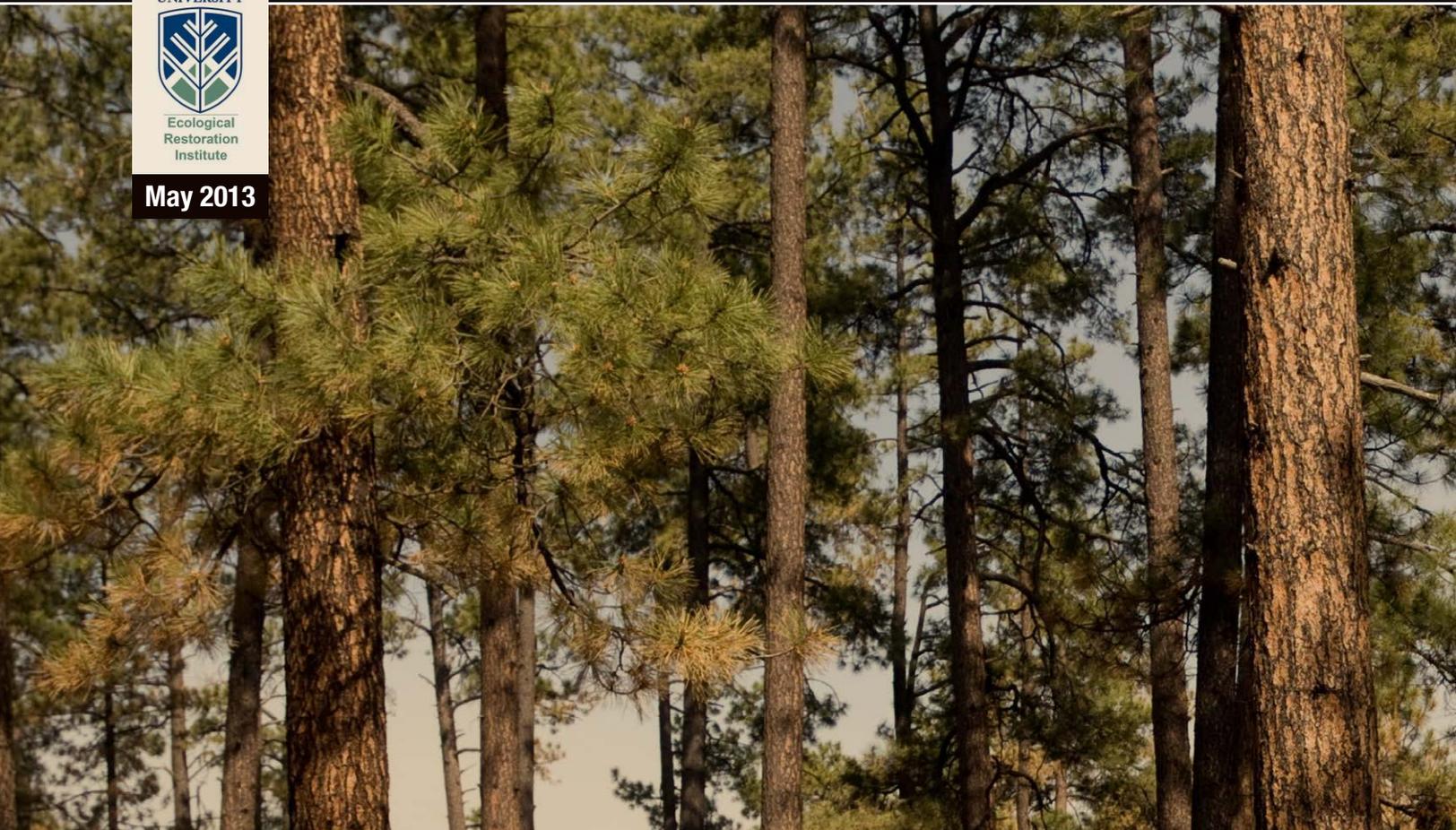




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The Efficacy of Hazardous Fuel Treatments:

A Rapid Assessment of the Economic and Ecologic
Consequences of Alternative Hazardous Fuel Treatments

Authors and Researchers

The following authors and researchers contributed to this report:

- Dr. Yeon-Su Kim, Professor, School of Forestry, Northern Arizona University, Flagstaff, AZ – Project Lead
- Dr. Wally Covington, Executive Director and Regents' Professor, Ecological Restoration Institute, Northern Arizona University, Flagstaff, AZ
- Paul Ervin, PhD student, School of Economic Sciences, Washington State University, Pullman, WA
- Ryan Fitch, PhD student, School of Forestry, Northern Arizona University, Flagstaff, AZ
- Dr. Elizabeth L. Kalies, Postdoctoral Research Associate, Ecological Restoration Institute, Northern Arizona University, Flagstaff, AZ (currently with Bayer CropScience, Research Triangle Park, NC)
- Dr. Douglas Rideout, Professor and Director of Western Forest Fire Research Center, Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO
- Dr. Kimberly Rollins, Associate Professor, Department of Economics, University of Nevada, Reno, NV
- Dr. Andrew Sanchez-Meador, Assistant Professor, Ecological Restoration Institute and School of Forestry, Northern Arizona University, Flagstaff, AZ
- Dr. Mike Taylor (Research Professor), Department of Economics, University of Nevada, Reno, NV
- Diane Vosick, Director of Policy and Partnerships, Ecological Restoration Institute, Northern Arizona University, Flagstaff, AZ
- Tong Wu, Center for Forestry and Center for Fire Research and Outreach, College of Natural Resources, University of California, Berkeley, CA
- Dr. Jonathan Yoder, Professor, School of Economic Sciences, Washington State University, Pullman, WA

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Executive Summary

The Office of Management and Budget (OMB), Government Accountability Office (GAO) and the United States Congress have repeatedly asked the Office of Wildland Fire in the Department of Interior (DOI) and the United States Forest Service (USFS) to critically examine and demonstrate the role and effectiveness of fuel reduction treatments for addressing the increasing severity and cost of wildland fire. Federal budget analysts want to know if and when investments in fuel reduction treatments will reduce federal wildland fire suppression costs, decrease fire risk to communities, and avert resource damage.

Understanding the ecologic and economic effectiveness of hazardous fuel and restoration treatments at the national level poses challenges that prevent simple answers to these questions. Complicating factors include:

- **Scale.** Geography, fuels, forest types, and fire regimes vary nationally and therefore do not lend themselves to an easy comparison for analysis.
- **Time and treatment effectiveness.** The relationship of a treatment to long-term risk reduction is contingent on the quality of the treatment at the start, vegetation type, maintenance, and additional factors such as climate change.
- **Fire is inevitable and the choices made to suppress a fire will influence fire cost.** Numerous analyses have concluded that the most expensive fires occur under extreme weather conditions and that these fires are a small percentage of the entire ignitions that occur in the country.
- **Although federal budget analysts are most interested in investments in treatments and how they may influence suppression costs at the federal level, the damage caused by fire is externalized across multiple levels of government and the private sector.** Analyzing the costs and benefits only in terms of federal programs is inadequate for understanding the full value of restoration treatments, wildfire suppression cost, and losses avoided. In addition, it will underestimate the total cost of inaction.
- **From a theoretical standpoint, the economic relationship between investments in treatments and a reduction in suppression costs is complicated.** The analysis cannot be reduced to the simple formula of X dollars invested in treatments will yield Y dollars of savings in suppression.

In order to answer persistent questions related to wild-fire economics and fuel treatment effectiveness, the Office of Wildland Fire contracted with the Ecological Restoration Institute at Northern Arizona University to conduct a neutral, third party analysis. The research and analysis team included university-affiliated and independent economists. The key findings for five persistent questions are summarized below.

1. Have the past 10 years of hazardous fuel reduction treatments made a difference? Have fuel reduction treatments reduced fire risk to communities?

