A Research Report by

HEADWATERS ECONOMICS

The Full Community Costs of Wildfire

May 2018

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ABOUT HEADWATERS ECONOMICS

Headwaters Economics is an independent, nonprofit research group whose mission is to improve community development and land management decisions.

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Cover image by Colorado Springs Fire (2012), Associated Press

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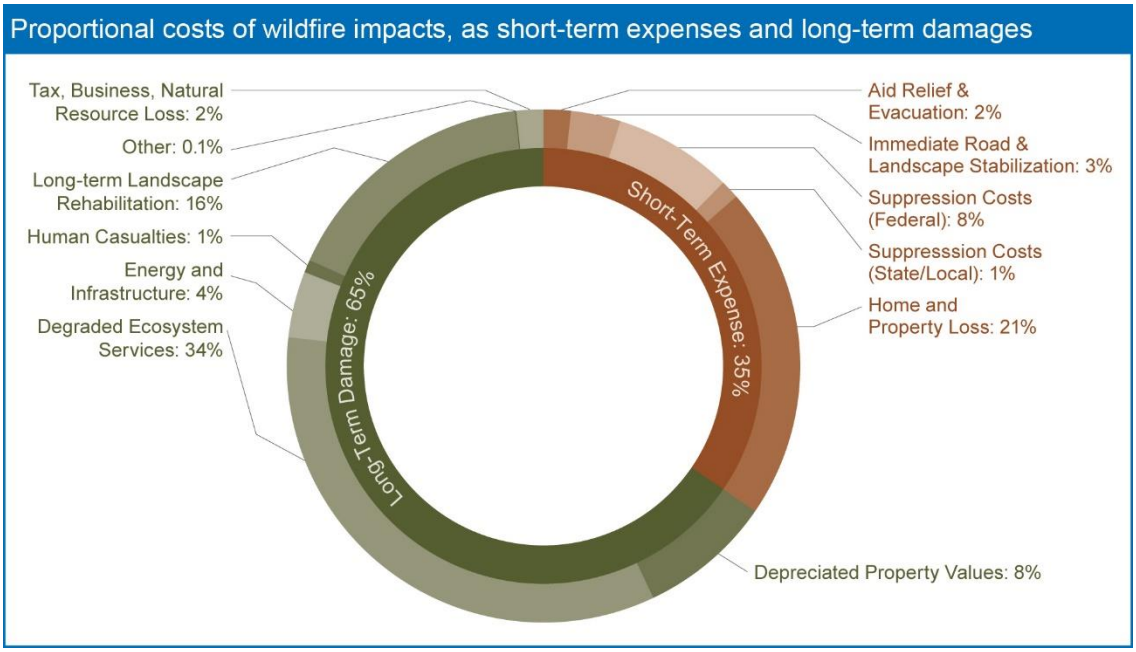
EXECUTIVE SUMMARY

This report summarizes the accumulated impacts and associated costs of wildfires at the local, state, and federal level. Drawing from existing literature and five case studies—the Hayman (2002), Old, Grand Prix, and Padua Complex (2003), Schultz (2010), Rim (2013), and Loma fires (2016)—we categorize wildfire impacts into short-term expenses including suppression costs spent on firefighting, and long-term damages including costs that accrue in the months and years after a wildfire.

Analysis of the literature suggests nearly half of all wildfire costs are paid at the local community level by government agencies, non-governmental organizations, businesses, and homeowners. Almost all wildfire costs accrued at the local level are the result of long-term damages such as landscape rehabilitation, lost business and tax revenues, degraded ecosystem services, depreciated property values, and impacts to tourism and recreation.

The remaining wildfire costs are paid at the state and federal level, or are paid by a combination of local, state, and federal organizations. State and federal agencies are responsible for paying the bulk of suppression costs. While substantial, suppression costs comprise only nine percent of total wildfire costs; additional short-term expenses and long-term damages account for 91 percent of total wildfire costs. Overall, short-term expenses such as relief aid, evacuation services, and home and property loss comprise around 35 percent of total wildfire costs. Related costs from long-term damages, which can take years to fully manifest, account for approximately 65 percent of total wildfire costs.

Wildfire costs greatly vary depending on factors within the built and unbuilt environment. Socioeconomic context, housing density, the duration and size of a wildfire, and other variables influence the overall cost of a wildfire. In general, upward trends in urban growth and development in areas at risk to wildfires suggest a parallel rise in total wildfire costs.



Additionally, climate change is influencing the frequency, intensity, and duration of wildfires and will likely exacerbate wildfire costs in the future. California's wildfire season in 2017, for example, demonstrates the extent of devastation that can result when wildfires spread into dense housing developments and are fueled by dry and windy weather conditions. While early projections of the full costs of California's historic wildfires are preliminary at the time of this writing, some estimates are into the hundreds of billions of dollars.

In the aftermath of a wildfire, local communities shoulder the responsibilities and costs of ongoing recovery. Homeowners, businesses, local organizations, and agencies can take years to financially rebound, and perhaps longer to heal emotionally and psychologically. Yet as more people continue to build in harm's way and as wildfire trends rise, wildfire costs will increase.

Planning new communities and developments with consideration of wildfire risk is one way to accommodate growth while living alongside wildfires. Land use planning strategies can be integrated into the development process. For instance, the prudent placement and layout of roads, infrastructure, and services can reduce wildfire risks to homes and improve evacuation and response efforts. Similarly, requiring ignition-resistant building materials in the construction and design of homes in at-risk areas can reduce wildfire impacts.

In Park County, Montana, the increasing threat from wildfire, alongside ongoing developmet in wildfire-prone areas, poses a significant concern to local communities. To better understand the potential impacts and related costs of a wildfire for Park County, wildfire costs were calculated using cost ratios determined from the analysis of five case studies. By extrapolating from the baseline suppression cost value of $461 per acre, and assuming suppression costs account for 9 percent of total wildfire costs, all other wildfire costs were calculated.

Under the scenario of a relatively large wildfire burning 15,000 acres in Park County, suppression costs total around $6.9 million. Long-term damages resulting from impacts realized in the months and years following a wildfire could exceed $50 million. Altogether, total potential wildfire costs for Park County could be as high as $80 million.

To further reduce wildfire risks and improve community safety, land use planning strategies must supplement other mitigation measures such as vegetation treatment projects and forest management approaches. By realizing that local communities bear the brunt of wildfire costs, elected officials and decisionmakers can take steps now in the planning and design of their communities to prevent devastating wildfire impacts in the future.

I. INTRODUCTION

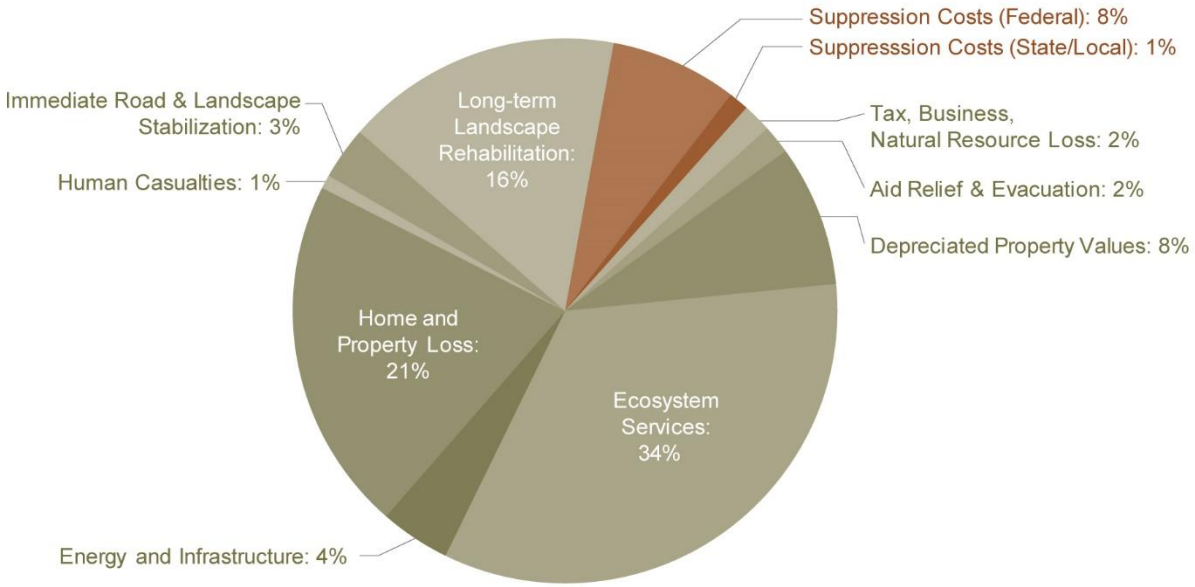
As wildfires increase in size and severity, the costs to protect homes and lives similarly rise. Yet protecting communities represents a relatively small portion of the total costs of a wildfire—a host of other short- and long-term impacts yields a variety of costs that often go unrecognized. Many of these costs—such as lost business revenue, depreciating property values, strained infrastructure, adverse community mental and health issues, and other economic and environmental losses—are borne by communities and may not be fully realized until years after the wildfire has occurred.

Identifying the total costs of wildfire is essential if we are to understand the true potential of wildfire threat. More people moving to wildfire-prone areas, coupled with the impacts from climate change and urban development, increase wildfire risks. Responding to these challenges requires innovative forest management and community planning approaches that are better leveraged by understanding the full scope of wildfire impacts and associated costs.

While significant, wildfire suppression costs (the money spent containing and extinguishing a wildfire) comprise only part of a much larger economic footprint (Figure 1). Other costs related to the long-term restoration and rebuilding of a community exponentially add to the overall costs of a wildfire. For example, post-fire analysis of the Schultz wildfire in Flagstaff, Arizona in 2010 determined that suppression costs conservatively accounted for less than seven percent of the total costs.[1] Other studies indicate the total costs of wildfire range between two to 30 times more than initial fire suppression costs, if not more.[2]

The purpose of this report is to: 1) identify the variety of wildfire impacts, 2) determine who pays for related wildfire costs, and 3) estimate total costs for a potential wildfire in Park County, Montana. The first section of the report reflects on existing literature and discusses traditional approaches used to calculate the comprehensive costs of a wildfire. We then explain our methodology and introduce five case studies that were reviewed in-depth to better identify how

Figure 1: Wildfire impacts as a proportion of total wildfire costs.



wildfire costs are documented and accounted for. Based on the case studies, we catalog the range of wildfire impacts into short-term expenses or long-term damages and then determine who pays for these costs at the local, state, and federal level. The latter half of the report draws on our analysis to project total wildfire costs for Park County, Montana. We conclude the report by suggesting that the implementation of land use planning tools can reduce wildfire impacts and associated costs by considering how, where, and when development occurs in relation to wildfire risks.

