoods (particularly black oak) and defect trees (i.e., those with cavities, broken tops, etc.) are valued wildlife habitat and should be protected whenever possible. Increasing understory light for shrub patch development, can increase habitat for some small mammals and birds.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments that selectively removed certain vegetation types. Actualizing this modeled scenario will rely on the SRCD implementation strategy
Riparian forest fuel reduction	Prescribed burning of riparian forest will help reduce fuels in these corridors that are also important wildlife habitat.	Indirect	Section 3, Fuel Management Strategies, talks about the benefits of performing prescribed burning, however, prescribed burning was never modeled
Spatial dispersion of treatments	Trees within a stratum (i.e., canopy layers or age cohorts) would often be clumped, but different strata would usually be spatially separated for fuel reasons. Give particular attention to providing horizontal heterogeneity to promote diverse habitat conditions.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments that selectively removed certain vegetation types. Actualizing this modeled scenario will rely on the SRCD implementation strategy. The SRCD's Forester should consider spatial dispersion of treatments when in the field assessing areas for fuel treatment
Spatial variation in forest structure	"Average" stand conditions were rare in active-fire forests because the interaction of fuels and stochastic fire behavior produced highly heterogeneous forest conditions. Creating "average" stand characteristics replicated hundreds of times over a watershed will not produce a resilient forest, nor one that provides for biodiversity. Managers could strive to produce different forest conditions and use topography as a guide for varying treatments. Within stands, important stand topographic features include concave sinks, cold air drainages, and moist microsites. Landscape topographic features include slope, aspect, and slope position.	Direct	Section 3, Reforestation, talks about a changing forest structure due to climate and how reforestation may look under as according to the Dinkey Reforestation Framework. Heterogeneity is an important aspect of the reforestation goals

USFS GTR-220 (2009)			
Plan Finding	**Description**	**Alignment**	**Discussion**
Stand density and habitat conditions vary by topographic features	Basic topographic features (i.e., slope, aspect, and slope position) result in fundamental differences in vegetation composition and density producing variable forest conditions across the Sierra landscape. Drainage bottoms, flat slopes, and northeast-facing slopes generally have higher site capacity, and thus treatments retain greater tree densities and basal areas.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments that selectively removed certain vegetation types. Adjusting this modeled scenario to fit specific landscape forest composition will rely on the SRCD implementation strategy. The SRCD's Forester should consider spatial dispersion of treatments when in the field assessing areas for fuel treatment
Tree-species-specific prescriptions	Hardwoods and pines, with much lower densities in current forests compared with historical conditions, would rarely be thinned. Thinning would be focused on firs and incense cedar. Address pine plantations separately.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments that selectively removed certain vegetation types. Adjusting this modeled scenario to fit specific landscape forest composition will rely on the SRCD implementation strategy. The SRCD's Forester should consider species-specific prescriptions when in the field assessing areas for fuel treatment
Silvicultural model and strategy	Tree diameter distributions in active fire forests vary but often have nearly equal numbers in all diameter size classes because of periodic episodes of fire-induced mortality and subsequent recruitment. Stand treatments that significantly reduce the proportion of small trees and increase the proportion of large trees compared to current stand conditions will improve forest resilience.	Direct	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments by reducing smaller diameter trees. Actualizing this modeled scenario will rely on the SRCD implementation strategy

USFS GTR-220			
Plan Finding	**Description**	**Coherence with Project Finding(s) #**	**Discussion**
Treatment of intermediate-size trees	In most cases, thinning 20- to 30-in DBH. trees will not affect fire severity, and, therefore, other objectives for their removal should be provided. Where those objectives are identified, silvicultural prescriptions would only remove intermediate-size trees when they are shade-tolerants on mid or upper slope sites.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments by prioritizing the reduction of smaller diameter trees. Adjusting this modeled scenario to fit specific landscape forest composition will rely on the SRCD implementation strategy
Field implementation of silvicultural strategy	Modify marking rules to ones based on species and crown strata or size and structure cohorts (a proxy for age cohorts) rather than uniform diameter limits applied to all species.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments by prioritizing the reduction of smaller diameter trees. Adjusting this modeled scenario to fit specific landscape forest composition will rely on the SRCD implementation strategy
Allocation of growing space	A large proportion of the growing space would be allocated to the largest tree stratum.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments by prioritizing the reduction of smaller diameter trees. Adjusting this modeled scenario to fit specific landscape forest composition will rely on the SRCD implementation strategy
Assessment of treatment effects	Emphasis is on what is left in a treated stand rather than what is removed.	Indirect	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments by prioritizing the reduction of smaller diameter trees. Adjusting this modeled scenario to fit specific landscape forest composition will rely on the SRCD implementation strategy

Table 6-A-3. Draft Revised Land Management Plan of Sierra National Forest Alignment Matrix