- Using an evidence-based approach to objectively evaluate the relevant literature, researchers found that for the forest ecosystems that were examined, the evidence suggests that restoration treatments can reduce fire severity and tree mortality in the face of wildfire, and also increase carbon storage over the long-term.
- Studies that use the avoided cost approach to examine the cost of fire demonstrate that treatments result in suppression cost savings.
- Modeling studies that evaluate the effectiveness of fuels treatments in terms of changes in wildland fire size, burn probabilities, and fire behavior demonstrate that fuel treatments applied at the proper scale can influence the risk, size, and behavior of fire therefore reducing suppression cost.
- Modeling also demonstrates that where treatments are sufficient to change dynamic fire behavior, suppression costs are reduced.
- Modeling demonstrates that fuel reduction treatments are effective at reducing fire behavior (severity) where implemented, and can successfully reduce fire risk to communities. However, it also shows that fuel reduction treatments that occur at broader scales would have bigger impacts on the overall reduction of crown fire. Perhaps most

importantly, the results show that WUI-only treatments result in areas of unchanged crown fire potential across the untreated landscape, therefore leaving it vulnerable to large, severe, and expensive (mega) landscape-scale fire.

- Although few studies exist on the topic, fuel reduction treatments significantly enhance the price of adjacent real estate, whereas homes in close proximity to a wildfire experience lower property values.

2. What is the relative value of treatment programs at the landscape scale? (Reframing Fire Regime Condition Class (FRCC) as an economic model.)

- A marginal analysis of benefit can be used to compare the relative value of alternative fire management strategies on a complex landscape instead of calculating actual dollar values. This approach allows managers to compare different treatment alternatives and assess which is economically more efficient without the need to calculate the total cost.
- Using a Colorado study site, it is possible to demonstrate that high level treatments (approximately 30% of the study site) will improve landscape condition by almost 20% over the current condition.

3. How can current and future economic returns to restoration-based hazardous fuel reduction treatments be improved?

- In the two ecosystems studied (ponderosa pine and mountain big sagebrush) it is more cost effective to treat degraded systems before they significantly depart from natural conditions.
- When short time horizons are used, such as 10 or 20 years, to evaluate the expected economic return from treatments, the value can appear to be negative. When the time horizon is lengthened to be consistent with the duration of expected effects of the treatment, the returns may be positive.
- The economic return on treatments is influenced by the ability to offset costs through sale of byproducts and/or biomass.

4. What are the fuel treatment, Wildland Urban Interface, and climate change effects on future suppression costs?

- Based on the analysis conducted for this project, the number of acres burned and total suppression cost increase with the amount of land classified as WUI intermix. Similar but smaller and statistically weaker effects are estimated for WUI interface.
- Extrapolations of WUI growth and weather variables suggest that if trends in these variables continue as they did in this analysis, wildfire acreage and suppression costs will increase in the future.

5. In conclusion: When or will investments in fuel reduction treatments lead to a reduction in suppression costs?

- Assessing the value of restoration and hazardous fuel treatments only in terms of reducing suppression costs is an inadequate analysis for understanding the full economic and ecologic value of treatments.
- Treatments designed to reduce *severe* fire behavior may contribute to a reduction in fire suppression costs.
- Proximity to the WUI and fire size are correlated with increases in suppression expenditures. A growing body of evidence demonstrates that WUI treatments are effective for reducing damage to communities. However, modeling shows that by failing to invest in treatments in the greater landscape, severe, landscape-scale fire will persist.
- By delaying restoration, the cost of treatments and the return on investment will be lower. It is more cost effective to restore systems before they depart significantly from desired conditions.
- If the current trends of development in the WUI and weather conditions consistent with the last 10 years continue, the cost of suppression and number of acres burned will likely increase. Addressing growth in the WUI and fire risk is essential to reducing suppression costs.



Several fire crews from across the country fought around the clock to suppress the Wallow Fire, which ignited on May 29, 2011 in eastern Arizona and burned more than 538,000 acres. Photo courtesy of the U.S. Forest Service

I. Introduction

The Forest Fires Emergency Act of 1908, also known as the 1908 Fire Act, authorized the United States Forest Service (USFS) to spend whatever was necessary (subject to supplemental appropriations) to combat forest fires. It was a logical response to the catastrophic fires of the late 19th and early 20th centuries. These unprecedented fires ruined not only forested landscapes, but also the economic and social systems that depended on them. Worse yet, both firefighters and civilians perished. The 1908 Fire Act was the first time the United States Congress opened its checkbook with few constraints for fire suppression.

By 1910, USFS fire prevention and suppression programs were firmly established. Those early decisions continue to impact discussions about federal fire policy and appropriations to this day.

As a first step toward answering key ecologic and economic questions about the effectiveness of hazardous fuels and restoration treatments, scientists from around the country were assembled to work across disciplinary boundaries to analyze data and provide innovative approaches and analyses to answer important questions. The goal, within time and funding constraints, was to find, analyze and synthesize the best available evidence that policy makers need to make decisions about how to spend the limited money available to address the nation's growing fire problem.

II. Background

Today, it is widely accepted that past management practices, in combination with fire suppression and prevention policies established in the late 19th and early 20th centuries, was the major cause for the ecological degradation and excessive fuels that choke frequent fire forests and woodlands (Covington et al. 1994, Reinhardt et.al 2008, Stephens and Ruth 2005). These unnatural fuels are the primary driver for the increased severity and size of uncharacteristic wildfire and increasing suppression costs in the past three decades. Concern about expanding fire suppression costs increased in the 1970s when Congress and the Office of Management and Budget (OMB) began demanding greater cost efficiency in fire management (Gonzalez-Caban, et al. 1984). Early efforts to contain suppression cost focused on the strategies, labor, and equipment used to accomplish suppression. The idea that investments in fuel treatments could ultimately reduce the need for suppression and lead to cost savings was not a central strategy in early discussions about cost containment. In 1994, the Report of the National Commission on Wildfire Disasters (*cited in GAO 2000*) stated:

The vegetative conditions that have resulted from past management policies have created a fire environment so disaster-prone in many

areas that it will periodically and tragically overwhelm our best efforts at fire prevention and suppression. The resulting loss of life and property, damage to natural resources, and enormous costs to the public treasury, are preventable. If the warning in this report is not heeded, and preventative actions are not aggressively pursued, the costs will, in our opinion, continue to escalate.

In 1995, the Federal Wildland Fire Management Policy and its update in 2001 set the stage for the federal land management agencies (as well as other jurisdictions) to take action to reduce fuel accumulation in order to avoid larger and more damaging fires and escalating fire cost (NWCG 2001).

Implementation of the recommendations of the National Fire Plan¹ and the Healthy Forest Restoration Act of 2003 created the expectations that fuel reduction treatments (sometimes synonymously referred to as restoration treatments—even though they are different) would alleviate the problem of landscape-scale wildfire and help reduce the need and cost for suppression.

After 15 years of marshaling political will, significant increases in federal appropriations, and public support for action, why do suppression costs continue to escalate and the number of acres burned—and burned severely—continue to increase? Policy makers are growing impatient and anxious to realize success. This report is focused on clarifying and addressing important questions on the minds of policy

makers today: What has been received for fuel treatment dollars? Why do large, landscape-scale fires not only persist, but continue to increase in size and severity? Why do suppression costs continue to increase? And when will a return on investment from fuel treatments be seen?

III. About this Report

Repeatedly since 1995, OMB, the Government Accountability Office (GAO), and Congress have asked the Office of Wildland Fire in the Department of Interior (DOI) and the USFS to critically examine the role and effectiveness of fuel reduction treatments as a means of addressing the increasing severity and cost of wildland fire (USDOJ 2012). Federal budget analysts want to know if and when investments in fuel reduction treatments will reduce federal wildland fire suppression costs, decrease fire risk to communities and avert resource damage.

Nine months after the launch of the National Fire Plan, the GAO began assessing and commenting on the ability of the federal agencies to implement the plan and to efficiently use the significant increase in funding they received in Fiscal Year 2001 (GAO 2001). Since 2001, federal land management agencies have been encouraged by the GAO and others to improve their coordination, treatment and spending prioritization processes, and overall organizational management in order to fulfill the goals of the Federal Wildland Fire Management Policy and National Fire Plan (GAO 2001, 2003,

2005, 2007, 2009). Persistent calls for a unified strategy that can efficiently use limited economic resources to help solve the wildfire crisis led to a requirement in the FLAME Act (2009) that the Secretaries of Agriculture and Interior develop a Cohesive Wildfire Management Strategy, or Cohesive Strategy. The departments were specifically directed to develop a strategy that is consistent with recommendations of the GAO. The Cohesive Strategy, based on a three-phase process, is intended to provide the tools necessary to evaluate alternative wildland fire management strategies that will reduce risk by using a trade-off approach (WFLC 2012).