II. DEFINING WILDFIRE COSTS

Studies differ in how wildfire impacts are delineated and calculated. Most studies divide wildfire impacts into direct costs and indirect losses, or some variation of this.[3] For instance, Dale (2009) identified costs such as suppression and rehabilitation from other indirect and long-term costs.[4] In a report by the Arizona Rural Policy Institute that examined the full costs of the Schultz Fire in Flagstaff in 2010, the authors distinguish response and remediation costs, or the immediate expenses incurred during and after a wildfire, from damages to habitat, property values, and infrastructure.[5] Zybach et al. (2009) encourages an appraisal of wildfire expenditures as a "cost-plus-loss" analysis whereby costs equate with suppression dollars and losses include other measurable short- and long-term damages.[6]

More recently, a comprehensive report by the National Institute of Standards and Technology (NIST) analyzed the financial impact that wildfires impose on the U.S. economy.[7] In its analysis, NIST enumerated all possible costs of wildfire management and wildfire-related losses. For costs, activities related to prevention, mitigation, suppression, or a combination of all three were considered. Losses were separated into direct and indirect, and ranged from financial losses in the agricultural sector to impacts on the local housing market and population decline. The report estimated an economic burden between $71.1 billion and $348 billion per year on the U.S. economy, and annual losses ranging between $63.5 billion and $285 billion.

In line with this approach, wildfire costs can generally be considered within the context of impact duration, such as an immediate consequence to homes and properties or a long-term effect on community resources. Broadly, this is broken down into direct, indirect, and post-fire costs.

Direct Costs

Often studies differentiate suppression costs, or the costs to contain and extinguish a fire, from other immediate and ongoing expenditures. Suppression costs involve contracted services, fire fighter salaries, equipment, administrative personnel, and supplies and services needed to manage a wildfire.[8] Suppression costs tend to involve the "direct" costs of wildfire and are easily reported and tracked by state and federal agencies including U.S. Forest Service (USFS), Bureau of Land Management (BLM), Federal Emergency Management Agency (FEMA), American Red Cross, state departments of natural resources, and other institutions.

Other direct costs include property insurance claims, immediate repair of roads and other infrastructure, aid for evacuees, and in some cases short-term rehabilitation costs.[9] Davis et al. (2014) noted that direct impacts can also consider effects to employment and wage earnings, and not necessarily in adverse ways.[10] In their study, local spending and the hiring of contracted

services increased some sectors of business. Depending on the industry, a wildfire event can temporarily stimulate economic growth. However, other sectors such as the tourism and recreation industry experienced immediate and deep financial losses during and after a wildfire.

Indirect Costs

In addition to suppression costs, there are myriad socioeconomic and ecological impacts from wildfires. These are considered the "indirect" costs of wildfire and are the impacts that can burden a community long after the wildfire has been extinguished. Examples of indirect costs include loss of human life, degraded ecosystem services, reduced air and water quality, wildlife casualties, habitat restoration, invasive species management, lost business and tax revenue, and other gradual effects. Indirect costs can be difficult to measure because not all impacts have a monetary value or are equally valued by society.[11]

Post-Fire Costs

A third common category of wildfire impacts involves post-fire or long-term rehabilitation costs.[12] This considers both direct and indirect costs and can occur immediately following a wildfire or years later. For rehabilitation costs that manifest long after a wildfire, it can be challenging to trace their origins back to any singular wildfire event.[13] For example, the costs to rehabilitate vegetative landscapes and forests, manage soil erosion and sediment buildup, and mitigate flood damages are examples of post-fire impacts that could take years to accumulate. Further, many rehabilitation costs are paid by county, state, and federal agencies, as well as private landowners. Identifying and documenting these accumulating costs across multiple levels of management and among different landowners requires an in-depth understanding of the scope and scale of wildfire damage.

III. APPROACH

This report enumerates the total costs of a wildfire by delineating wildfire impacts into short-term expenses and long-term damages. Short-term expenses include all suppression dollars and other immediate costs spent on the control of and immediate recovery from a wildfire. This includes direct costs such as relief aid for victims and evacuees, property and home insurance claims, and temporary rehabilitation and stabilization costs.[14]

Long-term damages are peripheral or incidental to the wildfire and can take years to materialize into a measurable impact on the community. They include long-term habitat restoration, watershed recovery, human health effects, tourism and business revenue loss, impacts to local infrastructure and recreational facilities, and other accrued damages that are both qualitative and quantitative in nature.

Five case studies were reviewed to identify the range of short-term expenses and long-term damages resulting from wildfires. Case studies were selected based on the availability of data, existing literature, and scope of impacts reported. Expenses and damages are not tracked consistently across different wildfires, therefore the impacts and costs identified in the case studies represent the spectrum of potential wildfire costs as reported by government agencies, nonprofit organizations, and other state and local entities. The wildfires varied widely in size, duration, and total costs (Table 1). For example, the Hayman, Old, Grand Prix, and Padua Complex, and Rim fires burned more than 100,000 acres. Alternatively, the Schultz Fire burned

15,000 acres and the Loma Fire burned fewer than 5,000 acres. Reported total costs varied widely with different accounting methods, the number of structures burned, and the degree of impact the wildfire had on critical resources, environmental amenities, and infrastructure.

Table 1: Summary of five case studies and related statistics.

FIRE	TOTAL COST	ACRES BURNED	DAYS BURNED	COST/ ACRE	COST/DAY	CITATION
Hayman Fire (2002)	$229,603,805	137,759	41	$1,667	$5,600,093	Graham, Russell T., Technical Editor. 2003. Hayman Fire Case Study. Gen. Tech. Rep. RMRSGTR-114.
Old, Grand Prix, & Padua Complex (2003)	$1,276,933,223	125,000	9	$10,215	$141,881,469	Dunn, A. 2005. The Old, Grand Prix, and Padua Wildfires: How Much did these Fires Really Cost? USFS.
Schultz Fire (2010)	$138,818,731	15,000	5	$9,255	$27,763,746	Combrink, T., et al. 2013. A Full Cost Accounting of the 2010 Schultz Fire. Northern AZ Univ. Eco. Restoration Institute.
Rim Fire (2013)	$1,287,100,000	257,314	69	$5,002	$18,653,623	Batker, D., et al. 2013. Preliminary Assessment: The Economic Impact of the 2013 Rim Fire on Natural Lands. Earth Economics.
Loma Fire (2016)	$34,504,808	4,474	17	$7,712	$2,029,695	Christin, Z., et al. 2017. The Economic Impact of the 2016 Loma Fire. Earth Economics.

All reported impacts identified in the case studies were itemized and then determined to be short-term expenses or long-term damages. Delineation of impacts as short-term expenses or long-term damages was based on the duration of the impact and the timeframe in which expenditures occurred (Table 2). “Expenses” include costs directly and often immediately incurred whereas “Damages” (sometimes referred to in the literature as “indirect damages” and “non-market damages,”[15] or “losses,”[16] or “indirect costs” and “additional costs”[17]) include losses that are realized in the weeks, months, and even years after a wildfire (Table 3). These damages have been assigned dollar values, when possible, based on peer-reviewed literature and generally accepted practices.

Placing a monetary value on all wildfire impacts is challenging because of inconsistencies in how different impacts are valued. Beyond wildfire suppression costs and other operational expenses, there is no standard assessment or conventional appraisal system to categorize and track wildfire impacts. There is a large degree of subjectivity involved when valuing wildfire impacts such as human casualties or ecosystem services.[18] In other words, not all wildfire costs are associated with a market value.

Table 2: Wildfire impacts identified in case studies.

FIRE	TYPE OF IMPACT	REPORTED IMPACTS
Hayman Fire (2002)	Short-Term Expenses	· American Red Cross relief · Property & home insurance claims · Flood damage and mitigation · Grants & loans for uninsured property loss · Federal suppression activities · State/Local suppression activities
	Long-Term Damages	· Loss of wilderness/roadless areas values · Loss of endangered species habitat · Power lines replacement · Human casualties · Rehabilitation projects (soil erosion) · Damaged recreational facilities · Loss of property tax revenue · Loss of business revenue · Loss of natural resources
Old, Grand Prix, & Padua Complex (2003)	Short-Term Expenses	· FEMA relief · American Red Cross relief · Federal suppression activities · State/Local suppression activities
	Long-Term Damages	· Power lines replacement · Infrastructure repair · Property & home insurance claims · Recovery & water quality mitigation
Schultz Fire (2010)	Short-Term Expenses	· Fire evacuation relief · Structural damage to homes · Federal suppression activities · State/Local suppression activities
	Long-Term Damages	· Devalued assessed property values · Loss of endangered species habitat · Human casualties · Flood response · Flood mitigation · Restoration (mud, debris, polluted soils, etc.) · Unpaid labor · Increased insurance premiums
Rim Fire (2013)	Short-Term Expenses	· Emergency road, trail, & watershed stabilization · Purchase of emergency energy · Federal suppression activities
	Long-Term Damages	· Degraded ecosystem services* · Forest carbon sequestration loss · Devalued assessed property values
Loma Fire (2016)	Short-Term Expenses	· Federal suppression activities · State/Local suppression activities
	Long-Term Damages	· Degraded ecosystem services* · Soil carbon sequestration loss · Ongoing ecosystem service loss · Repair of gas/electric utilities & infrastructure · Depreciated home & property values · Reservoir mitigation · Restoration (planning & mapping, fieldwork, etc.)

*Including diminished aesthetic values, biological control, forest carbon sequestration, habitat, recreation & tourism, climate change control, soil erosion control, waste treatment, stormwater treatment, and water supply.

Table 3: Wildfire impacts: short-term expenses vs. long-term damages

TYPE OF IMPACT	REPORTED IMPACTS
Short-Term Expenses	• Aid Relief & Evacuation Services • Home & Property Loss • Immediate Road & Landscape Stabilization • Federal Suppression Activities • State/Local Suppression Activities
Long-Term Damages	• Depreciated Property Values • Degraded Ecosystem Services • Energy & Infrastructure Repairs • Human Casualties • Long-term Landscape Rehabilitation • Tax, Business, & Natural Resource Loss • Other

IV. CASE STUDIES

Overview

Authors of the case studies used in this report all recognized that suppression costs are not the total cost of a wildfire. Beyond suppression costs, the case studies attempted to document and quantify other costs clearly linked to the wildfire. Therefore, in each case study we reiterate those costs that were reported and also note losses that were not.