Draft Revised Land Management Plan of the Sierra National Forest			
Goals	**Description**	**Alignment**	**Discussion**
WTR-FW-GOAL-1	Take a landscape- or watershed-scale approach to restoring aquatic and riparian ecosystems, integrating with recreation, fuels, and vegetation management in order to efficiently use limited resources, including partnerships, and to effectively address climate change.	Direct	Section 3, Fuel Management Strategies, talks about the watershed scale ecological benefit of performing fuel management across the landscape. Section 6, Funding, Planning and implementation Approach also advocates for these benefits via performing fuel treatments
WTR-FW-GOAL-3	Improve water quality and protect soil productivity by restoring deteriorated watersheds on the basis of economic efficiency and severity of problem and its impact on downstream beneficial uses.	Direct	Section 3, Fuel Management Strategies, talks about the watershed scale ecological benefit of performing fuel management across the landscape. Section 4, Cost Benefit Analysis, looks at the economic feasibility of such treatments
SPEC-FW-GOAL-1	Cooperate with private landowners to encourage resource protection on private lands.	Direct	This entire report focuses on encouraging fuel treatments on private lands
SPEC-FW-GOAL-4	For wildlife species that overlap in range and require areas of high canopy cover (e.g. California spotted owl, fisher and marten), target maintenance of high canopy cover conditions in areas that can meet the needs of multiple species in the same location, thereby increasing potential for more heterogeneous and resilient conditions outside of high canopy cover patches.	Direct	Section 6, Prioritization of Treatment Placement, mentions how outsourcing a private consultant to do further Marxan analysis could achieve treatment placement goals that weight conservation features such as California Spotted Owl. Considering sensitive wildlife when performing fuel treatments will rely on the SRCD implementation strategy
FIRE-FW-GOAL-1	Restore ecosystems to a more fire resilient condition and lessen the threat of wildfire to communities.	Direct	Section 3, Fuel Management Strategies, speaks to how fuel reduction strategies enhance forest health and resiliency

Draft Revised Land Management Plan of the Sierra National Forest			
Goals	**Description**	**Alignment**	**Discussion**
FIRE-FW-GOAL-2	Coordinate with other jurisdictions such as communities, tribes, service providers, and federal, state, county and local entities regarding prevention, preparedness, planned activities and responses to wildland fires. Notify those agencies about upcoming and ongoing fire season and any prescribed fire activity.	Direct	Section 6, Planning and Implementation Approach, advocate for partnership building and collaboration with agencies and private landowners to perform fuel treatments to reduce fire severity
FIRE-FW-GOAL-3	Help communities become more fire-adapted, improving their ability to withstand a fire without loss of life and property.	Direct	Section 6, Planning and Implementation Approach, advocate for partnership building and collaboration with agencies and private landowners to perform fuel treatments to reduce fire severity
FIRE-FW-GOAL-4	Where feasible and suitable, use grazing, mechanical treatment, prescribed fire and/or wildfires managed to meet resource objectives to reduce vegetation build-up to lower the risk of unwanted wildfire.	Direct	Section 6, Planning and Implementation Approach, advocate for partnership building and collaboration with agencies and private landowners to perform fuel treatments to reduce fire severity
FIRE-FW-GOAL-5	Provide defensible space as defined by the California Public Resource Code 4291- Defensible space around structures on administrative sites and structures authorized by permit.	Direct	Section 6, Planning and Implementation Approach, advocate for partnership building and collaboration with agencies and private landowners to perform fuel treatments to reduce fire severity. Defensible space would be of consideration when performing treatments
FIRE-FW-GOAL-6	Use wildfires forest-wide to meet multiple resource management objectives, where and when conditions permit and risk is within acceptable limits.	Indirect	Section 3, Background, speaks to the ecological benefits of naturally occurring wildfire
LOC-FW-GOAL-1	Develop memoranda of agreements or other protocols between the forest and local governments as appropriate to guide coordination processes and reflect local perspectives and interests.	Direct	Section 6, Planning and Implementation Approach, advocate for partnership building and collaboration with agencies and private landowners to perform fuel treatments to reduce fire severity. MOUs could be a part of this partnership building strategy

Draft Revised Land Management Plan of the Sierra National Forest			
Goals	**Description**	**Alignment**	**Discussion**
LOC-FW-GOAL-2	Identify important socioeconomic locations and activities on the forest with interested local agencies to promote a common understanding of these important contributions, to help identify potential projects that may enhance community benefits, and help identify mitigation measures that may address adverse impacts to these resources.	Direct	Section 6, Identification of Gaps in Financial and Human Capital, identifies gaps in community capacity for perform such fuel treatments in the local area
LOC-FW-GOAL-3	Work with local governments, businesses, and organizations to collect economic data to track changes for businesses in sectors dependent on forest activities.	Indirect	Section 6, Identification of Gaps in Financial and Human Capital, identifies gaps in community capacity for perform such fuel treatments in the local area. Much of this information was pulled from the socioeconomic report produced by the Sierra Institute for this region
VIPS-FW-GOAL-1	Work with neighboring communities, organizations, state and local agencies, tribes, and other federal agencies to sustain forest benefits to people across the broader landscape.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state, and federal partnerships to sustain local livelihoods in the community.
VIPS-FW-GOAL-2	Regularly report potential projects suitable for partnership and volunteer opportunities to the public.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state, and federal partnerships to sustain local livelihoods in the community. Education and outreach is also supported as a planning effort for the SRCD
VIPS-FW-GOAL-3	Maintain and expand contracting and partnering opportunities with local governments, businesses, and organizations. Develop partnerships that leverage different sources of funding to support opportunities to contribute to the economic and social sustainability of local communities.	Direct	Section 6, Funding, and Planning Approach and Implementation, calls for a variety of funding sources and to expand upon that funding to promote further community capacity

Draft Revised Land Management Plan of the Sierra National Forest			
Goals	**Description**	**Alignment**	**Discussion**
VIPS-FW-GOAL-4	Work with partners and volunteers to provide recreation opportunities, maintain and enhance recreation settings, collect and manage data on recreation use and demand, and contribute to socioeconomic benefits associated with recreation and tourism.	Indirect	Section 6, Funding, and Planning Approach and Implementation, calls for a variety of funding sources and to expand upon that funding to promote further community capacity. Recreation could be a driving mechanism to get further local support for future projects
VIPS-FW-GOAL-5	Work with skilled stewardship organizations in managing wilderness, wild and scenic rivers, national trails, and other designated areas.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state, and federal partnerships in order to participate in joint management of public and private lands
VIPS-FW-GOAL-6	Work with partners and volunteers in the coordination, development, and delivery of educational and community outreach programs. Actively engage urban populations, youth, and underserved communities in programs.	Direct	Section 6, Planning and implementation Approach, recommends that the SRCD employ education and outreach services to the community with garnered grant monies
VIPS-FW-GOAL-7	Work with partners and volunteers to prioritize and complete deferred maintenance and to engage in resource stewardship and restoration.	Direct	Section 6, Private Landowner Land Management Opportunities, explores programs in which promote private landowner stewardship and restoration
VIPS-FW-GOAL-8	Work with site stewards, volunteers, tribal governments, local governments, state and federal agencies, schools and universities and non-profit groups to protect, rehabilitate and restore cultural resource sites and facilitate development of research, educational and interpretive opportunities.	Indirect	Section 6, Planning and Implementation Approach, calls for the building of local, state, and federal partnerships in order to participate in joint management of public and private lands. One such partner of the SRCD is the Cold Springs Rancheria of Mono Indians of CA