In March, 2012, the Office of Wildland Fire contracted with the Ecological



Firefighters perform blacklining operations, where hand drip torches are used to back-burn fuels along a fire's perimeter to limit its growth. *Photo courtesy of the Ecological Restoration Institute*

¹ The National Fire Plan consists of the Report to the President in Response to the Wildfires of 2000 and the increase in federal appropriations to the land management agencies in Fiscal Year 2001.

Restoration Institute (ERI) at Northern Arizona University to analyze available information in order to answer several persistent questions related to wildfire economics and fuel treatment effectiveness. The Office of Wildland Fire contracted with the ERI² in order to obtain a neutral, third-party analysis external to the federal programs. However, it is noteworthy that the analyses in this report are meant to complement the ongoing work as a part of the Cohesive Strategy. It builds from the considerable expertise that has developed over the past 10 years within the federal agencies and academia to help provide information needed by decision makers.

To better identify and clarify the questions of greatest importance, staff at ERI conducted a series of interviews in January 2012 with staff from OMB, GAO, and relevant Congressional policy and appropriations committees. Following the interviews, invitations were extended to the leading experts in fire economics to attend a writing workshop at Northern Arizona University June 6–8, 2012. The questions were discussed and distributed to the attendees. The in-depth study summarized in this report is being submitted to scholarly journals for publication. In order to meet the deadlines established by the DOI Office of Wildland Fire, we are providing brief and preliminary summaries of the research in this report.

IV. Persistent Questions

1. Have the past 10 years of hazardous fuel reduction treatments made a difference? Have fuel reduction treatments reduced fire risk to communities
2. What is the relative value of treatment programs at the landscape scale?
3. How can current and future economic returns to restoration-based hazardous fuel reduction treatments be improved?
4. What are the fuel treatment, Wildland Urban Interface, and climate change effects on future suppression costs?
5. When or will investments in fuel reduction treatments lead to a reduction in suppression costs?

V. Why are these questions difficult to answer and why do they persist?

At the heart of these questions are two issues: whether or not the investment in hazardous fuel and restoration treatments is providing something in return; and, is it possible to determine how much investment will be required in restoration and fuel reduction treatments before the need for expensive suppression is reduced (in other words, risk is sufficiently low that suppression decisions can be scaled appropriately). While this seems like a straight-forward question, the analysis required for a sound answer requires considerable care. For a myriad of reasons the question doesn't lend itself to a tidy answer—especially at the national scale.

1. **The economic relationship between investments in treatments and a reduction in suppression costs is complicated.** Economists began grappling with how to optimize investments in pre-suppression (defined as capital expenditures of equipment as well as prevention and detection programs), suppression and losses over 75 years ago with the goal of finding the most efficient combination for minimizing damage and the associated costs of wildland fire (Sparhawk 1925). Although Sparhawk's original model did not explicitly address fuel reduction treatments as a component of pre-suppression, the economic theory based on Sparhawk's model generated a myth that "fuels treatment reduces optimal suppression expenditures (including initial attack)" (Rideout and Ziesler 2008). The issue is that investments in *both* treatment and suppression reduce fire damage and associated loss of ecosystem services (net value change).

As decisions that economists consider to be made independently in time and space, they have synergistic effects in reducing damage and cost. In other words, they are both inputs that together determine how much damage and loss will occur. In order to apply economic methods to find a point at which sufficient investment in fuel treatments will lead to reduced suppression

² The ERI was authorized by Congress (PL108-317) as a part of the "The Southwest Forest Health and Wildfire Prevention Act" as one of three institutes dedicated to assisting the federal agencies, land managers, and other affected entities to achieve landscape-scale restoration. More specifically, the Act directs the institutes to: facilitate the transfer of interdisciplinary knowledge required to understand the socioeconomic and environmental impacts of wildfire on ecosystems and landscapes.

expenditures, changes in loss would need to be determined from wildland fires associated with a series of different fuel treatments and fire suppression costs across the landscape and different vegetation types (to evaluate the trade-off between two components of fire management); or outcomes would need to be compared of the same wildland fires with and without fuel treatments, which would be very hard to do empirically. In addition, greater investment in both prevention and suppression is likely to be needed because fire damage and loss of ecosystem services are predicted to increase in the foreseeable future for the following reasons:

- Climate change is expected to contribute to longer and larger fires (Westerling et al. 2006)
- In order to reduce the size and severity of landscape-scale (mega) fire, emerging research demonstrates treatments must occur outside the WUI (wildland urban interface) (see discussion on page 18 for emerging research results)
- Construction and the value of homes in the WUI are positively correlated with higher suppression costs. Growth in the WUI, which continues, is under the control of local

and state government and is not a variable under the control of the federal government (Gude et al. 2012, Gebert et al. 2007).

2. **Scale.** Geography, fuels, forest types, and fire regimes vary nationally. Calculating the impact of fuels or restoration treatments on suppression costs across millions of acres of land with different site specific natural and constructed assets may be good for a trend-analysis, but does not lend itself to inform a national strategy (Calkin et al. 2011). However, it may be possible to analyze the question at a smaller scale and derive a credible answer that can be used to inform national policy.

The Collaborative Forest Landscape Restoration Act, or CFLRA (2009), established a program goal of facilitating the reduction of wildland fire costs by implementing landscape-scale restoration. It requires project proposals to analyze any anticipated cost savings from reduced wildfire management costs, wood utilization and decreases in the unit cost of implementing ecological restoration treatments over time. In order to assist the Collaborative Forest Landscape Restoration Program (CFLRP) projects with this endeavor, National Forest Systems economists, the Rocky Mountain Research Station, and the Western Wildlands Environmental Threat Assessment Center developed the Risk and Cost Analysis Tool, known as R-CAT, for estimating wildland fire management cost savings (CFLRP 2012). This tool is in the early stages



of application. Separately, the DOI and Colorado State University developed the STARFire system (Manley 2011) to address the value of changes to the landscape from implementing a system of fuel treatments aimed at hazardous fuel reduction and forest restoration. Principles in both R-CAT and STARFire are addressing integrated analysis to provide a more holistic assessment of ecological treatments over time.

The CFLRP provides momentum for increasing the pace of implementing treatments at the scale of the problem. Thus far, management actions over the last 10 years treat too few acres strategically to achieve widespread changes in fire extent and behavior. Schmidt and others (2002) estimated that there were nearly 190 million acres of federal forest and rangeland at risk for catastrophic fire. This was in addition to millions of other state and private lands at equal risk due to degraded land health (USDA Policy Paper on Fire and Fuels Buildup). The 2000 Cohesive Strategy (USDA Forest Service 2000) recognized the need to increase the number of acres treated and proposed ambitious goals using 10, 15, and 20-year planning horizons. At full implementation, the 2000 Cohesive Strategy 10-year plan called for treatments on up to 6.9 million acres per year. A reality check on the pace of treatments can be found in the performance report included in the USDA Forest Service Fiscal Year 2013 Budget Justification (2012). It

reveals that under performance measure 1.1) “Reduce the risk to communities and natural resources from wildfire,” the agency’s target in Fiscal Year 2011 was to move 960,000 acres toward desired condition and maintain 1.2 million acres in desired conditions. The agency achieved 82% and 86% of the goal, respectively. The number of acres treated in Fiscal Year 2011 is not even close to number of acres proposed per year in the 2000 Cohesive Strategy, or that are needed to reduce the threat of catastrophic fire at the landscape scale.

- 3. Time and treatment effectiveness.** Vegetation grows. Without maintenance, the restoration and fire risk reduction benefits of a treatment will diminish over time (Finney et al. 2005). Many treatments may already be sub-optimized in an ecological and hazardous fuel sense when socio-political influences such as diameter caps lead to the retention of excess trees (Abella 2006). The relationship of a treatment to long-term risk reduction is contingent on the quality of the treatment at the start, vegetation type, maintenance and exogenous factors such as climate change (see “evidence-based approach” on page 14).
- 4. Suppression decisions and inevitability.** Fire is inevitable and the choices made in the process to suppress a fire will influence fire cost. Numerous analyses have concluded that the most expensive fires occur under extreme weather



In this “before” photo, large trees are clearly marked as “leave trees” prior to the implementation of a forest restoration project near Williams, Arizona. Photo courtesy of the U.S. Forest Service, Southwestern Region, Kaibab National Forest

conditions and that these fires are a small percentage of the entire ignitions that occur in the country. About 1% of all fires account for 97.5% of the total acres burned (Calkin et al. 2005) and 85% of fire suppression costs (Brookings Institution 2005). Research shows that where they occur, restoration and fuel reduction treatments can be valuable assets for both suppressing and managing fire exhibiting moderate behavior. However, where fire behavior is extreme—such as plume-driven fires—the fire can overwhelm even the best treatments (Graham 2003), leading to expensive damage and ecological harm.