The following section includes a summary of each case study profiled for this report, including:

- Hayman Fire (2002)
- Old, Grand Prix, and Padua Complex (2003)
- Schultz Fire (2010)
- Rim Fire (2013)
- Loma Fire (2016)

We conclude each case study with a few sentences addressing who paid for the expenses and damages. In most cases, the literature did not categorize costs by administrative scale. Identifying costs incurred by federal, state, and/or local agencies was therefore based on existing literature and our best understanding of wildfire cost accounting.

Hayman Fire - Colorado, 2002

Dry, windy conditions combined with drought and heavy fuel loads resulted in the massive Hayman Fire on the Front Range of the Rocky Mountains 95 miles southwest of Denver, CO, in 2002. The fire spread fast through pine and fir forests on thick surface fuels of pine needles, short grasses, and shrubs.

Prized for their scenery and recreational opportunities, the Front Range mountains and forests are also critical sources of water for communities and cities downstream, including Denver. Following the fire, the greatest risk to the soil and water resource was erosion of burned areas and resulting sedimentation of streams and reservoirs.

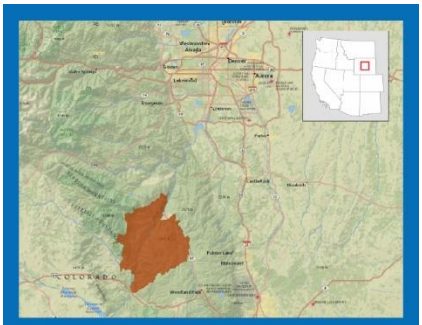
DATA COLLECTION

At the request of a Colorado congressman, a team of federal, state, and local experts was assembled to analyze information about socio-economic and ecological impacts of the fire as well as fire behavior and land rehabilitation. The report was peer-reviewed and published in 2003.[19] The socio-economic impacts chapter was based on academic literature, workshops with an impacted homeowners association, and interviews of residents and representatives of governmental and nonprofit organizations.[20]

EXPENSES AND DAMAGES

Fire suppression alone cost the federal government $42,279,000; another $1,015,741 of suppression costs were paid by the state and counties.[21] Suppression plus additional 2002 costs (listed below) totaled more than $207 million. Immediate additional costs included property insurance claims, private property losses, damaged power lines, and tourism impacts:[22]

- $38.7 million for insured property loss (600 structures)
- $4,851,552 for federal grants and loans for uninsured private property losses
- $880,000 for power lines lost
- $56,600 for U.S. Forest Service recreation facilities lost
- $37 million for decreases in water storage
- $34 million value of timber loss ($47 million for National Forest resource losses (including $3.7 million for timber)



SUMMARY

Date: June-July 2002

Setting: The Ponderosa pine forests on the mountains and drainages of Pike National Forest between Denver and Colorado Springs, CO.

Burned area: 137,759 acres

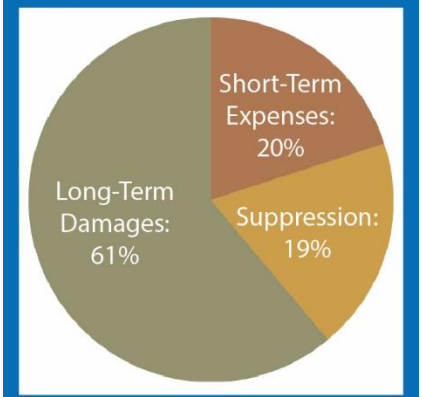
Buildings destroyed:
- 132 residences
- 468 other structures

Land ownership:
- 85% federal
- 15% state and private

Estimated costs: $207,700,049

Most expensive costs:
- Home & property loss
- Suppression costs (Federal)
- Tax, business, & natural resource loss

Proportional Costs of Wildfire



- $2 million for FEMA reimbursements, State of CO, American Red Cross relief ($765,940)
- $39,930,000 for rehabilitation projects, primarily erosion control, paid by the federal government

The Hayman Fire was the largest in Colorado history, burning 138,000 acres and destroying 600 structures. (Photo: http://cusp.ws/)

- $2,691,601 for impacts such as tax revenue losses, sales tax and business losses at a guest ranch, youth camps, and campground concessionaires
- $18 million for deaths of five firefighters and an asthma victim
- $679,614 plus more than 10 jobs for loss of wilderness values
- $10,850,000 annually for loss of endangered butterfly habitat

In addition, economic data on the Hayman Fire was collected for another year. The costs detailed for 2003 included:[23]

- $548,915 for property tax revenue losses to counties
- $7,997,972 for land rehabilitation costs incurred by federal agencies, the Denver Water Board, the state, and a coalition of private citizens
- $810,608 for flood damages to public property paid by counties and the state Department of Transportation, plus $730,000 for flood damages to private property
- $414,000 for loss of business for a guest ranch and a fishing business
- $11,529,613 for loss of endangered butterfly habitat and loss of wilderness and roadless area values

COSTS NOT EVALUATED

- Loss of South Platte River trout fishery value
- Public health including physical and mental injury, stress, and trauma incurred during the fire and in succeeding years
- Ecosystem services such as water filtration, food provisioning, raw materials, medicinal resources, soil formation, and science and education.

WHO PAYS

Costs of the Hayman Fire were not broken down by who paid. However, the literature indicates that the federal government (Forest Service, FEMA, Small Business Administration, U.S. Geological Survey, National Resources Conservation Service) paid much of the immediate cost of the fire, most of which burned on federal lands. The state and counties also paid, however, particularly in succeeding years for business loss, flooding, and ongoing rehabilitation. Losses to habitat and ecosystem services are paid by all.

Old, Grand Prix, and Padua Complex - California, 2003

A series of fires was ignited in late October 2003 in California's San Bernardino Mountains that rise up from a heavily developed valley. Fanned by southern California's extremely dry, down-slope Santa Ana winds, the fires burned 125,000 acres of the headwaters of the Santa Ana River watershed and down the hillsides to threaten the cities of Rancho Cucamonga and San Bernardino. The fires severely disturbed the upper watershed which resulted in degraded water quality and flooding downstream.

The San Bernardino National Forest was heavily burned. The area comprises chaparral, and dry pine/mixed conifer forest ecosystems in steep mountains. The forest includes 71 threatened or endangered wildlife species and more than 85 species of sensitive plants.[24]

Approximately 100,000 residents were evacuated. Ultimately 993 homes were destroyed and 3,860 partial losses were recorded.[25] Many residents were under- or uninsured. Critical electrical utility infrastructure was damaged.

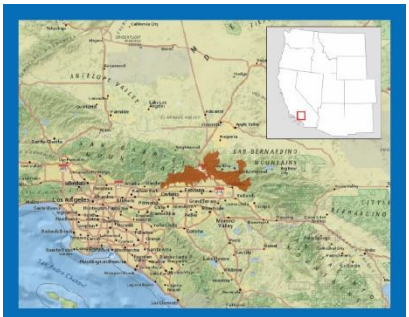
DATA COLLECTION

Preliminary cost data were compiled by the U.S. Forest Service and reported as of April 2005.

EXPENSES AND DAMAGES

This wildfire complex initially cost more than $1.276 billion. Approximately 92 percent of expenditures were for mitigating soil erosion, providing federal grants to state and local agencies, and providing grants to private citizens and businesses to recover from fire-related damage; serving individuals suffering physical and emotional trauma; and insurance claims for property losses. Expenditures incurred during the fires and in the following 18 months included:

- $61,335,684 for fire suppression (more than $43 million paid by federal agencies)
- $45,380,000 for post-fire flood and water quality costs paid by water districts



SUMMARY

Date: October- November 2003

Setting: The rugged San Bernardino National Forest east of Los Angeles, CA.

Burned area: 125,000 acres

Buildings destroyed:

- 787 homes and businesses
- 3,860 damaged

Estimated Watershed Damage:

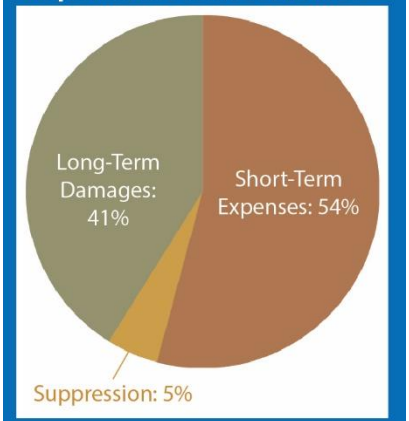
- $450 million in mitigation
- $800 million in cumulative costs
- 6 million people potentially impacted

Estimated costs:
More than $1.2 billion

Most expensive costs:

- Home & property loss
- Landscape rehabilitation

Proportional Costs of Wildfire



- $45,202,317 for public and private assistance paid by the Federal Emergency Management Agency (FEMA)
- $21,500,000 for recovery and water quality mitigation paid by federal agencies
- $9,721,108 for recover and water quality mitigation paid by the state Department of Transportation
- $576,171,965 in insurance claims
- $70,000,000 for the power company (S. California Edison)
- $3,632,149 for assistance by the American Red Cross and other social service agencies

Eighteen months later, municipalities, water districts, government agencies and communities were still dealing with "severe negative effects" of fires including erosion, public land closures, and trauma, according to a U.S. Forest Service report.[26] The report notes that an additional $443,990,000 total would be required to repair damages according to projected expenses of water districts, the state Department of Transportation, electric utility, and the American Red Cross.

COSTS NOT EVALUATED

- Local fire department costs for fire suppression and emergency response
- Railroad companies' and freight trucking industry's loss of income due to rail and highway closures
- Evacuation of private individuals
- Loss of ecosystem services and wildlife habitat
- Timber value
- Lost recreation value
- Public health including physical and mental injury, stress, and trauma incurred during the fire and in succeeding years
- Longer-term economic damages (decreased tax base, lower property value, reduced sales, increased insurance premiums, etc.)
- Degraded viewshed

WHO PAYS

Sixty-nine percent of the fire's total costs in the first 18 months were claims received by the top 13 insurance companies.[5] The federal government (U.S. Forest Service, U.S. Bureau of Land Management, Natural Resources Conservation Service, Federal Emergency Management Agency, and Army Corps of Engineers) paid about 13 percent of the costs including fire suppression, post-fire recovery, public and private assistance (reimbursements), and water quality mitigation. Utilities and water districts paid approximately 14 percent of the costs. The remaining four percent of costs tabulated was covered by the county, state, and nonprofits. Many local and longer-term costs were not evaluated for the report.