Draft Revised Land Management Plan of the Sierra National Forest			
Goals	**Description**	**Alignment**	**Discussion**
VIPS-FW-GOAL-9	Develop heritage tourism opportunities with tribal governments, local organizations, and businesses to provide an economic benefit to the community, while fostering long-term sustainability of cultural resources.	Indirect	Section 6, Planning and Implementation Approach, calls for the building of local, state, federal, and native tribes partnerships in order to participate in joint management of public and private lands. One such partner of the SRCD is the Cold Springs Rancheria of Mono Indians
RANG-FW-GOAL-2	Emphasize multi-purpose brush manipulation treatments such as fuel reduction and/or prescribed burn projects, which will benefit wildlife, watershed, range, recreation and fire management.	Direct	Section 3, Fuel Management Strategies, speaks to how fuel reduction strategies benefit landscape scale ecological and physical processes
SCEN-FW-GOAL-1	The Forest Service works with other agencies and adjacent landowners to maintain shared vistas.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state and federal partnerships in order to participate in joint management of public and private lands
TRIB-FW-GOAL-1	Manage the land in a spirit of shared stewardship with tribes, supporting tribal rights and recognizing the mutual benefits of restoration.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state and federal partnerships in order to participate in joint management of public and private lands
TRIB-FW-GOAL-2	Partner with tribes to contribute to the socioeconomic sustainability of tribal communities.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state, federal, and native tribes partnerships in order to participate in joint management of public and private lands. One such partner of the SRCD is the Cold Springs Rancheria of Mono Indians
TRIB-FW-GOAL-3	Develop memoranda of agreements or other protocols between the forests and Native American tribes as appropriate to guide consultation processes, reflect tribes' particular perspectives and interests, and protect sacred sites.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state, federal, and native tribes partnerships in order to participate in joint management of public and private lands. One such partner of the SRCD is the Cold Springs Rancheria of Mono Indians

Table 6-A-4. DWR IWRM Alignment Matrix

CA Department of Water Resources—Integrated Regional Water Management Plan Southern Sierra (2014)			
Goals & Objectives	**Description**	**Alignment**	**Discussion**
Goal No. 1: Improve Water Supply Management	Ensure adequate water supply to meet the Region's expected surface and groundwater needs between now and 2045 while minimizing environmental impacts.	Direct	Section 3, Fuel Management Strategies, talks about the watershed scale benefits of performing fuel management across the landscape
Objective 1a: Promote natural water storage through meadow, stream and forest restoration	Natural features such as streams, meadows, and forest landscapes have been impacted and their ability to store water has been reduced. This objective includes reducing live fuel loads and excessive vegetation (where fire has been suppressed). Restoration projects can help restore the natural hydrologic functions and provide better storage and release of water vegetation transpiration, and increase water storage in soils and streams. Removal of exotic vegetation, that has higher water use than native vegetation, can also improve water storage. When natural features such as meadows and stream/riparian areas have been impacted, their ability to store water likely has been reduced. Restoration projects can help restore the natural hydrologic functions and provide better storage and release of water.	Direct	Section 3, Fuel Management Strategies, talks about the watershed scale benefits of performing fuel management across the landscape
Goal No. 2: Protect and Improve Water Quality	Improve water quality to help ensure drinking water meets California health standards, and natural water bodies can support livestock and native wildlife.	Direct	Section 3, Fuel Management Strategies, talks about the watershed scale benefits of performing fuel management across the landscape

CA Department of Water Resources—Integrated Regional Water Management Plan Southern Sierra (2014)

Goals & Objectives	Description	Alignment	Discussion
Objective 2c: Reduce erosion and sedimentation.	Excessive erosion and sedimentation can negatively impact wetlands, water courses and storage capacity of reservoirs. Take measures to reduce erosion and sedimentation, such asslope stabilization, road maintenance, road decommissioning, grading and drainage improvements, and best management practices during construction.	Direct	Section 3, Fuel Management Strategies, talks about the watershed scale benefits of performing fuel management across the landscape
Goal No. 4 - Improve Watershed and Environmental Resource Management	Promote best management practices for all land uses in the Region: range, forest, agriculture, urban, and wildland-urban interface to protect ecosystems thereby improving water supplies and water quality. Preserve open space and natural habitats that protect and enhance water resources and native species.	Direct	Section 3, Fuel Management Strategies, talks about the watershed scale benefits of performing fuel management across the landscape
Objective 4b. Manage vegetation to reduce fire risk and attempt to keep fires within their natural range of variability.	Forest and brush fires can lead to erosive conditions that contribute soil, ash, nutrients, and debris to water supplies. Educate and encourage local landowners to reduce fire risk by using fire resistant and retardant landscaping. Land managers can reduce fire risk by creating strategic fuel breaks, conducting fuel treatments and forest restoration, thinning underbrush, and allowing low-intensity fires to consume accumulated fuel.	Direct	Section 3, Fuel Management Strategies, talks about the watershed scale benefit of performing fuel management across the landscape. Section 6, Short Term Approach for Fuel Reduction on Private Lands, explores strategies for implementation of such treatments