The probability and cost of landscape-scale (mega) fires will continue unless more effort is placed on solving the problem where it first ignites—in the greater forest landscape. The National Fire Policy in 1995 and the National Fire Plan in 2000 recognized that in order to address the wildfire crisis, degraded forest ecosystems required ecological restoration. These documents recognized that the problem was bigger than the WUI and would require a strategy that would restore forest health and resiliency and in turn would allow fire to resume its natural role. In the early 2000s, socio-political forces led to increasing investments in WUI treatments at the expense of treatments in the greater landscape. Congressional report language, the Healthy Forest Restoration Act (2003), and directives from OMB all pushed the land management agencies to focus treatments

in the WUI. At the same time, the litigious environmental community, with a long history of opposing cutting trees, allowed treatments in the WUI to proceed with minimal interference.

Severe fires are a landscape phenomenon. They most often occur under extreme weather conditions, which limit the effectiveness of suppression efforts (Bessie et al. 1995). One approach to reverse the trend in increasing severe landscape-scale (mega) fire may be to implement a sufficient number and size of treatments in the greater landscape that will reduce fuels and modify fire behavior. Modeling research by Finney and others demonstrates how it is hypothetically possible to configure treatments in order to change fire behavior (Finney 2007). Cochrane (2012) empirically established that even “modest quantities” of treatments on the landscape can affect the final size of wildfire. The problem is that despite considerable theoretical support for this solution, the land management agencies have been unwilling, unable, and/or have lacked the resources and political support to move ahead with landscape-scale treatments. The CFLRA (2009) provides a platform for a more comprehensive approach to restoring forest health and resiliency while simultaneously reducing the risk of severe fire. Assuming funding and investments in this approach match the scale of the problem, it may be possible to see some effective landscape-scale restoration unfold (Wu et al. 2011).



With overstocked, dense trees now thinned out and surface fuels removed, there is a decreased chance of a high-intensity crown fire occurring in this “after” photo of the same restoration project near Williams, Arizona. *Photo courtesy of the U.S. Forest Service, Southwestern Region, Kaibab National Forest*



Two burn areas from the 2011 Wallow Fire in eastern Arizona experienced drastically different fire intensities. The previously treated area (top) had a low fire intensity due to the prior removal of excess fuels. This fire burned mostly on the ground with a large tree survival rate. The untreated area (bottom) experienced a high-intensity crown fire that scorched all of the trees and understory. *Photo courtesy of the Ecological Restoration Institute*

5. **Although the cost of treatments and suppression are internalized in the federal budget, the damage caused by fire is externalized across multiple levels of government and the private sector. Analyzing this problem solely between federal programs is inadequate for calculating the value of restoration treatments, and wildfire suppression cost and losses avoided.** According to the Western Forestry Leadership Coalition (2010), the total or true cost of fire is between two and thirty times the suppression cost. The Cerro Grande Fire of 2000 burned nearly 43,000 acres with an estimated final cost of \$800 million (Morton et al. 2003). The 2010 Schultz Fire in northern Arizona on the Coconino National Forest provides an insightful case study of how the

brunt of the fire damage is distributed broadly over multiple federal, state, and local units of government, nonprofit organizations, the private sector, and impacted citizens. It also presents an interesting example of how citizens, when they understand the full cost impact of unnatural fire, may choose economically rational approaches to prevent it.

The Schultz Fire ignited in June of 2010 and burned approximately 15,000 acres “in major part across moderate to very steep Ponderosa pine and mixed conifer covered slopes” (Coconino National Forest 2012). The total cost of suppression was shared across local and federal fire fighters and was estimated at \$9.4 million (Coconino National Forest 2012). However, it was post-fire flooding that caused the greatest damage. The federal agencies involved in the fire and post-flood recovery included the USFS, Federal Emergency Management Authority (FEMA), Natural Resource Conservation Service (NRCS), and Federal Highway Commission, paying an estimated and projected \$30 million. The remaining direct costs were covered by state, county, city and local government, private businesses, a nonprofit, and utilities. Preliminary results from a survey conducted of residents impacted by the fire and flood, combined with an analysis of lost property values and out-of-pocket expenditures suggest that the total cost is between \$133 and \$146 million (Table 1). This figure also includes the value placed on a 12-year-old who drowned during the post-fire flood event (Combrink et al. 2013).

Total Impact

Loss in Property Value	\$59,353,523
Government Agencies	\$59,104,394
Loss of Life	\$6,000,000
Structural damage	\$3,097,978
Cleanup	\$1,825,127
Unpaid Labor	\$1,516,103
Armoring	\$823,100
Home Contents	\$548,235
Fire Evacuation Costs	\$223,572
Flood Insurance Premiums	\$198,034
Habitat	\$400,000 - \$14,200,000
Total	\$133,090,066 - \$146,890,066

Table 1. Total estimated impact of the Schultz Fire and flood.

Summary

A recent synthesis of studies examining public attitudes toward fire and forest management, specifically fuel reduction, concluded that some level of active management that includes prescribed fire and mechanical thinning is acceptable for more than three-quarters of the public and is preferred by the public over no management action (McCaffrey et al. 2012). An analysis of polling results from the Southwest further demonstrates that the public supports restoration-related activities, specifically prescribed fire and mechanical thinning, to achieve a reduction in fire risk and severity (Abrams and Lowe 2005). In order to fully understand the logic and efficiency of treatments, a comprehensive analysis should focus on what is being received from the investment in treatments and how should treatments and wildland fire management be integrated to provide a holistic solution to restoring degraded landscapes? By framing the question this way, there can be improvement on the economic and ecologic efficiency of management decisions. The following section summarizes the analyses conducted by individual researchers and provides some preliminary answers.



In the aftermath of the 2010 Schultz Fire, heavy flooding carved deep channels below the burn area, inundating residential properties below with debris, mud, and ash and causing millions of dollars in damage. *Photo courtesy of the Ecological Restoration Institute*



A plume of smoke from the Schultz Fire dwarfs the San Francisco Peaks, north of Flagstaff, Arizona. *Photo by Mike Elson, U.S. Forest Service, Coconino National Forest*

VI. Persistent Questions: Summary of Research

Economic studies that comprehensively evaluate the economic efficiency of fuel management programs at multiple scales are still lacking (Kline 2004, Mercer et al. 2007). Most previous research is based on anecdotal case studies and simulated changes in wildland fire size and behavior on fuel treatments at small or fine scales. This makes it difficult to credibly draw broader policy insights about the overall effectiveness of fuel management across different spatial and temporal scales (Hesseln 2000, Prestemon et al. 2002, Fernandes and Botelho 2003). In order to inform answers to large-scale economic and fuel effectiveness questions, several different approaches were used; they are briefly described under each section. More detail will be provided in the journal articles associated with this report.

1. Have the past 10 years of hazardous fuels reduction treatments made a difference? Have fuel reduction treatments reduced fire risk to communities?

What is the evidence-based approach?

Conventional literature reviews often summarize studies with little analytical attention paid to the quality of the sources. As a result, the results of conventional reviews are usually qualitatively described and often lead the practitioner and the policy maker down an unproductive path, e.g., “on the one hand X, on the other hand Y.” A more methodical and replicable approach is that of evidence-based reviews, including, when possible, the systematic review (Pullin and Stewart 2006). Whether in medical, business, engineering, or conservation practice, evidence-based approaches strive to answer practical questions based on a careful analysis of available evidence. Ideally, the goal is to exhaustively search and obtain all relevant peer-reviewed journal publications as well as unpublished gray literature and research findings. In practice, evidence (knowledge) search and acquisition is limited by time and resources available. No matter how thorough, the final review: 1) explicitly states how evidence was collected (what was the knowledge search strategy?), 2) quantitatively summarizes the findings, 3) highlights areas where additional research is needed, and 4) provides information needed by decision makers that incorporate the quality (i.e., rigor and strength) of individual science findings. Evidence-based conservation is increasingly used in conservation and environmental decision making as an objectively rigorous method of accessing and synthesizing relevant literature (e.g., Peppin et al. 2010, Kalies et al. 2010, Pullin et al. 2009, Pullin and Knight 2009).