Schultz Fire - Arizona, 2010

The hot, wind-blown Schultz Fire quickly spread across the steep eastern slopes of the San Francisco Peaks in the Coconino National Forest northeast of Flagstaff, AZ, in June 2010. The fire burned 15,000 acres over three weeks. No private residences were destroyed but more than 700 properties were evacuated. Moderate- to high-severity burns impacted watershed drainages that provided approximately 20 percent of Flagstaff's summer water.[27]

The fire was soon followed by monsoon rains that resulted in heavy flooding of residential areas downstream from charred hillsides. Flooding caused one casualty and extensive damage to homes, property and infrastructure up to four miles from the burn.[28]

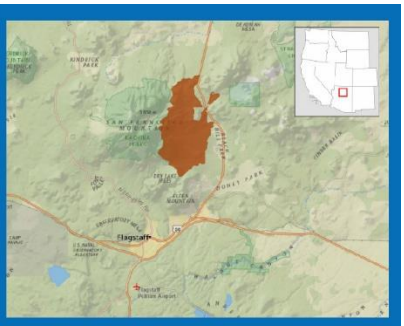
DATA COLLECTION

Northern Arizona University conducted a comprehensive study of the Schultz Fire's costs.[29] Surveys were sent to 1,339 households in the fire/flood area. Researchers also consulted the county assessor's records and official reports from city, county, state, and federal government agencies.

EXPENSES AND DAMAGES

Fire and flood response and mitigation costs were officially reported to be close to $60 million. However, according to a study conducted afterwards by Northern Arizona University, total impact of the Schultz Fire was between $133 million and $147 million:[30]

- $9,460,909 for fire suppression ($9.4 million paid by federal agencies, $32,909 paid by the City of Flagstaff, and $28,000 paid by Summit Fire District)
- $59,104,394 for fire and flood response (2010) followed by flood mitigation actual (2011-2012) and projected (2012-2014) by city, county, and federal government agencies and utilities
- $1,825,127 for cleanup of mud, ash, polluted soils, noxious weeds
- $1,516,103 for unpaid labor by homeowners, friends, and family
- $823,100 for armoring against flooding after the fire
- $223,572 for fire evacuation including emergency food and lodging, and boarding of livestock and pets



SUMMARY

Date: June 2010

Setting: Steep slopes covered with Ponderosa pine and mixed conifer forests adjacent to a metropolitan area, and the City of Flagstaff. Post-fire flooding significantly impacted the city.

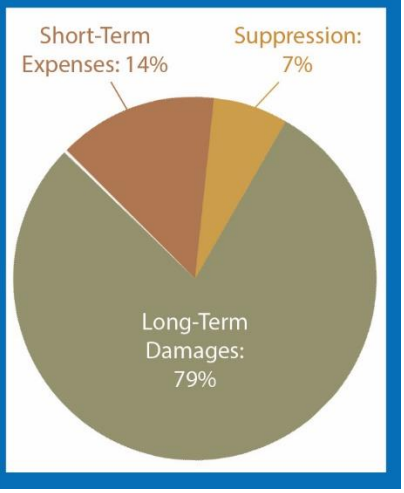
Burned area: 15,000+ acres

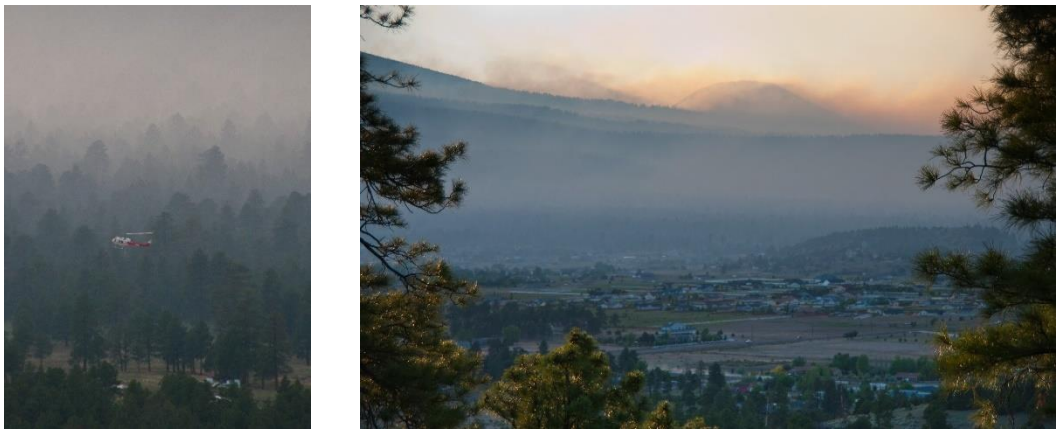
Land ownership:
- 100% federal

Estimated costs:
$133 million to $147 million

Most expensive costs:
- Depreciated property values
- Long-term rehabilitation
- Immediate stabilization
- Suppression costs (Federal)

Proportional Costs of Wildfire





Day 4 of the Schultz Fire, Flagstaff, Arizona. At this point, the fire has consumed over 12,000 acres, nearing the city limits. (Photo: Deborah Lee Soltesz)

- $59,353,523 for loss in personal wealth due to reduced property values
- $3,097,978 for structural damage to homes
- $198,034 for flood insurance premiums (new annual cost)
- $400,000 to $14,200,000 for destruction of habitat including significant loss of habitat for the federally threatened Mexican spotted owl
- $6,000,000 for loss of life in post-fire flooding

COSTS NOT EVALUATED

- Volunteer work by nonprofits
- Damage to recreation areas and archaeological sites
- Loss of timber and other forest products
- Public health including physical and mental injury, stress, and trauma incurred during the fire and in succeeding years
- Degraded viewshed (beyond effects on property values)
- Long-term effects on region's amenity-based economy
- Loss of ecosystem services such as water filtration, food provisioning, raw materials, medicinal resources, soil formation, and science and education

WHO PAYS

Authors of the Schultz Fire report concluded that the loss in personal wealth due to reduced property values – borne by homeowners, businesses, and non-governmental agencies – amounted to more than 50 percent of the true cost of the fire. More than 23 percent of the cost was paid by federal agencies. The county covered 10 percent and the state almost 3 percent. The City of Flagstaff and utilities paid four percent, and the remaining 9.7 percent – the value of the habitat destroyed – is borne by the general public. Many expenses such as public health were not evaluated.

Rim Fire - California, 2013

The Rim Fire was the third-largest in California's recorded history, burning 402 square miles and destroying 112 structures primarily in drought-stricken national forest and national park lands.

Blackened ecosystems ranged from lower-elevation wet meadows and chaparral to diverse subalpine forests of pine, oak, and aspen. Important nesting areas for spotted owls and goshawks were destroyed. The burned area supplies drinking and irrigation water to the San Francisco Bay Area and California's Central Valley. The fire quickly and completely consumed dense stands of pine and other vegetation on high ridges and in steep canyons, but burned as a lower-intensity (some say beneficial) ground fire around a critical reservoir.[31]

DATA COLLECTION

The San Francisco Public Utilities Commission hired Earth Economics – a Tacoma, WA-based organization that specializes in putting a dollar value on "ecosystem services" – to collect environmental data and compile a rapid assessment of economic impacts. Based on satellite data collected in mid-September 2013 before the fire was completely contained, Earth Economics estimated losses for the first year based on a range of environmental values available in academic, peer-reviewed literature. Losses to 10 categories of environmental benefits (ecosystem services) totaled $100 million to $736 million and considered air quality, carbon sequestration, moderation of extreme events, soil retention, biological control, water regulation, pollination, habitat and biodiversity, aesthetic values, recreation and tourism.[32]

EXPENSES AND DAMAGES

The cost of fire suppression was more than $127 million.[33] The cost included the loss of several commercial buildings and 11 residences. In addition, the fire cost:

- $8.5 million for emergency road, trail, and watershed stabilization[34]
- $900,000 to purchase alternative energy when three hydroelectric powerhouses had to be taken offline
- Losses "in the millions" to the ranching community for destroyed grazing land, killed livestock, and damaged infrastructure

SUMMARY

Date: August-October 2013

Setting: The Sierra Nevada Mountains of central California, east of San Francisco in the Stanislaus National Forest and Yosemite National Park.

Burned area:
257,314 acres (402 square miles)

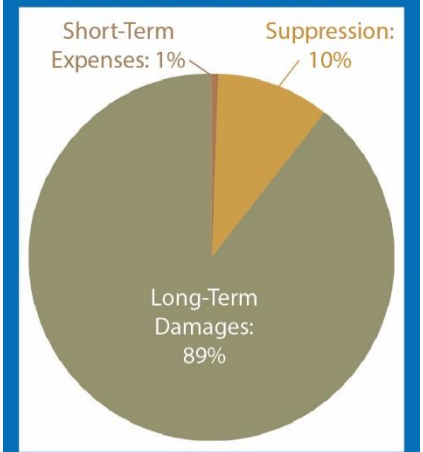
Buildings destroyed:
- 3 commercial buildings
- 98 outbuildings
- 11 residences

Injuries: 10

Land ownership:
- 91% federal
- 9% private

Estimated costs:
$388 million to $1.271 billion

Proportional Costs of Wildfire



- Between $102 million and $797 million for the loss of carbon storage
- Between $49.7 million and $265 million for losses to private property values
- Between $100 million and $736 million for loss of ecosystem services – that is, environmental benefits. (These costs are being tabulated more often as ecosystem service valuation becomes more accepted in courts to support damage assessments.)

The Rim Fire, burning near Yosemite National Park, from space. (Photo: NASA)

COSTS NOT EVALUATED

- Ecosystem services not evaluated due to lack of data or absence of appropriate studies included food provisioning, raw materials, medicinal resources, soil formation, and science and education
- Impacts on water supply, quality, timing, and reliability
- Impacts of hydrophobic soils (i.e., ash-encrusted soil that repels water, thereby increasing runoff and decreasing infiltration)
- Longer-term economic damages (loss of property taxes, decreased economic activity, increased insurance premiums, etc.)
- Rehabilitation and restoration
- Public health including physical and mental injury, stress, and trauma incurred during the fire and in succeeding years

WHO PAYS

In the case of the Rim Fire which burned primarily on federal land, the federal government paid for most of the firefighting costs. However, ongoing environmental costs will be paid by the general public, including the 2.6 million Bay-area users of drinking water that originates in the Rim Fire area.