Table 6-A-5. Fresno County General Plan Alignment Matrix

Fresno County General Plan (2000)			
Goals and Policies	**Description**	**Alignment**	**Discussion**
Conservation and Open Space Element			
Goal OS-A	Protect and enhance the water quality and quantity in Fresno County's streams, creeks, and groundwater basins.	Indirect	Section 3, Fuel Management Strategies, talks about the watershed scale benefits of performing fuel management across the landscape
Policy OS-A.6	The County shall support efforts to create additional water storage that benefits Fresno County, and is economically, environmentally, and technically feasible.	Indirect	Section 3, Fuel Management Strategies, talks about the watershed scale benefits of performing fuel management across the landscape
Policy OS-A.13	The County shall encourage, where economically, environmentally, and technically feasible, efforts aimed at directly or indirectly recharging the county's groundwater.	Indirect	Section 3, Fuel Management Strategies, talks about the watershed scale benefits of performing fuel management across the landscape.
Goal OS-B	Maintain healthy, sustainable forests in Fresno County, conserve forest resources, enhance the quality and diversity of forest ecosystems, reduce conflicts between forestry and other uses, encourage a sustained yield of forest products, protect and conserve lands identified as suitable for commercial timber production within the county, and conserve forest lands that have other resource values including recreation, grazing, watershed, and wildlife habitats.	Direct	Section 3, Fuel Management Strategies, talks about the watershed scale benefits of performing fuel management across the landscape. Section 6, Short Term Approach for Fuel Reduction on Private Lands, explores strategies for implementation of such treatments that promote forest health

Fresno County General Plan (2000)			
Goals and Policies	**Description**	**Alignment**	**Discussion**
Policy OS-B.2	The County shall work closely with agencies involved in the management of forest ecosystems and shall coordinate with State and Federal agencies, private landowners, and private preservation/conservation groups in habitat preservation and protection of rare, endangered, threatened, and special concern species, to ensure consistency in efforts and to encourage joint planning and development of areas to be preserved. The County will encourage State and Federal agencies to address adverse impacts on citizens and communities of Fresno County, including environmental, health, safety, private property, and economic impacts.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state, and federal partnerships in order to participate in joint management of public and private lands
Policy OS-B.5	The County shall encourage and promote the productive use of wood waste generated in the county.	Direct	Section 6, Identification of Gaps in Financial and Human Capital, identifies the working progress for instituting a biomass utilization campus at the Auberry Mill site to promote productive use of wood waste
Policy OS-B.6	The County shall encourage and support conservation programs to reforest private timberlands	Direct	This entire report focuses on encouraging fuel treatments on private lands
Goal OS-E	Help protect, restore, and enhance habitats in Fresno County that support fish and wildlife species so that populations are maintained at viable levels.	Indirect	Section 4, Fuel Treatment Feasibility, takes into account that species of concern can be weighted in geospatial Marxan analysis. Conservation features such as California Spotted Owl can be considered
Policy OS-E.4	The County shall encourage private landowners to adopt sound wildlife habitat management practices, as recommended by the California Department of Fish and Game officials and the U.S. Fish and Wildlife Service.	Direct	Section 6, Private Landowner Land Management Opportunities, explores programs in which promote private landowner stewardship and restoration for sensitive species

Fresno County General Plan (2000)			
Goals and Policies	**Description**	**Alignment**	**Discussion**
Goal OS-F	Preserve and protect the valuable vegetation resources of Fresno County.	Direct	Section 4, FVS Simulated Fuel Reduction Treatments, simulated fuel treatments that selectively removed certain vegetation types. Adjusting this modeled scenario to fit specific landscape forest composition will rely on the SRCD implementation strategy. The SRCD's Forester should consider species-specific prescriptions when in the field assessing areas for fuel treatment
Policy OS-F.9	The County shall support the continued use of prescribed burning to mimic the effects of natural fires to reduce fuel volumes and associated fire hazards to human residents and to enhance the health of biotic communities	Indirect	Section 3, Fuel Management Strategies, talks about the benefits of performing prescribed burning, however, prescribed burning was never modeled
Policy OS-F.11	Take steps to increase fire safety on wooded parcels.	Direct	Section 4, Fuel and Fire Behavior Modeling, uses fire risk reduction as a metric to display treatment effects on safety
Health and Safety Element			
Goal HS-A	Protect public health and safety by preparing for, responding to, and recovering from the effects of natural or technological disasters.	Direct	Section 7, Findings and Recommendations, addresses frontloading costs for treatment rather than back loading costs for fire suppression resultant of catastrophic wildfire. This reduces the potential for public safety risk in the WUI
Goal HS-B	Minimize the risk of loss of life, injury, and damage to property and natural resources resulting from fire hazards	Direct	This entire report focuses on encouraging fuel treatments on private lands to minimize loss of life, injury and damage of private property
Policy HS-B.13	The County shall work with local fire agencies to develop high-visibility fire prevention programs, including education programs and voluntary home inspections.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state and federal partnerships in order to participate in joint management of public and private lands