During the interviews, researchers were urged to rigorously evaluate the effectiveness of hazardous fuel and restoration treatments and go beyond anecdotes. Using an *evidence-based approach* (see description below), the value of landscape-level ecological restoration and hazardous fuel treatments subjected to wildfire was analyzed. Researchers considered the value of treatments for addressing the sharp increase in fire suppression costs and damages, and perhaps more importantly, in enhancing natural resource and ecosystem service values.

Findings:

Evidence evaluating the effectiveness of fuel treatments on ecosystem services

- Thirty-three papers were found that compared the effects of fuel treatments (thin, burn, or thin/burn) with untreated sites post-wildfire.
- Restoration treatments (i.e., tree thinning and/or controlled burning) had a positive impact on the ecosystem service under consideration. Three studies found a neutral relationship, and two concluded that treatments had a negative impact.

This study asked: Are forest restoration treatments effective at enhancing or protecting ecosystem services following stand-replacing wildfire? None of the studies reviewed were carried out explicitly as a study of an “ecosystem service,” but after the sources of information were selected, the treatment effectiveness was classified under the relevant ecosystem service categories *post hoc*.

Web of Science and Google Scholar databases were searched for papers published prior to June 2012, using the keywords: “WILDFIRE and EFFECTS and TREATMENT.” Peer-reviewed papers, conference proceedings, government documents, and theses and dissertations were considered. Based on the full text of each paper, studies that met the following four criteria were selected and summarized:

1. **Subject:** U.S. western dry forests burned in a wildfire; study had to be conducted on actual effects of wildfire (not predicted effects based on models)
2. **Intervention:** fuel treatments including tree thinning, burning, prescribed burning, or thinning/burning
3. **Comparator:** untreated (dense) forest stands or sites
4. **Outcome:** any ecosystem or human response variable, including but not limited to fire behavior, acres burned, property lost, carbon stored/lost, wildlife habitat, etc.

- The ecosystem services under review were grouped into the four categories identified in the Millennium Ecosystem Assessment commissioned by the United Nations (2006): “provisioning services,” “regulating services,” “cultural services,” and “supporting services.”
- For regulating services (fire risk and severity reduction, carbon sequestration), all relationships were positive.
- For supporting services (soil, nitrogen cycling, understory productivity, biodiversity/wildlife), 11 were positive, three were neutral (all in understory productivity), and two were negative (one each in soil formation and nitrogen cycling).
- Although there are many studies that demonstrated fuel treatment effectiveness on protecting watershed services, recreation and cultural values (e.g., reflected in real estate values) and commodity values, there has been no study that met the search criteria. In other words, no studies were found that systematically compared the changes in these values with and without fuel treatments after a wildfire. This represents an urgent future research need.
- **For the environments examined in the literature, the evidence suggests that restoration treatments can reduce fire severity and tree mortality in the face of wildfire, and also increase carbon storage over the long-term.** For the non-regulating services, although the weight of the evidence suggests a positive overall relationship between treatments and ecosystem services, there is a much larger data gap, and the conclusions are less confident.



Wildlife viewing is an ecosystem service enhanced by healthy forests.
Photo by George Andreijko, Arizona Game and Fish Department

Analyzing the economic efficiency of fuels management in relation to wildland fire suppression

Only a handful of studies exist to rigorously evaluate the long-term impacts of management on wildland fire risk and the economic efficiency of fuel management. In order to analyze the economic efficiency of fuel management treatments, researchers synthesized the available literature on the topic.

Modeling studies show a strong correlation between fire size, proximity to the WUI, and higher suppression costs. Less research has been done to understand the influence of fire behavior characteristics on suppression costs (Gebert et al 2007). In order to analyze the relationship between fire behavior and suppression costs, a regression analysis was conducted on burn severity maps and reported suppression costs for 39 historical fires (>1,000 acres) that occurred between 2001 and 2009. A procedure similar to the R-CAT (Risk and Cost Analysis Tool) model was applied to predict the changes in wildland fire suppression costs from a proposed large-landscape restoration project within the Four Forest Restoration Initiative (4FRI) in northern Arizona.



Photo by George Andreijko, Arizona Game and Fish Department

Findings:

- Studies that use the avoided cost approach demonstrate that treatments result in suppression cost savings.
- There are relatively more modeling studies that evaluate the effectiveness of fuels treatments in terms of changes in wildland fire size, burn probabilities, and fire behavior.
- These studies demonstrate that fuel treatments applied at the proper scale can influence the risk, size, and behavior of fire therefore reducing suppression cost.
- The USFS is developing and testing the R-CAT model to meet the requirements of the Collaborative Forest Landscape Restoration Act. The model has been pilot tested on a CFLR project on the Deschutes National Forest in central Oregon where 46% of the landscape is proposed for treatment over 10 years. On an annual basis, the results show a substantial treatment effect. For fires igniting within treated areas, mean annual area burned and suppression costs drop by 36.25% and 35.30%, respectively, after treatment.
- Preliminary modeling results of treatments proposed under the 4FRI show that fire severity is a significant factor in explaining the variation in fire suppression costs.
- When fuel treatments modify fire behavior and reduce fire severity, they may also enhance the effectiveness of fire suppression efforts.

There are a limited number of studies that rigorously evaluate the *long-term impacts* of fuel management on wildland fire risk (e.g., Prestemon et al. 2002, Mercer et al. 2007, 2008) and the economic efficiency of fuel management explicitly (Butry 2009). Butry (2009) examined this question in Florida and applied propensity score matching to account for the treatment selection bias where the sites with high risk of wildland fire were more likely to be chosen for fuel treatments, thus skewing the evaluation of treatment effectiveness. He evaluated the large-scale effects on landscapes and found that every dollar spent on prescribed fire returns \$1.53 worth of wildland fire damages avoided (with prescribed fire cost at \$26.30/acre). These existing studies use data from Florida where prescribed burning is well established as a fuel treatment tool. This geographic focus limits the ability to generalize these conclusions to the dry forests of the West where many treatments include some type of mechanical thinning. In the Southwest, Snider et al. (2006) applied the avoided

cost approach to find that spending \$238–\$601 per acre for hazard reduction treatments can be justified in terms of future suppression cost savings with a number of simplifying assumptions to directly link lower fire risk accomplished by fuel treatments to lower suppression and rehabilitation costs.

There is a relative abundance of fire modeling studies that demonstrate the effectiveness of fuel treatments in terms of potential changes in wildland fire size, burn probabilities, and fire behavior (e.g., Pollet and Omi 2002, Stratton 2004, Finney et al. 2005, Calkin et al. 2005, Finney 2005, Ager et al. 2011, Cochrane et al. 2012). Much of the recent literature analyzing the suppression costs of large wildfires have indicated that the size of the wildfire is a consistently significant explanatory variable in modeling suppression costs (e.g., Calkin et al. 2005, Gebert et al. 2007, Liang et al. 2008, Prestemon et al. 2008). More research is needed to identify the relationship between suppression costs and fire behavior in order to assess the overall effectiveness of restoration and fuel treatments on suppression costs.

There are three economic studies that considered fuel treatments, changes in potential fire behavior, and their influence on wildland fire suppression costs explicitly. Abt et al. (2007) simulated wildland fire outcomes of a large landscape (400,000 acres) in the Lincoln National Forest in New Mexico with and without treatments with a set of models (Forest Vegetation Simulator (FVS) and RangeLg/FlamMap). Their results showed that treating 23% of the landscape over 10 years would reduce acres burned by 64% and suppression costs by 69%. Their regression model for fire suppression costs include burn intensity measures derived from flame lengths, as well as fire size classes. Even with high treatment costs of \$1,100/acre, they estimated the expected saving in suppression costs per year would be \$2.2 million after treatments are fully in place.