USFS firefighters starting back fires to suppress the Rim Fire. (Photo: Mike McMillan, USFS)

Loma Fire - California, 2016

California's Loma Fire blew up fast in the drought-stricken Santa Cruz Mountains south of San Francisco Bay and the Silicon Valley area in 2016. The 4,474-acre fire burned in a sparsely populated part of Santa Clara County, one of the most affluent counties in the U.S.

Steep, dry, mountainous terrain is primarily covered with mixed hardwood and evergreen forests interspersed with coastal scrub and grasslands. Several fish, wildlife, and botanical special-status species were present in the burned area.[35] The fire burned sections of two watersheds that drain into reservoirs that provide flood control and recharge groundwater.

The high-intensity fire was followed by the heaviest rainfall in California's recorded history, resulting in landslides, failed culverts, damaged roads, and increased sediment in streams.

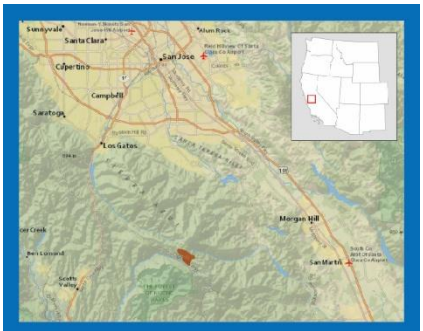
DATA COLLECTION

Earth Economics, a Tacoma, WA-based organization that specializes in putting a dollar value on "ecosystem services," was hired by the Santa Clara Valley Open Space Authority (OSA) to conduct a comprehensive cost analysis of the fire soon after it had been extinguished. Data were collected from state and county fire and emergency response officials, water and power utilities, the Santa Clara Valley Open Space Authority, and local realtors. Earth Economics also estimated ecosystem services losses based on a range of environmental values available in academic, peer-reviewed literature.

EXPENSES AND DAMAGES

The cost of fire suppression and response was estimated at $16,548,224 with the California Department of Forestry and Fire Protection (CalFire) covering 96 percent of that cost and the county paying the balance. In addition, the fire cost:[36]

- $756,584 for immediate loss of ecosystem services, including waste treatment and stormwater retention, recreation and tourism, moderation of extreme events, habitat, carbon sequestration, biological control, and soil erosion control
- Up to $1 million/year for loss of ecosystem services for the next nine years



SUMMARY

Date: September-October 2016

Setting: The remote and rugged Santa Cruz Mountains south of San Francisco Bay and the Silicon Valley area.

Burned area: 4,474 acres

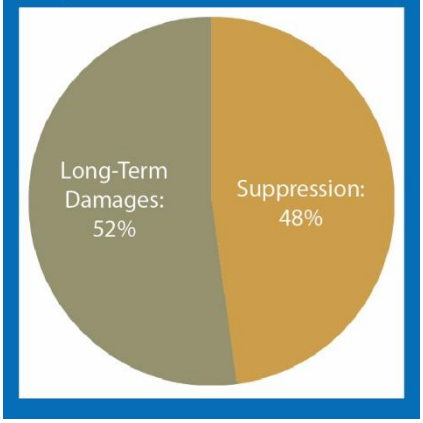
Buildings destroyed:
- 16 outbuildings
- 12 residences

Land ownership:
- 54% private
- 46% two community open space districts

Estimated costs:
$29 million to $34.5 million

Most expensive costs:
- Depreciated property values
- Suppression costs (State)
- Degraded ecosystem services

Proportional Costs of Wildfire



- Up to $3.1 million for the loss of carbon storage in soils and mature vegetation
- Up to $2.9 million projected for dredging reservoirs downstream from the fire for one year (Erosion is likely to continue for multiple years.)
- $7.2 million for the loss of 12 homes
- $1.7 million for rebuilding gas and electric utility infrastructure
- $1.3 million for restoration including planning and mapping, field work, and stabilizing and widening roads

The Loma Fire burning near the Santa Cruz Mountains (Photo: Don DeBold)

COSTS NOT EVALUATED

- Property loss – destruction of outbuildings and damage to residences
- Evacuation shelters for displaced families provided by the Red Cross
- Ecosystem services such as food provisioning, raw materials, medicinal resources, soil formation, and science and education
- Financial risk of future damages from flooding or landslides to homes and other structures, culverts, and roads
- Longer-term economic damages such as lost recreation and tourism, decreased taxes due to lower property values, increased insurance premiums, etc.
- Public health including physical and mental injury, stress, and trauma incurred during the fire and in succeeding years

WHO PAYS

Fire suppression and response were paid almost entirely by the State of California; the county incurred suppression costs as well. Insurance paid for property losses (homes and utilities), that were insured. Post-fire restoration of public areas was undertaken by a local Open Space special district funded by a property tax. Losses to ecosystem services and ongoing environmental costs are paid by all.

V. THE COSTS OF WILDFIRE IMPACTS

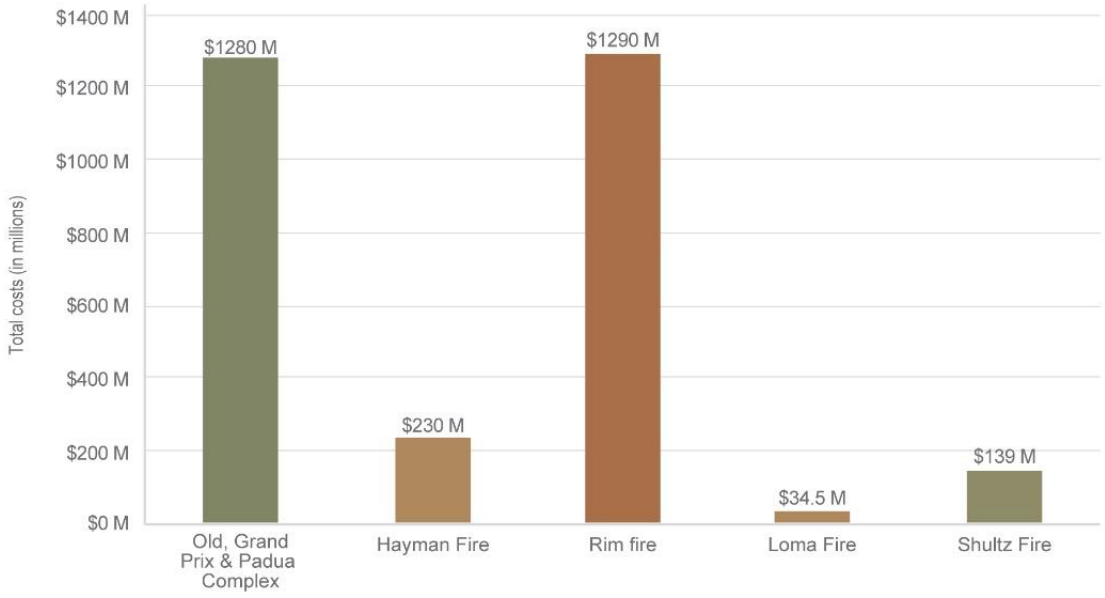
Vast discrepancies in total wildfire costs are largely due to differences in land cover, population and housing density, wildfire behavior, and other key characteristics of the built and unbuilt environment.[37] The size and duration of a wildfire does not necessarily correlate with the total wildfire cost. Rather, the concentration of homes and properties is a more likely determinant of a wildfire's total cost. In addition, the degree of impact on surrounding natural resources can significantly add to wildfire costs, especially when it comes to long-term restoration efforts.

For example, the Old, Grand Prix, and Padua Complex burned into the sprawling metropolis of San Bernardino, California, directly threatening the greater Los Angeles area.[38] When it was over, 993 homes were destroyed, 100 people were evacuated, and six people died.[39] Total wildfire costs from the Old, Grand Prix, and Padua Complex exceeded $1.2 billion. A significant portion of these costs was due to post-fire rehabilitation of the Santa Ana watershed, the largest watershed in southern California that supplies water to more than 6 million people.[40] Estimated costs related to soil erosion and water quality control alone totaled half a billion dollars for the first five years of post-fire work.[41]

In addition, wildfire costs vary due to inconsistencies in accounting and documentation. While federal agencies generally track suppression costs, other short-term expenses and long-term damages are not systematically measured. Lack of administrative capacity, record-keeping, and the qualitative nature of some wildfire impacts can influence how wildfire costs are categorized and calculated.

Figure 2 shows the cost of wildfire for the case studies. The Old, Grand Prix, and Padua Complex and the Rim Fire were by far the most expensive wildfires, each totaling close to $1.3 billion. While the Rim Fire cost the same as the Old, Grand Prix, and Padua Complex, it was twice the size and burned more than 250,000 acres, compared to the Old, Grand Prix, and Padua Complex burning 125,000 acres. The Hayman Fire, Colorado's largest wildfire in recorded

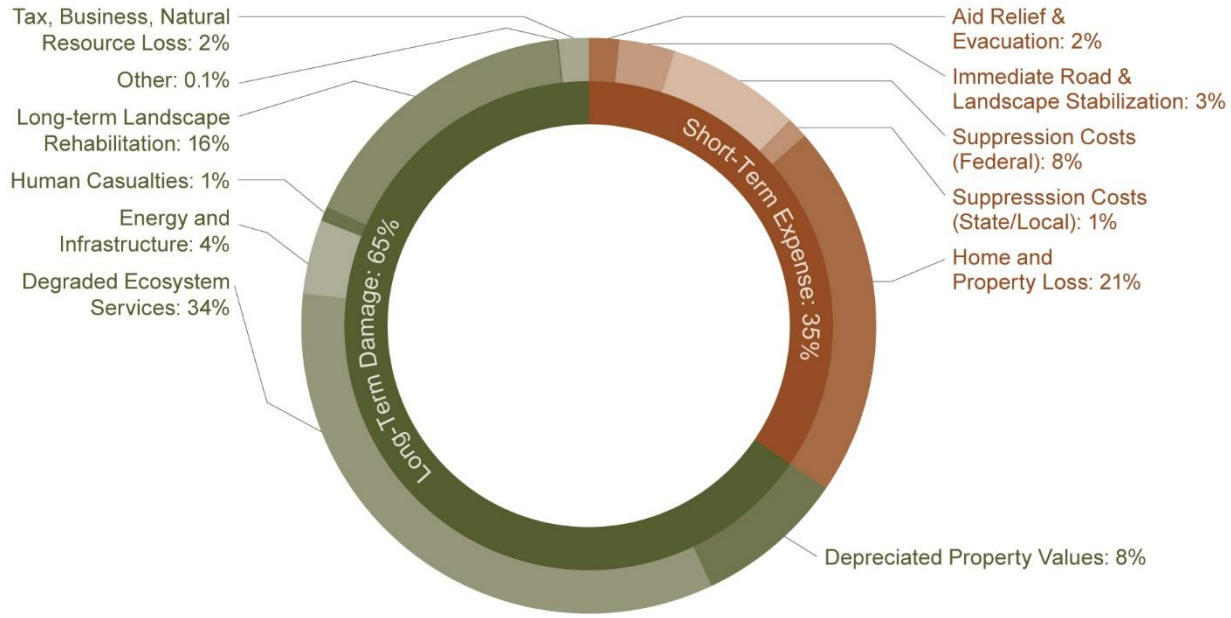
Figure 2: Total costs of the wildfires profiled in each case study.



history, also burned more acreage than the Grand Prix Fires, yet cost considerably less at around $230 million. The Schultz Fire burned 15,000 acres and cost nearly $140 million, while the Loma Fire burned around 4,500 acres and cost $34.5 million.