Table 6-A-6. Fresno County Multi-Hazard Mitigation Plan Alignment Matrix

Fresno County Multi-Hazard Mitigation Plan (2008)			
Goals & Objectives	**Description**	**Alignment**	**Discussion**
Goal 1	Provide protection for people's lives from hazards.	Direct	This entire report focuses on encouraging fuel treatments on private lands to minimize loss of life, injury and damage of private property
Objective 1.1	Provide timely notification and direction to the public of imminent and potential hazards.	Direct	Section 6, Planning and implementation Approach, recommends that the SRCD employ education and outreach services to the community with garnered grant monies to educate the public about the associated risks of wildfire and actin they can take to mitigate that risk
Objective 1.2	Protect public health and safety by preparing for, responding to, and recovering from the effects of natural or technological disasters.	Direct	This entire report focuses on encouraging fuel treatments on private lands to minimize loss of life, injury and damage of private property
Objective 1.3	Improve community transportation corridors to allow for better evacuation routes for the public and better access for emergency responders.	Direct	Section 6, SRCD Land Management Funding Opportunities, addresses that 50 % of Title II funds that have the potential to be acquired, must be used on road improvements
Goal 2	Improve communities' capabilities to mitigate hazards and reduce exposure to hazard-related losses.	Direct	Section 6, Short Term Fuel Reduction Approach, addresses in many ways how fuel treatments could improve community capability to reduce exposure of risk via wildfire
Objective 2.1	Reduce wildfires/protect life, property, and natural resources from damaging wildfires.	Direct	This entire report focuses on encouraging fuel treatments on private lands to minimize loss of life, injury and damage of private property

Fresno County Multi-Hazard Mitigation Plan (2008)			
Goals & Objectives	**Description**	**Alignment**	**Discussion**
Objective 2.5	Minimize the risk/loss to endangered species, native plants, land (erosion), and native wildlife.	Direct	Section 4, Fuel Treatment Feasibility, takes into account that conservation features of concern can be weighted in geospatial Marxan analysis to enhance ecological health via optimization of treatment locations
Goal 5	Maintain coordination of disaster planning.	Indirect	Section 6, Planning and Implementation Approach, calls for the building of local, state, and federal partnerships in order to participate in joint management of public and private lands to prevent major disasters
Objective 5.2	Coordinate with other community plans.	Direct	Section 6, Management Plan Alignment, attempts to overlay community management plans with fuel treatment recommendations
Objective 5.3	Maximize the use of shared resources between jurisdictions and special districts for mitigation/communication.	Direct	Section 6, Planning and Implementation Approach, calls for the building of local, state, and federal partnerships in order to participate in joint management of public and private lands
Goal 6	Maintain and provide for FEMA eligibility and work to position jurisdictions for grant funding.	Direct	Section 6, Funding Approach, advocates for the acquisition of FEMA pre-disaster mitigation grant that focuses on WUI protection fuel treatments
Objective 6.2	As part of plan implementation, review actions in this plan on an annual basis to be considered for annual FEMA Pre-Disaster Mitigation grant allocations or after a presidential disaster declaration in California for Hazard Mitigation Grant Program funding as well as for other local, state, and federal funding opportunities.	Direct	Section 6, Funding Approach, advocates for the acquisition of FEMA pre-disaster mitigation grant that focuses on WUI protection fuel treatments

Table 6-A-7. HWY 168 Community Wildfire Protection Plan Alignment Matrix

HWY 168 Community Wildfire Protection Plan			
Objectives & Prescriptions	**Description**	**Alignment**	**Discussion**
Objective 1	Solicit stakeholders and community involvement in wildfire mitigation through public education and awareness projects.	Direct	Section 6, Planning and implementation Approach, recommends that the SRCD employ education and outreach services to the community with garnered grant monies to educate the public about the associated risks of wildfire and actin they can take to mitigate that risk
Objective 2	Plan and implement fuel reduction programs on private and public land.	Direct	This entire report focuses on encouraging fuel treatments on private lands
Objective 3	Escalate the "Defensible Space" program to include the watershed, wildlife, transportation, recreational and commercial areas in the council's sphere of influence.	Direct	Section 6, Planning and Implementation Approach, advocate for partnership building and collaboration with agencies and private landowners to perform fuel treatments to reduce fire severity. Defensible space would be of consideration when performing treatments
Objective 4	Support and promote prescribed burning to mimic natural fire cycles and create wildland ecosystems which are resistant to destructive wildfires.	Indirect	Section 3, Fuel Management Strategies, talks about the benefits of performing prescribed burning, however, prescribed burning was never modeled
Prescription 1	Educate stakeholders within their communities through the Fire Safe Council.	Direct	Section 6, Planning and implementation Approach, recommends that the SRCD employ education and outreach services to the community

Section 7—Findings and Recommendations

Findings and Recommendations

Finding 1:

A significant information gap exists for private land forest stands that severely limited the predictive capacity of this project for determining fire behavior on private lands. The data inputs needed for the tools used by the USFS to assess forest regrowth and fire behavior do not exist for private lands. The data that does exist for private lands does not provide a robust relationship for predicting fire severity on private lands, even given public land model results. Neither did this analysis take into account the impacts of climate change, beyond the effect of climate change on frequency of fire occurrence, on such environmental characteristics as precipitation and vegetation distribution that will likely impact fire severity.

Recommendation 1-A:

SRCD should assess the options that exist for employing fire models that utilize currently available data for private lands within the Dinkey Landscape to provide more robust information on fire behavior, ecological impacts, and future climate conditions for private lands. Such models do currently exist. One model which will soon have this capability is the Regional Hydro-Ecological Simulation System (RHESSys), and is currently being refined by the Tague Lab at the University of California at Santa Barbara.