More recently, a group of USFS researchers, fire modelers, and economists developed a standardized procedure that combines fire modeling with an economic model of suppression costs for estimating expected changes in suppression costs due to fuel treatments. The use of this procedure, termed R-CAT (Risk and Cost Analysis Tool), is required for all projects funded by the CFLR program. This standardized procedure will help account the effectiveness of fuel treatments systematically in the future.

The Deschutes CFLR project on the Deschutes National Forest, Oregon is the first demonstration site for the use of R-CAT. The west-central Oregon project area is 145,000 acres in size; 112,000 of which are managed by the USFS. The broad treatment goals of the project are restoring forest ecosystems, promoting resiliency, and protecting highly valued resources and assets, and the primary vegetation treatment is thinning from below (commercial and non-commercial), with

surface fuels treated through a combination of hand-piling and burning, mowing, and prescribed fire. In total 66,808 acres, or approximately 46% of the landscape, are projected to receive treatment during the planning period from 2010 to 2019. Results of the analysis on the Deschutes show that within treated areas, the mean and median fire sizes decrease by 17.08% and 22.24%, respectively, with per fire cost reductions of a similar magnitude. On an annual basis, the results also show a substantial treatment effect. For fires igniting within treated areas, mean annual area burned and suppression costs drop by 36.25% and 35.30%, respectively, after treatment (Thompson et al. 2012).

The R-CAT analysis has not been conducted for other CFLRP sites. Therefore, a similar procedure was applied to predict the changes in wildland fire suppression costs from a proposed large-landscape restoration project within the Four Forest Restoration Initiative (4FRI) in northern Arizona (Fitch et al. 2013). To understand the effects of fire behavior characteristics on wildland fire suppression costs, a regression analysis was conducted on burn severity maps and reported suppression costs for 39 recent fires (>1,000 acres) that occurred between 2001 and 2009. Preliminary results show that fire severity was significant in explaining the variation in fire suppression costs. The analysis showed that if the whole restoration unit (175,617 acres within the 4FRI analysis area) burned under current conditions, wildland fire suppression would cost about \$25

million. Treatment costs were not incorporated into this calculation, because final costs of the proposed treatments are highly uncertain at this point, depending on the rate of biomass utilization resulting from the treatments. For example, past estimates of similar mechanical thinning operations in the area were \$300–433 per acre (Kim 2010). However, the current contractor proposed to pay the USFS \$22 per acre for thinning 300,000 acres.

After the proposed treatments, the area that burned under high severity conditions will be reduced and fire suppression

is estimated to cost about \$22.5 million. A situation was assumed where the fire burns the whole project area in order to illustrate the saving of fire suppression cost resulting from reduced fire severity. Previous studies report reduced fire size due to fuel treatments (e.g., Ager et al. 2010), and therefore support the assumption that the saving on fire suppression costs would likely be larger due to reduced fire size and enhanced effectiveness of firefighting efforts.

When fuel treatments modify fire behavior and reduce fire severity, they may also enhance the effectiveness of fire suppression efforts. Mercer et al. (2008) evaluated the tradeoffs between investing in initial attack resource deployment and fuel management with an engineering model. They found that fuel treatments may increase the probability of containing a fire during initial attack, although the magnitude of the tradeoffs is site-specific. Empirically, firefighting effectiveness was reportedly increased by treatments, attributed to increased visibility in treated areas, and decreased heat and smoke (Murphy et al. 2007, Rogers et al. 2008, Bostwick et al. 2011). Moghaddas and Craggs (2007) reported similar results with treatments resulting in increased penetration of retardant to surface fuels, improved visibility between fire crew, safe access to the fire, and quick suppression of spot fires. Another study also reported that treatments increased the speed of evacuations (Rogers et al. 2008), which may have helped save human lives.



Research shows that ecological restoration treatments which thin excess trees and remove understory fuel loads allow for the reintroduction of more natural fire regimes, like this low-severity ground-fire. Photo courtesy of the Ecological Restoration Institute

The effectiveness of WUI treatments and influence on property values

There is growing, albeit anecdotal, evidence that fuel treatments have saved homes (Bostwick et al. 2011). The overall effectiveness of treatments was evaluated in the aforementioned systematic review. In response to the 2011 Wallow Fire in Arizona, the Ecological Restoration Institute (ERI) was asked to analyze the effectiveness of the USFS national prioritization process for altering landscape-scale (mega) fire outcomes (Waltz

2012). The management question the ERI sought to answer was: If nationally developed USFS fuel reduction priorities had been implemented in the Apache-Sitgreaves National Forests prior to the Wallow Fire, would wildfire outcomes under large-fire (Wallow-like) conditions have different fire severity and probability patterns when compared to no implementation (2010 conditions)? Because the federal land management agencies have been directed to prioritize treatments in the WUI, this project became a surrogate for understanding the effectiveness of WUI treatments (Figure 1).

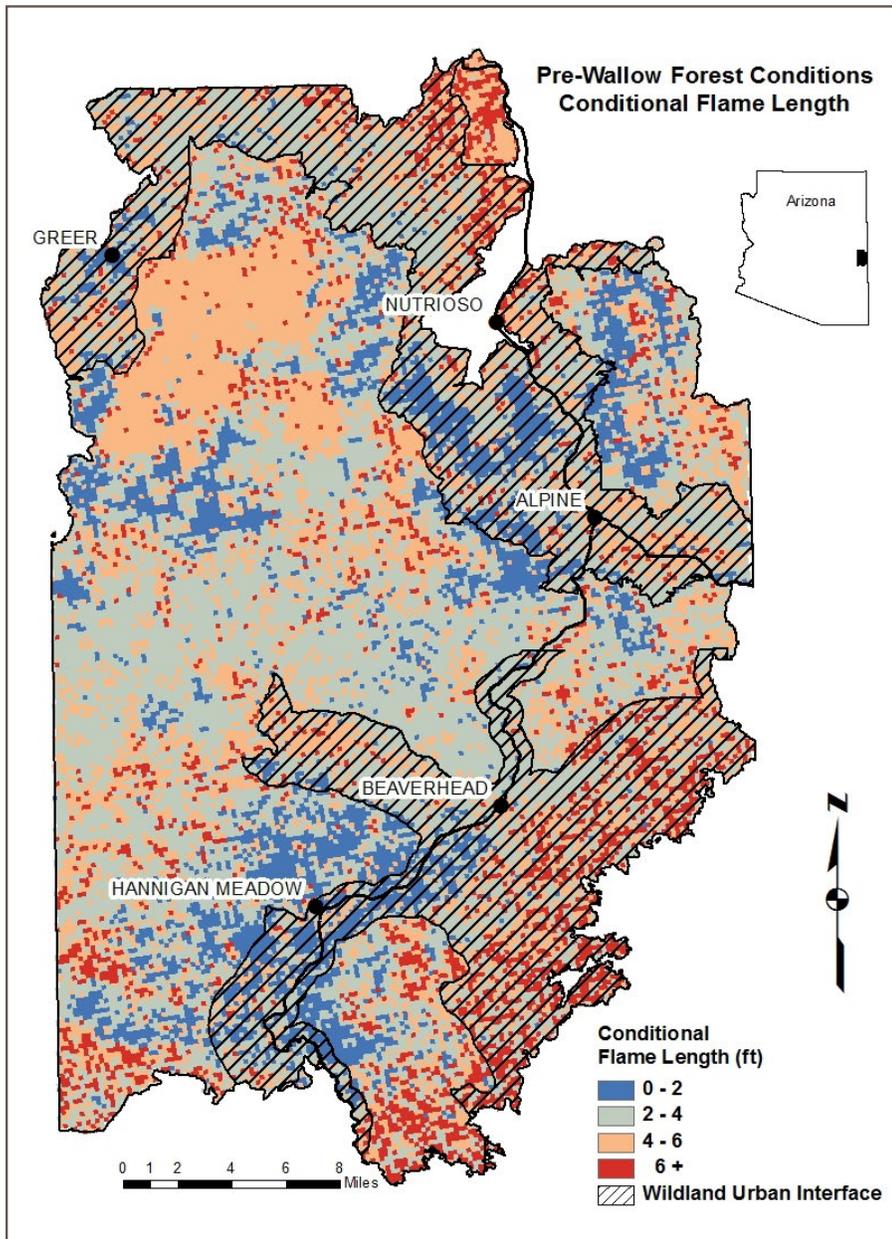


Figure 1. Conditional Flame Length data from fire modeling results for pre-Wallow Fire forest conditions. Red pixels denote high average probability of larger than 6-foot flame lengths and were selected for hypothetical treatment implementation. Treatments were implemented by changing the fuel and tree canopy data layers in the input data files for the Flam-Map fire modeling software.