While some impacts are quickly accounted for and result in short-term expenses, other costs from long-term damages manifest over time and recovery does not occur until many years later. In the five wildfire events documented in this report, short-term expenses were far surpassed by long-term damages. Costs related to short-term expenses—such as federal, state, and local suppression activities, relief aid, and home and property loss—averaged 35 percent of total wildfire costs. By contrast, long-term damages involving depreciated property values, degraded ecosystem services, lost business and tax revenue, damaged infrastructure, and other long-lasting effects comprised 65 percent of total wildfire costs (Figure 3).

Figure 3: Proportional costs of short-term expenses and long-term damages.



Short-Term Expenses

When reporting on wildfire costs, short-term expenses such as wildfire suppression are often the only figures cited. This is because short-term expenses are immediately captured and accounted for by federal and state agencies and insurance companies. While suppression costs are the most commonly referenced cost, other short-term expenses include relief aid to impacted communities and damages to homes and properties.

Suppression Costs

Suppression costs, or the costs of containing and extinguishing a wildfire, are commonly cited to measure the impact of a wildfire. In part, this is because suppression costs are easily tracked and are readily available at the time the fire is occurring.[42]

In our five case studies, suppression costs averaged nine percent of total wildfire costs including federal, state, and local suppression activities. On the higher end of suppression costs were the Loma and Hayman fires. Suppression activities totaled more than $16.5 million or 47 percent of the total cost of the Loma Fire. Nearly all costs were incurred by the state and paid for by the California Department of Forestry and Fire Protection (CalFire). Santa Clara County, where the fire occurred, paid the remaining balance of $548,224. No federal suppression dollars were accounted for in the Loma Fire.

With the Hayman Fire, suppression costs were the second-largest financial impact following lost natural resources and timber. At the federal level, suppression costs totaled more than $42 million, or 18 percent of the total wildfire cost. The state, county, and local agencies paid an additional $1 million in suppression activities.

Yet, for the three remaining wildfire case studies, suppression costs were relatively minimal in comparison to other short- and long-term costs. With the Old, Grand Prix, and Padua Complex, for instance, combined suppression costs at the federal, state, and local level totaled less than five percent of total wildfire costs, coming far behind the financial impact of home and property losses and infrastructure repair costs.

For both the Rim and Schultz fires, suppression activities were around eight percent of total wildfire costs. Given its location within Yosemite National Park and surrounding federal lands, Rim Fire suppression costs were incurred by federal agencies and totaled $127 million. For the Schultz Fire, federal suppression costs were $9.4 million and state and local suppression costs were more than $61,000.[43]

While substantial, particularly in the case of the Loma and Hayman Fires, suppression costs were moderate relative to other short-term expenses and long-term damages. This suggests the total costs of a wildfire are far-reaching and impact a community and its residents much more than initial response costs may convey.

Home and Property Loss

The financial impact from lost homes and properties averaged 20 percent of the overall wildfire costs. The exception was the Rim Fire, which largely occurred on undeveloped federal lands. While accurate tracking of home and property damage can be difficult due to differences in insurance coverage and processing procedures, the immediate financial and emotional impact to the homeowner remains considerable. Lost structures, commercial sites, vehicles, equipment, and land can rapidly amount to millions of dollars in the days and weeks following a wildfire. Additionally, there is the loss of pets, agriculture, and livestock that can be difficult to quantify yet augment the overall impacts and costs of a wildfire. There is no monetary value for the psychological toll of losing a home and family belongings to a wildfire. Short-term expenses related to home and property damage therefore reflect submitted insurance claims and grant dollars, but do not fully account for the impact to the homeowner.

Home and property loss was the most expensive with the Old, Grand Prix, and Padua Complex, totaling more than $576 million or 45 percent of total wildfire costs. Located on the periphery of the larger Los Angeles metropolitan area, the Old, Grand Prix, and Padua Complex forced the

evacuation of approximately 100,000 residents and partially or totally burned more than 4,600 structures.[44]

Home and property losses were also reported for the Hayman Fire. Considered one of Colorado's most destructive wildfires, the Hayman Fire burned 600 structures, including 132 homes.[45] Expenses for burned buildings, land, homes, and other residential and commercial losses covered by insurance totaled $38.7 million. Additional losses to homes and property not covered under insurance totaled nearly $4.9 million and were paid for through loans and grants from the Small Business Administration and FEMA. Flood damages to private and public properties added another $1.5 million to overall wildfire costs.

In the aftermath of the Schultz Fire, researchers with the University of Northern Arizona surveyed affected homeowners. Data from the survey were used to measure the economic impact of the Schultz Fire on the larger Flagstaff area. In the survey, "home and property loss" was defined as damage to home interiors and exteriors, including electrical, plumbing, landscaping, decking, among many other features. According to the study, the most common and widespread impact, and therefore the costliest, was landscaping damage outside the home such as culverts and driveways.[46] The total cost for structural damages was estimated at more than $3 million with an additional estimated $500,000 for ruined possessions in or near the home such as vehicles, furniture, appliances, and electronics.

Systematic reporting of home and property losses does not occur with every wildfire. Although insurance claims are the easiest way to estimate these expenses, many other unreported costs are absorbed by the homeowner. Uninsured damages to structures, homes, and properties are rarely included in wildfire cost totals. Home and property losses accounted for in the Loma, Hayman, and Schultz fires were therefore conservative estimates.

Aid Relief, Immediate Landscape Mitigation, and Other Short-Term Expenses

Other short-term expenses reported during and shortly following a wildfire include costs related to securing the safety of people and communities. These costs include financial relief to victims and evacuees, immediate landscape mitigation, infrastructure repair, and purchasing emergency services. Together, these expenses are comparatively minimal and average less than three percent of total wildfire costs.

Financial aid and relief services to people impacted by wildfires are generally provided by the Federal Emergency Management Agency (FEMA) and American Red Cross. While other agencies and organizations additionally supply funds and resources for wildfire victims, FEMA and the American Red Cross are among the largest contributors.

In the case of the Old, Grand Prix, and Padua Complex, for instance, FEMA spent more than $45 million in grants and reimbursements. A majority of this ($37.6 million) was in the form of public assistance programs directed toward water quality mitigation and recovery activities. In addition, American Red Cross spent $2.6 million at the time of the fires and estimated an additional $1.2 million would be incurred in post-fire activities.

Disaster relief includes evacuation services, such as administrative staff time, traffic control, food and lodging, and the sheltering of pets and livestock.[47] With the Schultz Fire, 700 properties

were evacuated and an estimated $220,000 was spent housing the evacuees and their animals for up to three nights.

Significant post-fire flooding from the Schultz Fire near Flagstaff, AZ, required immediate mitigation of hillsides, roads, and slopes. (Photo: J. Bacon)

In severe situations, FEMA, the U.S. Forest Service (through the Burned Area Emergency Recovery program), and other government and local organizations spend a substantial amount of money on immediate mitigation. This includes repairing basic infrastructure and services to meet the demand of evacuation and suppression activities, as well as stabilizing hillsides, streambanks, and roads for general safety.

In the immediate aftermath of the Schultz Fire, for instance, historic monsoon rains drenched the City of Flagstaff. Flooding, debris flows, and slope erosion heavily impacted downstream residences. Carrying sediments and ashes, the floods caused extensive damage to homes, property, and infrastructure up to four miles from the burn perimeter.[48] One fatality resulted from flash flooding of a residential neighborhood.

Nearly $16.5 million was spent on flood mitigation in the days and weeks following the Schultz Fire. Adding to the complexity of mitigation management was the location of the fire and its impact on several large watersheds upstream of Flagstaff. Immediate response was therefore extensive and involved treating the forests, soils, and slopes within multiple basins.[49] Long-term funding for ongoing recovery and rehabilitation nearly doubled this amount and is reported in the next section.

Short-term expenses related to wildfire response, home and property damage, and landscape mitigation are significant. While many of these direct costs are paid by federal agencies, local and state organizations and homeowners also share this financial burden.

Long-Term Damages

After a wildfire has been contained and extinguished, work begins on the long and exhausting process of recovery. Costs associated with long-term damages are a majority of total wildfire costs and may impact a community's economy long after the wildfire has occurred.

Some of the most prevalent and enduring long-term damages are related to restoring local landscapes. The restoration of forests, viewsheds, and critical natural resources such as watersheds is a slow and painstaking task. In the years and decades it takes to recover from a catastrophic wildfire, communities may experience decreasing property values, degraded ecosystem services, declining business and tax revenues, and other persistent adverse impacts.

Depreciated Home and Property Values

Closely aligned with home and property loss are diminished property values. A loss in personal wealth through depreciating property values can be substantial. In the Schultz Fire, reduced property values totaled around $60 million or nearly 43 percent of the total wildfire costs. Assessed property values for homes directly impacted by the wildfire were particularly affected

by post-fire flooding and erosion, which compromised landowners' scenic amenities, ground stability, and access.[50]

Reduced property values were also calculated for the Rim Fire in California. The authors of this study assessed declining property values for homes situated in unburned areas but adjacent to burned areas. The report determined that diminished property values conservatively accounted for $50 million, and ranged as high as $265 million depending on location and land cover.[51] Drawing from three previous reports, results from this analysis estimated property value loss between 3 and 16 percent of total wildfire costs.


The Loma Fire burned in an area where homes were valued as much as $1.5 million (Photo: Noah Berger, AP)

The Loma Fire, also in California, burned in an area where home values ranged from $750,000 to more than $1.5 million.[52] Researchers conducting analysis of post-fire impacts for the Loma Fire used 80 percent of the low range of home values, or $600,000, to conservatively estimate the decline in home and property values. The fire burned 12 residences and resulted in around $7.2 million in lost housing values.