Recommendation 1-B:

This analysis of fire severity reduction potential would also benefit from an extended analysis of fuel treatment cycle lengths, intensities of thinning (different SDI targets), and methods of treatment. This analysis performed fuel treatments every 10 years, however, results indicated that the benefits of treatment started to degrade around the eight year of the treatment cycle (Section 4, Results**)**. An analysis that simulates treatments on a shorter cycle may be beneficial to determine how shorter return intervals affect long-term forest regrowth, fire severity reduction, and carbon sequestration. The SDI targets used in this analysis simulated fuel treatments that thin to SDIs that are similar to natural forest densities during the pre-fire suppression era in the southern Sierras and are in the range of forest density that limits mortality due to bark beetle infestation. Adjusting the thinning densities within this range may give a better indication of the relative benefits of fuel treatment intensity. Fuel treatment methods in this analysis were limited to hand thinning and mechanical thinning, but previous research has shown that a combination treatment of thinning and prescribed burning is the most effective form of fuel treatment for reducing fire severity and restoring ecological function (Section 3, Fuel Management Strategies**)**. Further analyses that simulate the fire severity reduction potential of thinning and prescribed burning may be informative for the SRCD's and private landowners' fuel treatment priorities. Finally, this analysis ignored the potential impacts of reforestation following fuel treatments on forest regrowth and fire severity reduction (Section 4, Limitations**)**. Although reforestation is not currently largely employed on the private parcel landscape, an analysis of the impacts of reforestation under current and future climatic conditions could help quantify the necessity for, and benefits of, reforestation projects on private lands.

Finding 2:

The potential implementation of fuel treatments identified by this project is likely to be severely hindered by physical and human capacity gaps. The Dinkey Landscape and surrounding communities lack sufficient local contractors with the labor capacity or machinery to take on large fuel reduction projects. There are three identified local contractors with the capability to undertake hand thinning fuel treatments on the landscape. However, at the identified rate of hand thinning, approximately 0.2 acres per day, limited fuel treatment reduction projects can be completed within a treatment season (Section 4, Discussion; Section 5, Discussion). This indicates that the fuel treatments currently feasible on the landscape are not sufficiently scalable to treat a subset of the landscape that results in the reduction of fire severity on the same level as that of a full landscape treatment. However, this analysis did show that, although they do not achieve reductions in fire severity on par with a full landscape treatment, fuel treatments of 15% - 10% of the landscape do still significantly reduce fire severity compared to a no treatment scenario. This shows that although capacity for completing fuel treatments is limited for the communities on the Dinkey Landscape, there is still the potential to reduce fire severity for the landscape through smaller, less costly fuel treatment projects (Figure 7-1).

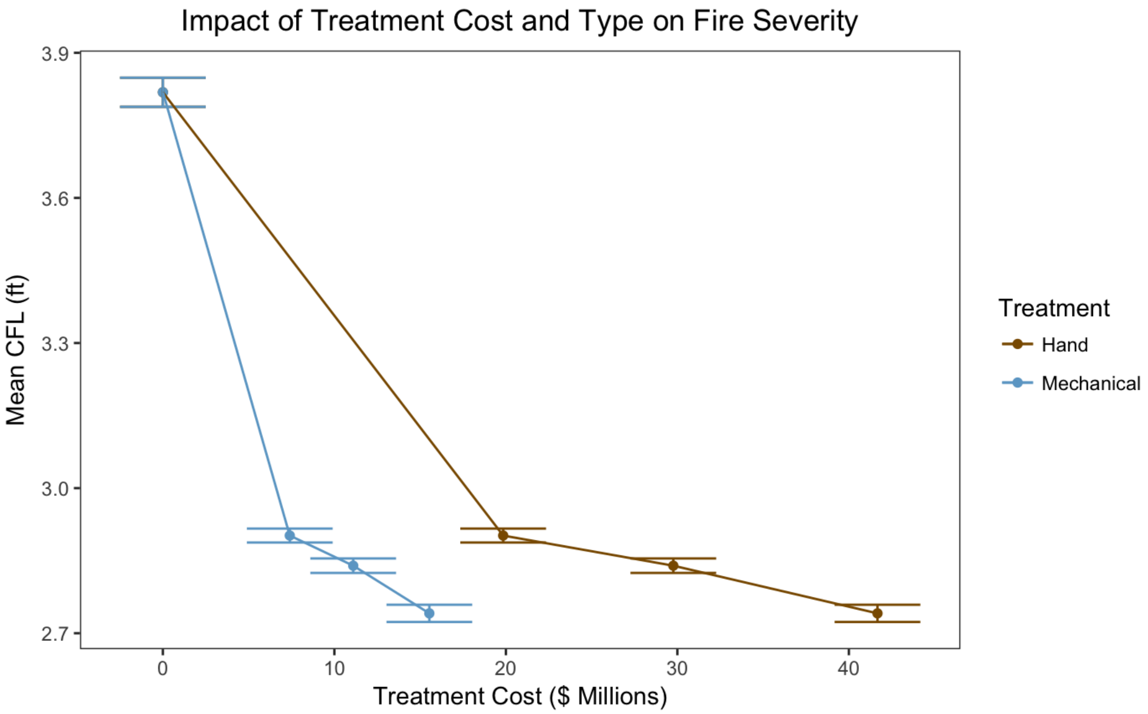

Figure 7-1. Tradeoff curve of funds spent on one cycle of fuel treatment versus the mean conditional flame length (CFL) – a measure of fire severity with lower conditional flame lengths corresponding to lower fire severity – produced by the fuel treatments under both hand and mechanical treatment methods. The curve shows the tradeoff between spending additional funds to treat progressively larger percentages of the landscape and the subsequent reductions in fire severity that could be achieved from those larger fuel treatments projects.

Further, in Section—6, three grant packages were identified as potential sources of funding for various fuel treatment actions. If all three packages were applied for and subsequent funding was received, a conservative estimate of 1.35 million dollars is speculated to be received by the SRCD. If the SRCD was to use this money for fuel treatments on private lands by supplying the entire costs of treatment themselves, or by supplementing cost disparities private landowners incur under cost-share programs, it is estimated that roughly 500 acres of lands could be treated. While this is far from the amount of land treated in the modeled scenarios of 21% (~5,600 acres) or 10% (~2,700 acres) which create fire reduction benefits at the landscape scale, the localized area of treatment would still receive many of the benefits associated with employing fuel reductions. This validates the worthwhileness of spending grant funding on smaller scale treatments on private lands, although such projects would unlikely produce landscape scale benefits of fire severity reduction.