Findings:

- The ERI modeling results demonstrate that fuel reduction treatments are effective at reducing fire behavior (severity) where implemented, and can successfully reduce fire risk to communities.
- Fuel reduction treatments that occur at broader scales would have bigger impacts on the overall reduction of crown fire. Perhaps most important, the results show that WUI-only treatments result in areas of unchanged crowning potential across the pre-treatment landscape.
- Continuous fuels in uncharacteristically high loadings continue to support high intensity and severe (mega) fire at landscape scales with losses to ecological integrity in forests adapted to more frequent fire conditions.

Effects of fuel treatments on property values

In order to understand the value of treatments and fire suppression on property values, the ERI synthesized available literature. There are several studies that investigate the effects of fuel treatments and fire on real estate values. A study by Kim and Wells (2005), using a hedonic model, found that fuel reduction treatments significantly enhance the price of adjacent real estate — by approximately \$190 per 1,000 m² per house. This conclusion is supported by another study of the flip-side of the forest aesthetics-property value relationship:

Mueller et al. (2009) found that a wildfire occurring within a 1.75-mile radius of a property lowered that house's value by approximately \$15,000 (9.71%), while a second fire occurring within the same distance causes a further decline of \$34,000 (22.7%). In Montana, the value of homes within 3.1 miles of a wildfire burned area were 13.7% (\$33,232) lower than those at least 12 miles from a fire (Stetler et al. 2010).

Findings:

- Fuel reduction treatments significantly enhance the price of adjacent real estate.
- Homes located in close proximity to wildfire experience lower property values.

2. What is the relative value of treatment programs at the landscape scale?

Reframing Fire Regime Condition Class (FRCC) as an economic model

Assessing the value of management alternatives on natural ecosystems has long challenged resource professionals. The scope of the problem has significantly widened from a commercial focus to include a full range of ecosystem and

amenity considerations. Recent reviews demonstrate the importance of addressing the return on investment for fire management in a restoration context and also note the difficulties of comparing changes across different resource values (US-DOI Office of Policy Analysis 2012).

As discussed previously, the persistent questions, especially the desire to understand when investment in treatments will lead to a reduction in the need for expensive suppression, are difficult to answer using a conventional benefit-cost analysis. Instead of trying to estimate the total value of ecosystem services, changes were estimated in total value with respect to changes in restoration and fuel treatments (marginal values). In other words, the relative value of a management scenario can be evaluated compared to other alternatives in moving the ecosystem closer toward the desired fire management condition. Thus, the fire management problem was re-framed to connect essential elements of restoration with the economists' definition of marginal value (the incremental value of additional management action) without having to attach monetary values. The extent of restoration achieved is an outcome of management actions applied to a given site condition, defined in part by the Fire Regime Condition Class, other management variables and physical attributes. By estimating and comparing the relative value of fuel treatment options researchers were able to directly address their relative return on investment.



The 2012 Waldo Canyon Fire destroyed approximately 346 homes, including several homes in this neighborhood near Colorado Springs, Colorado. The Waldo Canyon Fire forced the evacuation of 32,000 residents and burned 18,247 acres. *Photo by Kari Greer, courtesy of the U.S. Forest Service*

A case study application from Colorado's fire-prone Front Range was used to illustrate the potential for integrating restoration ecology with microeconomics. The study site includes diverse values for watershed, WUI and wildlife habitat, and is adjacent to the 2012 Waldo Canyon fire. The spatial planning system STARFire (Manley et al. 2011) was used to implement a series of planning alternatives including low and high levels of fuel treatment options to show the difference in the return on investment. Burn probabilities and marginal values for restoring the site were used to estimate a demand curve for the fire management effort for each fire planning alternative. Comparisons of the landscape deviations from desired fire management condition were processed to show the relative value of each alternative, and these can be interpreted as alternative returns on investment.

The strength and innovation of this approach to analysis and application is that it allows consideration for the return on investment from planning alternatives without requiring total cost information. It also suggests a contextual framework with extensive flexibility and refinement for those interested in a more thorough development. For this initial integration of ecological restoration with the marginal value of fire management, researchers were required to make many simplifying assumptions that might benefit from future refinements.

Findings:

- A classic economic approach that attempts to place a total economic value on management outcomes is costly and difficult. This study demonstrates that a marginal analysis of benefit can be used to compare the relative value of alternative fire management strategies on a complex landscape. This approach allows managers to compare different treatment alternatives and assess which is economically more efficient without the need to calculate the total cost.
- The study site used to demonstrate this approach suggests that high level treatments (approximately 30% of the study site) will improve landscape condition by almost 20% over the current condition and that combining fuel treatments with an aggressive suppression program generated an almost 30% improvement relative to the current condition.

3. How can current and future economic returns to restoration-based hazardous fuel reduction treatments be improved?

In order to understand how to improve the economic efficiency of treatments, the cost and benefits of different treatments can be analyzed in the context of moving an ecosystem toward desired conditions. To accomplish this analysis, a unified analytical model was built to evaluate the economic efficiency of fuel treatments in diverse ecological settings. This model simulated long-run wildfire suppression costs with and without fuel treatments, and then compared the reduction in wildfire suppression costs due to implementing fuel treatments with treatment costs to determine economic returns. This approach describes the economic return of future fuel treatments in terms of expected wildfire suppression costs averted. This model accounts for 1) the cumulative cost of fuel treatments over time, 2) the likelihood of wildfire events with and without treatments, 3) the costs of wildfire suppression and post-fire restoration, and 4) the combined influence of wildfires and management actions on ecological conditions and ecological services over time.

This project combined an economic model with a stylized ecological state-and-transition model for two ecosystems in the western United States: the ponderosa pine forest ecosystem of the Southern Colorado Plateau (henceforth the "PIPO ecosystem") and the mountain big sagebrush ecosystem of the Great Basin (henceforth the "MBS ecosystem").

State-and-transition (STM) models describe an ecosystem as being in one of several ecological states, which are separated by ecological thresholds (Stringham et al. 2003). The stylized STM consists of five ecological states for the PIPO system and three ecological states for the MBS system. The stylized STMs are numerically implemented to simulate the benefits of fuel treatment with treatment costs, suppression costs, wildfire frequencies, and the transitions between ecological states in the PIPO and MBS systems. It is assumed that both the PIPO ecosystem and MBS ecosystem will transition between an ecological state if a finite amount of time passes without either fuel treatment or wildfire.

In the two simulation models of PIPO and MBS systems, parameters and model assumptions were chosen to avoid either overstating the benefits or understating the costs of fuel treatments. Most importantly, only one category of fuel treatment benefits—reductions in wildfire suppression costs—is considered, and, as such, all of the other ecosystem goods and services that can potentially benefit from fuel treatments are ignored in the analysis. Benefits from fuel treatments not considered include reductions in wildfire damage to housing and other infrastructure, reduced risk to firefighters, and improvements in wildfire habitat, erosion control and esthetic beauty. Given that these additional benefits from fuel treatments are not considered, the analysis can only draw conclusions about the conditions under which certain

fuel treatments are economically efficient. Conversely, the analysis cannot draw conclusions about the conditions under which other fuel treatments are not efficient.

Findings:

- In the two ecosystems studied, it is more cost effective to treat degraded systems before they significantly depart from natural conditions.
- The results indicate that fuel treatments are economically efficient in the MBS ecosystems on the basis of wildfire suppression costs savings alone when applied to MBS systems that are in relatively good ecological health, before pinyon pine and juniper trees reach closed-canopy conditions.
- Wildfire suppression costs averted alone are not sufficient to offset the expected costs of fuel treatments applied to MBS systems that have transitioned to closed-canopy systems with pinyon pine and junipers, or that have previously burned and transitioned to monoculture invasive grass dominated communities.
- In the PIPO ecosystem, fuel treatments aimed at rehabilitating dense, overcrowded forests are not economically efficient on the basis of wildfire suppression cost savings alone. It should be emphasized that the results on the economic efficiency of fuel treatments for the PIPO ecosystem are preliminary and further development of the state-and-transition model may be required before firm conclusions about the efficiency of fuel treatments for this ecosystem can be made.
- A measure of the wildfire suppression costs averted can only be a lower bound on the return on investment for fuel treatments. Where the returns are positive, the need to measure the magnitude of other values may be avoided—in other words the treatments are a worthwhile investment in terms of wildfire suppression costs averted alone. Where the differences

are negative, these results indicate, on a per acre basis, the level of the additional benefit necessary for fuel treatments to generate expected benefits to suppression costs averted are greater than the costs of treatment. This distinction is important for the PIPO and MBS ecosystems, where restoration of ecosystem function is one of the primary goals of fuel treatments.