A large body of literature examines the relationship between perceptions of wildfire risk and housing values. Much of the evidence suggests proximity to an area burned by wildfire decreases housing prices and increases perceptions of wildfire risk.[53] However, after time and when the vegetation has regrown, housing values can return to if not exceed their previous values. The appeal of beautiful scenery and neighborhoods, such as exurban communities near forests, can sometimes outweigh awareness of or concern about wildfires.[54] Long-term damages from declining property values can therefore be significant in the initial years following a wildfire and then gradually rebound.

Energy and Infrastructure Repair

A wildfire can severely damage local utilities and infrastructure. The replacement and repair of transmission lines, gas lines, electric utility poles, and transportation routes can take years and quickly add to the overall costs of a wildfire.

After the Old, Grand Prix, and Padua Complex, Southern California Edison Company spent $70 million repairing power lines. They projected an additional $30 million would be spent to fully replace all of the power lines damaged by the fire.[55] Roads were also damaged and cost the California Department of Transportation more than $9.7 million in repairs. It was estimated that an additional $11.4 million would be needed in subsequent years to complete the roadwork.

As a result of the Loma Fire, Pacific Gas & Electric Company (PG&E) replaced 47 distribution poles and 25,000 feet of wire in the burned area, requiring 100 staff to complete the work.[56] PG&E spent a minimum of $1.76 million and likely higher given the extent of repairs needed.

Overall, long-term damages to energy and infrastructure cost an average of four percent of total wildfire costs in the five profiled wildfires.

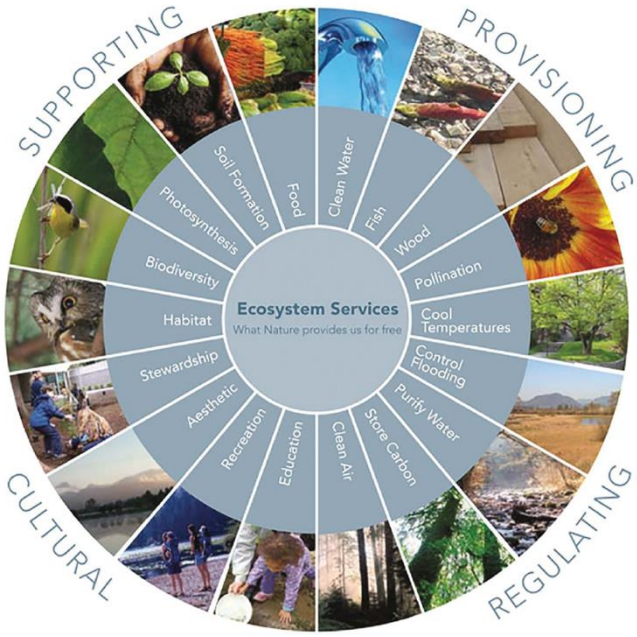
Ecosystem Services

Another costly and diverse impact is degradation of ecosystem services. Ecosystem services are defined as the benefits that people obtain from ecosystems.[57] More difficult to quantify than other wildfire impacts, ecosystem services vary from consumptive natural resource uses to recreation, aesthetic enjoyment, and ethical and stewardship preferences.[58] Ecosystem services span and link ecology, economics, and social well-being, and are fundamentally linked to human welfare and quality of life.[59] Examples of ecosystem services include clean water and air, flood risk reduction, climate change mitigation, soil and erosion control, and other environmental functions that society relies on.

Economists take a variety of approaches to estimate the dollar measure of ecosystem services and goods. While some of these methods assign an economic value based on current market trends, other methods measure people's preferences based on questionnaires designed to reveal values.

To better define the value of ecosystem services, the United Nations Environmental Programme initiated the Millennium Ecosystem Assessment (MA) in 2001. The objective of the MA was to establish a methodology to measure environmental contributions to society, and in doing so, better understand the influence that ecosystem change has on human well-being.[60] The assessment defines ecosystem services in four broad categories, including provisioning benefits (physical materials and energy), regulating services (natural control of ecosystem processes), supporting services (food production and nutrient cycling), and information benefits (amenity values and human interactions with nature) (Figure 4).[61]

Figure 4: The Millennium Ecosystem Assessment (MA) four categories of ecosystem services.



Loss of ecosystem services, as defined in the MA report, was incorporated into total wildfire costs for the Loma and Rim fires. These economic losses are not commonly cited in wildfire cost studies and included lost benefits for water storage, climate stability, and aesthetic values.

Degraded ecosystem services were a considerable financial impact of both fires. For instance, environmental benefit losses from the Rim Fire were estimated at $100 to $736 million in the first year alone.[62] This was expected to increase in following years after more data became available. The wide range of estimated losses was based on different types of land cover, land ownership, and the type of ecosystem service lost. For the Loma Fire, degraded ecosystem

services averaged approximately 14 percent of the total wildfire costs, or approximately $5 million.

In the analysis of the Rim and Loma fires, carbon storage loss (i.e., loss of carbon sequestration) was considered a significantly degraded ecosystem service. The value of reduced carbon storage resulting from the Rim and Loma fires was estimated based on land cover type and the market value of carbon, as determined by California's Cap-and-Trade Program.[63] While carbon storage loss was relatively moderate for the Loma Fire, ranging between $1 million and $3 million, the loss was considerably higher for the Rim Fire and averaged $500 million, or as much as 40 percent of the total wildfire cost.

Damaged wildlife habitat and loss of biodiversity were also considered a degraded ecosystem service. In the Hayman and Schultz fires, burned wildlife habitat was reported as a substantial long-term damage. For example, nearly 50 percent of habitat for the Pawnee montane skipper, a threatened butterfly species, was lost in the Hayman Fire.

Similarly, the Schultz Fire burned critical habitat for the Mexican spotted owl, also a threatened species. Since 2012, the federal government has spent a minimum of $43 million on the protection and recovery of the owl. This includes conservation efforts across the southwest part of the country and in and around Flagstaff where the Schultz Fire burned. Long-term impacts from the fire posed ongoing threats to the owls' survival, including continued erosion, loss of soil productivity, and debris slides. Accounting for these long-term impacts, post-fire analysis of the Schultz Fire estimated that between $400,000 to more than $14 million, or an average of $7.5 million, would be spent redeveloping suitable habitat for the owl.[64]

Other ecosystem services losses reported in the case studies included loss of wilderness values, air and water quality, and other environmental benefits. If accounted for, degraded ecosystem services can add considerably to the overall cost of a wildfire. On average, funds directed toward the restoration and recovery of ecosystem services averaged nearly 34 percent of total wildfire costs and were the most expensive impact reported. In part, this is due to the broad definition of ecosystem services and its wide applicability to wildfire impacts. Yet even a conservative estimate of the costs for degraded ecosystem services is often a large sum. Including these long-term damages into an overall accounting of wildfire costs provides a more complete understanding of the material and non-material impacts of wildfire on a community.

Tax, Business, and Natural Resource Loss

Wildfires can have an enduring effect on the local economy by impacting tax and business revenue and other forms of income. Less visible than other wildfire impacts, long-term damages resulting from a depreciated tax and business base can add up to millions of dollars over succeeding years.

Wildfire impacts on tax and business revenues can be particularly acute in places dependent on tourism and recreation. Fewer tourists and recreational users result in less business for local retailers, outfitters, hotels, and restaurants, as well as reduced income from user fees in national parks and recreational areas.[65] While wildfires' evacuation alerts, smoke, and road closures can have immediate effects on tourism, impacts to recreational sites and scenery can hamper the ability of a community to economically rebound for many years.

With the Hayman Fire, for example, several businesses, youth camps, and campground concessionaires reported a loss in revenue totaling nearly $3 million.[66] A majority of this, or nearly $2 million, was an estimated loss from one guest ranch alone. Located completely within the Hayman Fire perimeter, the Lost Valley Guest Ranch was closed for three months and operated at 40 percent occupancy when it reopened for the fall season. The following year, guest occupancy was at 50 percent and the ranch was still rebuilding after the fire.

Also detrimental to the local economy is the decrease in property tax revenue from areas impacted by wildfire. The four counties where the Hayman Fire was located reported an estimated loss in property values of nearly $550,000.[67] One county assessor's office reduced property values by 50 percent for burned acreages and up to 100 percent for burned structures.[68]

Another long-term damage quantified for the Hayman Fire was the loss of natural resources, including timber, fisheries, wildlife, rangeland, and recreational sites. Water storage was the single most expensive natural resource loss and totaled $37 million or 80 percent of the overall estimated loss. Lost timber sales conservatively accounted for $3.7 million and as much as $34 million. Damages to rangeland, fisheries, wildlife, and recreational infrastructure comprised the remaining $6 million of natural resource loss.

Although the Hayman Fire was the only case study to explicitly report financial damages to tax, business, and natural resource revenues, these costs are prevalent with other large wildfires, especially in tourist areas with high scenic amenities. While these long-term damages accounted for less than two percent of the total costs of the Hayman Fire, they still amounted to more than $50 million in damages. Further, the emotional heartache and psychological stress experienced by business owners, residents, and recreationalists in the wake of a wildfire is incalculable.

Landscape Mitigation and Rehabilitation

A substantial amount of resources is directed toward post-fire landscape restoration and recovery. Post-fire erosion and flooding can generate risks to downstream populations from debris flows, landslides, and sedimentation buildup. Federal, state, and local organizations are involved in these long-term mitigation efforts, which begin shortly after a wildfire is contained and can continue for many months and years after.

With the Old, Grand Prix, and Padua Complex, post-fire monitoring and recovery of the Santa Ana watershed was a large-scale and expensive undertaking. According to the Santa Ana Watershed Project Authority, around $45 million was spent on watershed mitigation in the first two years following the wildfire, including water quality monitoring, sediment removal, and habitat restoration.[69] The Natural Resources Conservation Service, BAER, and Army Corp of Engineers spent an additional $21.5 million on watershed mitigation measures. It was projected that ongoing stabilization efforts would require an additional $360 million over subsequent years.[70] To maintain these efforts after five years, another $400 million was needed for a cumulative cost of $800 million in the decade following the fires.

Long-term mitigation activities for the Hayman Fire similarly focused on protecting the water supply for the City of Denver. Nearly $40 million was spent on soil erosion control projects within the first year, and an additional $8 million was spent in the second year after the fire.[71]

These efforts largely focused on increasing ground cover within burned areas through mulching and seeding. More than 20 percent of the total Hayman Fire costs were dedicated to land and water rehabilitation.