Recommendation 2:

The SRCD should explore opportunities to engage with contractors to increase local capacity to provide a diverse portfolio of fuel treatments and increase the efficiency and effectiveness of those treatments. This engagement may include assisting in planning profit investment and machinery purchasing, assisting in the actual purchasing of machinery that may increase overall community capacity, or seeking out additional contractors from a wider region of interest to supplement local contractor capacity.

Finding 3:

A strategic approach to implementing fuel treatment reductions on a subset of the landscape will still provide significant reductions in fire severity when compared to a landscape that is not treated for fuel reductions (Figure 7-2). By treating just 21% of the private parcel landscape (5,650 acres), reductions in fire severity are achieved that are not significantly different from those produced by a full landscape treatment. The minimum amount of land that can be treated to achieve these similar results is between 15% and 21%. However, even fuel treatments of 10%-15% achieve significantly lower fire severities for the entirety of the landscape when compared to a no treatment scenario (Section 4, Results).

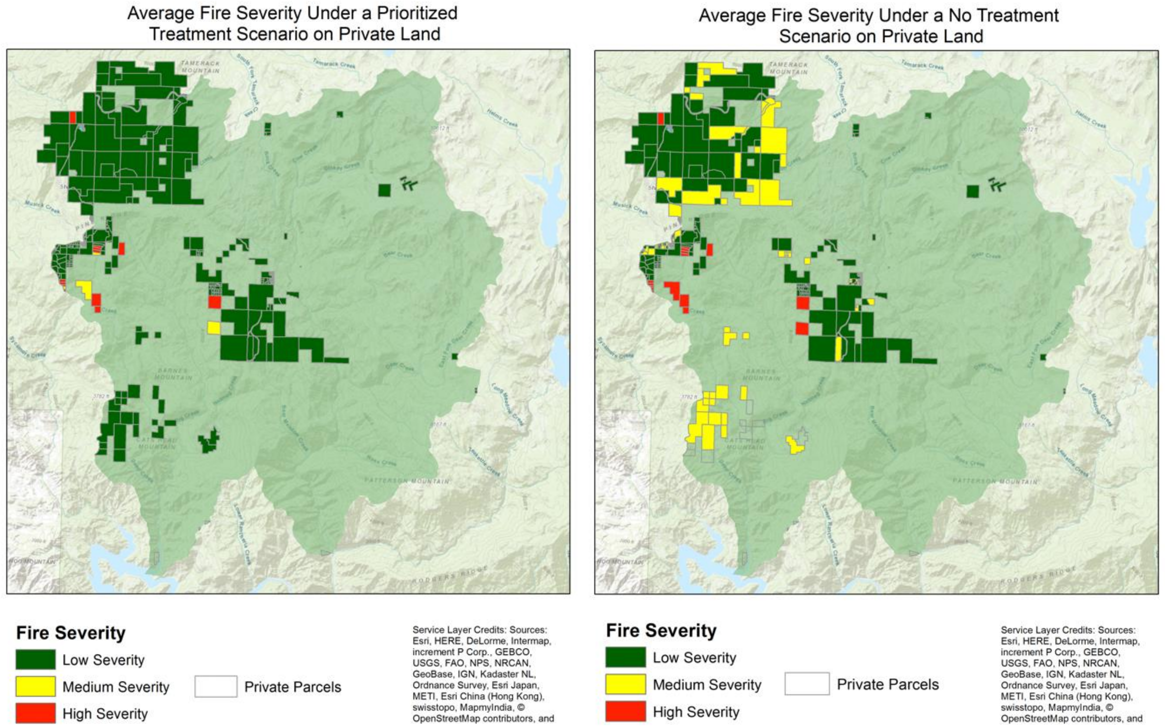

Figure 7-2. Reduction in fire severity resulting from treating 21% of the landscape as compared to fire severities under a no treatment scenario.

The timeline of treatment completion, however, is very important. At a rate of approximately 0.2 acres/day per hand thinning crew, fuel treatments performed by hand are much less time efficient than mechanical treatments, which can treat up to 5 acres/day per crew. If reductions in fire severity are to be achieved, fuel treatments must treat significant portions of the landscape during a single year and must revisit those lands at least every ten years to maintain the benefits of fire severity reduction. Fuel treatments by hand thinning take 25 times longer to complete than by mechanical thinning. If 10% of the landscape (2,690 acres) is to be treated, hand thinning operations would take 55 years to complete the treatments (assuming a 244 day season for fuel treatment – April to November) versus 2.2 years by mechanical thinning.

Recommendation 3-A:

It is recommended that the SRCD strategically engage private landowners to implement fuel reductions on those parcels that are projected to experience the greatest potential reduction in fire severity as a result of treatment. The schema that the SRCD uses to prioritize private parcels for treatment is flexible. Prioritization can be based on a variety of priority metrics, including, but not limited to, the fire severity reduction potential, fire ignition probability, and the presence of endangered species on a given private parcel. Examples of the flexibility of the optimization schemas for prioritizing parcel fuel reductions are provided in Section 4, Results.

Recommendation 3-B:

Private landowners and the SRCD should seek to establish a diverse portfolio of fuel treatment strategies for implementation on the landscape to balance ecological impacts from fuel treatments themselves with the urgency of completing sufficient area of fuel treatments in a timely enough fashion that reduction in the risk of severe fire is actually achieved through those treatments (Section 4, Discussion; Section 5, Discussion).

Finding 4:

Fuel treatments have a limited period of effectiveness and need to be repeated to continue to realize the reductions in fire severity afforded by reduced fuel levels. On the Dinkey Landscape the effectiveness of a fuel treatment begins to diminish around the eighth year since the treatment has been performed (Section 4, Results).