In addition to estimating the long-run economic returns to fuel treatments for the PIPO and MBS ecosystems, two issues relevant for evaluating the costs and benefits of any fuel treatment program or policy were analyzed. First, the appropriate time horizon for evaluating the economic returns to fuel treatments was considered. The time horizon used to evaluate policy is important because the benefits of restoration-based fuel treatments are often relatively long-lived in the two ecosystems studied. Second, how the economic returns to fuel treatments are influenced by treatment effectiveness and treatment costs is analyzed. This information is necessary to evaluate how the current and future economic returns to fuel treatments would change as a result of anticipated improvements in treatment effectiveness and/or reductions in treatment costs due to advances in applied ecology and management.



Fire Crew 7 marches toward the fire zone to protect an area of rangeland that was not yet burned by the Long Draw Fire. The Long Draw Fire burned more than 557,000 acres in southeast Oregon in July 2012. Photo by Kevin Abel, Bureau of Land Management

Findings:

- The simulation results illustrate that when short time horizons are used, such as 10 or 20 years, the expected return from fuel treatment strategies can appear to be negative; but when the time horizon is lengthened to be consistent with the duration of expected effects of the treatment, the returns may be positive.

- Analyzing how economic returns for fuel treatments will be influenced by effectiveness and offsets for treatment costs are especially important for the PIPO system, because the current costs of treatments are quite high due to a lack of viable markets for biomass. It is anticipated that treatment costs will go down in the near future as markets develop for restoration by-products coming out of CFLR sites and as new technology comes on-line to utilize small diameter wood.

4. What are the fuel treatment, Wildland Urban Interface, and climate change effects on future suppression costs?

The objective of this analysis was to identify and estimate effects of fuel treatments and demographic and environmental changes on suppression costs and fire outcomes. The analysis used a strategy based on spatiotemporally aggregated data to the county level for the western U.S. to estimate the impact of county-level fuel treatments, WUI characteristics, and weather effects on total county-level suppression cost and acres burned.

Data on wildfires and fuel management derive from three primary sources: the National Interagency Fire Management Integrated Database (NIFMID), Incident Command Summaries (ICS-209), and the National Fire Plan Operations and Reporting System (NFPORS). A random effects Tobit model was used to account for censoring of the dependent variables and the panel structure of the data. Of the extant published literature

on this topic, this approach is most similar to Prestemon et al. (2002), who examined the effects of prescribed fire on wildfire activity in Florida based on annual, county-level data. Regression results were used to extrapolate the effects of treatments, WUI, and weather factors to the next decade.

Findings:

- The number of acres burned and total suppression costs increase with the amount of land classified as WUI intermix. Similar but smaller and statistically weaker effects are estimated for WUI interface.
- Extrapolations of WUI and weather variables in the sample suggest that if trends in these variables continue as they did in the sample, wildfire acreage and suppression costs would increase in the future.
- Results show limited and mixed effects associated with fuel treatments. One of the reasons may be due to the selection bias of fuel treatments, meaning the more wildfire prone the areas are, the more likely they receive fuel reduction treatments.

5. In conclusion: When or will investments in fuel reduction treatments lead to a reduction in suppression costs?

- **Assessing the value of restoration and hazardous fuel treatments only in terms of**



The area where forested land and urban homes are interfaced, or side-by-side (left), or intermixed (right) is known as the wildland urban interface, or WUI. As population densities increase in WUI areas, a growing body of evidence suggests that fuel reduction treatments are effective in reducing damage to property and infrastructure from catastrophic wildfires. *Illustrations by Adriel Begay, courtesy of the Ecological Restoration Institute*

reducing suppression costs is an inadequate analysis for understanding the full economic and ecologic value of treatments.

An evidence-based systematic review shows that fuel and restoration treatments improve the value of ecosystem services. Accounting for the full economic benefits of the ecosystem services enhanced by treatments and the full cost of the damage avoided when the risk of unnatural fire is averted results in a positive economic and ecologic return on treatments.

- **To determine whether, where, and when investments in treatments may lead to decreases in suppression costs requires a new perspective on economic analyses at the national level.** By analyzing the benefits of management actions in terms of moving the ecosystem closer to desired conditions, the relative effectiveness of different management actions can be analyzed. This approach also allows ecosystem services and other important values to be considered. As a next step, this framework will be combined with the Wildland Fire Management Risk and Cost Analysis Tools Package (R-CAT) developed by the USFS. With the combined framework, it will be possible to provide a robust and consistent procedure that can evaluate overall efficacy of proposed treatments, incorporating a wide array of ecosystem benefits and management costs.
- A link between fire behavior characteristics (severity) and suppression costs was demonstrated using a modified application of the R-CAT tool for a treatment area proposed as a part of the Four Forest Restoration Initiative in Arizona. **Treatments designed to reduce severe fire behavior may contribute to a reduction in fire suppression costs.** As a next step, this link will be explored further to estimate the suppression cost savings resulting from fuel treatment focused on mitigating fire severity, rather than limiting the extent of fires.
- **Proximity to the WUI and fire size are correlated with increases in suppression expenditures.** A growing body of evidence demonstrates that WUI treatments are effective for reducing damage to communities. However, **modeling shows that by failing to invest in treatments in the greater landscape, severe landscape-scale fire will**

persist. Increasing treatments in the greater landscape can contribute to the reduction of uncharacteristically large and severe (mega) fires, and therefore fire expenditures, in the future.

- By delaying restoration action in the mountain big sagebrush and ponderosa pine ecosystems, the cost of treatments and the return on investment will be lower. **It is more cost effective to restore systems before they depart significantly from desired conditions.**
- **If the current trends of development in the WUI and weather conditions consistent with the last 10 years continue, the cost of suppression and number of acres burned will likely increase.** Addressing the WUI and fire risk is essential to reducing suppression costs.



Many properties within the wildland urban interface were protected from the 2011 Wallow Fire as a result of forest restoration treatments implemented adjacent to the homes prior to the fire. *Photo courtesy of the Ecological Restoration Institute*

VII. Research Recommendations

Recommendation #1

Continue investigations that assess the relative marginal value of fire management with the Risk and Cost Analysis Tools Package (R-CAT) developed by the USFS in combination with the STARFire model. With this combined framework, it will be possible to provide a robust and consistent procedure to evaluate the overall efficacy of proposed treatments, incorporating a wide array of ecosystem benefits and management costs. The R-CAT and STARFire systems are highly synergistic and they leverage certain common input data to integrate R-CAT's cost-avoided estimates with STARFire's ecosystem and restoration metrics of return on investment.

Recommendation #2

Identify solutions to address the increase in unnaturally large and severe (mega) fire. In particular, implement and test treatments designed to modify extreme fire behavior outside the WUI.

Recommendation #3

Implement a common or universal fire identifier framework to be used by all units of government in order to improve the ability of researchers to analyze data and answer research questions.

Recommendation #4

Although many studies demonstrated fuel treatment effectiveness on protecting watershed services, recreation, cultural values (e.g., reflected in real estate values), and commodity values, there has been no study that met the search criteria. In other words, researchers could not find any studies that systematically compared the changes in these values with and without fuel treatments after a wildfire. This represents an urgent future research need.

Recommendation #5

Conduct additional research to identify the relationship between suppression costs and fire behavior in order to assess the overall effectiveness of restoration and fuel treatments on suppression costs.



Studies show that protecting watersheds, recreation opportunities, and cultural values through forest restoration treatments provides valuable ecosystem services for all ages. *Photo by Evie Bradley, U.S. Fish and Wildlife Service*

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