Recommendation 4-A:

Private landowner outreach should include the acknowledgement of this benefit decay and stress that fuel reductions and vegetative management should be performed on a cyclical basis of approximately 7-10 years.

Recommendation 4-B:

SRCD application timelines for grant funding specific to fuel reductions on private lands in the WUI and planning of the implementation of those treatments should mirror the length of this treatment cycle. Re-entry to lands previously treated over 7-10 years prior should not be considered a redundant treatment or an inefficient use of funds.

Finding 5:

Large woody debris – the result of thinning for fuel reduction – that is left on the landscape can greatly increase fire severity. This analysis maintained slash piles of woody material less than 12 inches in diameter on the landscape for one year following a fuel treatment. Even these unburnt piles of slash material diminished the fuel treatment's effectiveness by increasing the conditional flame lengths of that year of the treatment cycle relative to all other years of the treatment cycle (Section 4, Results).The maintenance of just slash piles on the landscape is not entirely reflective of the current and potential woody debris prevalence on the landscape in that larger woody material is likely to be present on the landscape following fuel treatments and be maintained for longer. The presence of this material is likely to increase fire severity across the years of the treatment cycle as compared to the fire severities simulated in this analysis.

Recommendation 5:

Future fuel treatment procedures must ensure that large woody debris is transported offsite or otherwise reduced to minimize fuel loading, and small woody debris is removed or burned under safe and permitted conditions following the required curing period (Section 3, Fuel Management Strategies).

Finding 6:

Cost-benefit analysis shows that, while fuel treatments are cost-efficient for private landowners to undertake, they cannot afford the up-front costs of treatments without financial assistance (Section 5, Summary of Results). The SRCD and the USFS achieve positive NPVs from investments in fuel treatments on private lands and could be beneficial partners to private landowners in helping to achieve the implementation of fuel treatments on private lands by assisting in the up-front costs or physical implementation of the treatments.

Recommendation 6:

As significant beneficiaries of the implementation of fuel treatments on private lands, the SRCD and the USFS should be engaged as contributors to the cost – in the form of financial, human, or physical capital – of those treatments. To engage the private landowners in a fuel treatment strategy that will benefit the landowners over the long-run, grants and funding strategies need to be pursued that can supplement or reimburse private landowner expenditures on private land fuel treatments. Programs private landowners can engage in on an independent and individual basis are the EQIP Program and the Healthy Forest Reserve Program under NRCS and the Cal Fire Forest Improvement Program (Section 6, Private Landowner Land Management Program Opportunities). Grants and programs that the SRCD is eligible for and can use to support private lands fuel treatments are: the U.S. Forest Service Western Wildland Urban Interface Grants, California Department of Fire and Forestry (CAL FIRE) Forest Health Program grants, Federal Emergency Management Agency Pre-Disaster Mitigation Funding, Secure Rural Schools and Community Self Determination Act of 2000 (Title II), National Foundation of Fish and Wildlife/Wells Fargo Community Resiliency Grants and DWR IWRM Grants (Section 6, SRCD Land Management Funding Opportunities).

Fuel Reduction Strategies and Considerations

In Section 6, funding approaches were identified to help the SRCD and private landowners achieve various pathways to fund and support the strategic implementation of fuel treatments and vegetation management strategies to reduce wildfire risks and increase ecological health. This section aims to consolidate those recommendations and easily display how they fit in the context of different funding scenario

Considerations

1. Educating private landowners on the benefits of reducing hazardous fuels on private lands through the Bren-developed online app.

2. Hosting forums to engage private landowners with the benefits of reducing hazardous fuels and to connect private landowners with NRCS representative

3. Allocating funds for funding matches to reimburse private landowners for fuel treatment expenditures through the EQIP or Cal Fire CFIP programs.

4. Building a relationship with the NRCS representative to best allocate EQIP funds matched or unmatched with other external, non-federal funds to maximize funding impact by supplying match funds for EQIP in appropriate or necessary situations.

5. In the event of EQIP program mis-match of priorities, consider developing a cost-share program for private landowners informed by an optimization schema similar to those examples produced by this project (Section 4, Results) and constrained by the limitations of the grant.

6. Increasing community and labor capital through purchasing equipment.
   a. Equipment can be owned by SRCD and rented out to contractors to increase contractor capabilities and generate revenue for SRCD.
   b. Equipment can be donated to community –at-large or individual contracting services group to improve fuel treatment scale, capability, and debris processing.

7. Advocating for the Shaver Lake community to apply to the CPAW program through Headwaters Economics.

8. Continuing relationship-building with local fuel treatment contractors to provide private landowners with lists of applicable local contractors that can be used for fuel treatments on private lands independent of grant support or in the event of a successful grant application.

9. Continuing to engage with the Dinkey Collaborative and the USFS to direct attention towards the information and capacity gaps between catastrophic fire preventative capacity for public and private lands.

10. Staying apprised of state and federal agency funding and grant opportunities that require local engagement or the support of a local entity, which can then be leveraged to support work on private lands.

11. Engaging academic or research group that could improve the fire severity modeling work carried out in this report by exploring fuel treatment impacts on fire severity under different climate scenarios and quantifying fuel treatment impacts on a wider array of ecological benefits.

Table 7-1: Alignment of Suggested Considerations and Grant Packages

Consideration	Grant Package A	Grant Package B	Grant Package C	No Grants Obtained
1	X	X	X	X
2		X	X	
3	X	X	X	
4	X	X	X	
5	X	X	X	
6	X			
7	X*	X*	X*	X
8	X*	X*	X*	X
9	X*	X*	X*	X
10	X*	X*	X*	X
11	X*	X*	X*	X

* denotes that this action is not an eligible cost under the specific grant package, however, such an action can be completed at no to nominal cost to the SRCD and should be considered under any grant package.