Following the Schultz Fire, post-fire flooding was a significant concern for the City of Flagstaff, AZ. In the years after the fire, federal, state, and local agencies spent more than $30 million on flood mitigation. A series of collaborative rehabilitation projects known as Emergency Watershed Protection (EWP) projects were initiated between local landowners, agencies, and organizations. EWP projects address transboundary flooding and mitigation work at both the forest and neighborhood scale. Examples include repairing and lining canals, replanting, and other measures to reduce erosion and prevent future flooding.

The Schultz Fire also led to the formation of the Flagstaff Watershed Protection Project (FWPP), an innovative community-based initiative to reduce wildfire risk through selective forest treatments.[72] Funded by a resident-approved $10 million bond measure in 2010, the purpose of the FWPP is to prevent wildfires through forest-thinning projects as well as minimize post-fire impacts to Flagstaff's water supply.

The establishment of the FWPP, like EWP projects, demonstrated the City of Flagstaff's heightened awareness around wildfires. Recognizing that wildfires are frequently accompanied by a myriad of secondary impacts, such as flooding and erosion, residents and government took aggressive steps to reducing these risks in the future.

Post-fire mitigation and rehabilitation can cost millions of dollars. These long-term efforts generally involve restoring watersheds, hillsides, drainage systems, and forests over many years to ensure the safety and health of nearby communities. In some situations, post-fire flooding can overwhelm the recovery process and greatly add to long-term mitigation costs. Yet, rehabilitation after a fire also affords a unique opportunity to rebuild a community and address potential future threats, like the City of Flagstaff did following the Schultz Fire.

Human Casualties

By far the most difficult and ethically complicated wildfire impact to place a monetary value on is the loss of human life. It is important, however, to recognize human fatalities as a very real and tragic outcome of wildfires. Human casualties are therefore included in this report as a long-term damage, although any dollar amount fails to account for the true emotional impact to friends and family who lost a loved one to wildfire.

Human casualties from wildfires have risen over recent decades. As more people build homes within wildfire-prone areas, and as wildfires increase in size and frequency, more firefighters and civilians are at risk. Quantifying loss of life is routinely done by the government and insurance companies to inform policies and public health regulations.[73] For example, when an agency wants to calculate the value of pollution control regulations, a cost-benefit analysis is conducted to determine how much society is willing to pay to reduce risks from adverse health effects. These estimates of "willingness to pay" correspond with the economic value of statistical life (VSL).[74]

In the United States, value of statistical human life is estimated between $4 and $10 million, with an average value of $7 million.[75] This value depends on the nature of the risk, wage and labor characteristics, and how risks are currently being perceived by individuals and society.[76] For example, the Department of Transportation estimated VSL was $9.6 million in 2016, while the Environmental Protection Agency used a value of $7.4 million.[77]
In the case of wildfire fatalities and firefighters who die in the line of duty, calculating the value of life varies according to the employment status of the victim and which organization or agency the victim works for. In general, full-time federal firefighters are eligible for death benefits that firefighters working through a private contractor are not.[78] Further, death benefits do not reflect the long-term value of lost income following the death of a family member.

In his report of the Hayman Fire, Lynch (2004) estimated the value of loss of life between $3 million and $7 million per person.[79] As one of Colorado's most destructive wildfires, the Hayman Fire resulted in the death of five firefighters and one civilian. Using the conservative estimate of $3 million, Lynch determined human casualties added $18 million to overall costs of the Hayman Fire.[80] Alternatively, authors of the Schultz Fire cost analysis valued loss of life at $6 million.[81] The Schultz Fire resulted in one fatality from post-fire flooding. Human fatalities were not included in the other three case studies.

In this report, human casualties are considered a long-term economic damage although this clearly does not reflect the true value of a life to family and friends. While loss of income, life insurance, and compensated death benefits are explicit financial costs, other mental and psychological impacts related to the death of a family member are unmeasurable. The full impacts of human fatalities resulting from wildfires extend well beyond direct expenditures and financial impacts.

Other Damages

A host of other long-term damages surface many months and years later. For example, thousands of hours of volunteer time are spent cleaning, restoring, and rebuilding a community after a wildfire. While volunteer labor is uncompensated, this time is valuable and worth considering as a long-term impact. As an opportunity cost, this is time not spent working for money elsewhere.[82] With the Schultz Fire, for example, an estimated 77,000 hours of volunteer time was spent replacing damaged goods and removing debris from the flood. At nearly $20 per hour, this totaled more than $1.5 million in unpaid labor.[83]

Until recently, the adverse health effects from wildfires were often overlooked impacts. In particular, exposure to smoke and air particulates have been shown to increase hospitalization visits during and following a wildfire.[84] In one study by Moore et al. (2003), the number of physician visits increased between 46 and 78 percent following a devastating wildfire in British Columbia.[85] To calculate the economic impact of increased hospital admissions, Kochi et al. (2016) examined hospital records following the wildfires in California in 2007. The authors found significant acute adverse health reactions to wildfire-smoke exposure and estimated associated medical costs were more than $3.4 million.[86]

Who Pays for Wildfire Impacts?

While federal dollars pay for suppression and relief efforts, communities bear the brunt of wildfire costs for many years afterward. With a clearer delineation of the full impacts and associated costs of a wildfire, we can start to identify who pays for these costs.

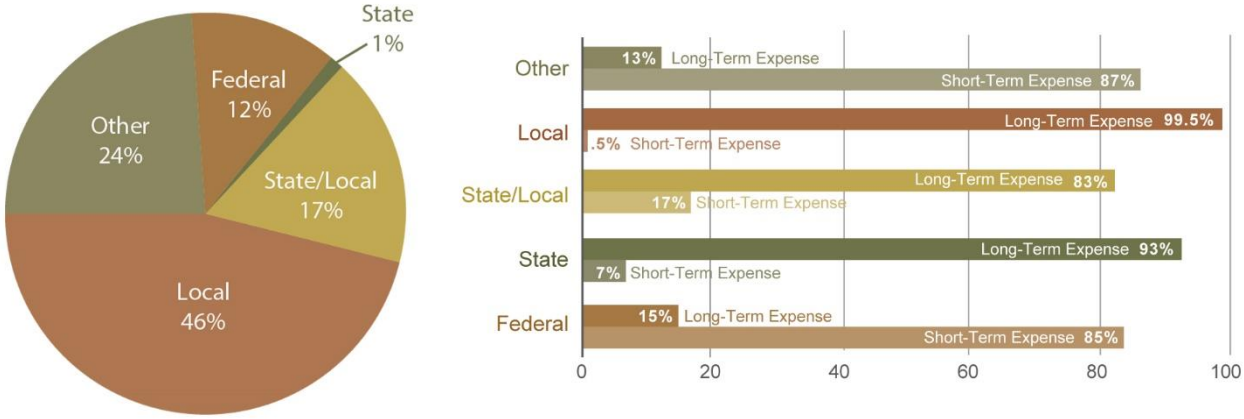
In the most general terms, state and federal government agencies and insurance companies seem to underwrite most of the short-term expenses, while the longer-term (and ultimately more expensive) damages are borne by individuals, the local economy, and the public at large. Long-term damages are much more costly than short-term expenses. In our five case studies, short-term expenses totaled $1,025,776,321 (35 percent of total cost) compared to long-term damages of $1,942,045,240 (65 percent of total).

To determine who bears the costs associated with wildfires, we separated all costs enumerated in the five case studies by paying entity (Table 4). Analysis of the five case studies indicates that the biggest share (46 percent) of total wildfire costs was paid by Local entities over time. Costs in the Federal category amounted to another 24 percent, followed by State/Local (17 percent), Other (12 percent), and State (1 percent) (Figure 5).

Table 4: Summary of local, state, and federal organizations and agencies that pay for wildfire costs.

SCALE	PAYING AGENCY/ENTITY	EXAMPLES OF COSTS
Federal	Federal government agencies, primarily the U.S. Forest Service and Bureau of Land Management for fire suppression, but also FEMA, USDA NRCS, and the Federal Highway Administration.	Evacuation and emergency aid; immediate flood mitigation, stabilization, and rehabilitation projects; grants and loans for uninsured private property loss; loss of government recreational facilities; and water quality mitigation.
State	State government agencies such as departments of natural resources and forestry.	Road repair, immediate flood mitigation and response, and emergency purchase of energy
State/Local	Combination of state and local government agencies	Fire suppression, flood damage to public and private property, replacement of power lines, repair of public utilities and infrastructure, home and property loss, loss of wilderness value and endangered species habitat, recovery of water quality, and restoration including planning and mapping, field work, invasive species management, and road stabilization.
Local	Local government, businesses, individuals, and citizens at large	Loss of homes and businesses, loss of property value, replacement of infrastructure, clean-up and restoration from fire and flood, value of volunteer labor, loss of property tax revenue, increased insurance premiums, and flood mitigation and response. This category also includes loss of ecosystem services such as recreation and tourism, soil erosion control, waste treatment, air purification, carbon sequestration, wildlife habitat, biological control, and climate change mitigation.
Other	Combinations of local, state, and federal government agencies, insurance companies, and non-government organizations and nonprofits such as the Red Cross	Evacuation and aid, property and home insurance claims, National Forest resource losses (timber, wildfire, range, watersheds), reservoir dredging, rehabilitation projects, and emergency stabilization of roads, trails, and watersheds. This category also includes human casualties.

Figure 5: Summary of proportional costs paid at the local, state, and federal level and how these costs are distributed as short-term expenses or long-term damages.



Cross-categorizing the costs according to short-term expenses versus long-term damages illuminates the roles of different entities. In general, the federal government, insurance agencies, and relief agencies such as the Red Cross serve as the initial strike team that provides immediate fire suppression, emergency relief, and short-term financial help. However, the costs of longer-term damages are primarily borne by state and local entities, individuals, and the public at large across many years. For example, the percentages of short-term expenses paid by federal agencies and the "Other" category in the five case studies total 85 and 87 percent, respectively, while the percentages of long-term damages paid by Local and State entities are 99 and 93 percent, respectively.

VI. COMMUNITY WILDFIRE COSTS: A Case Study of Park County, Montana

In 1988, Park County, Montana experienced its worst wildfire season on record. Situated adjacent to Yellowstone National Park, the county saw more than 525,000 acres burn that year.[87] Altogether, the fires burned nearly 1.7 million acres in parts of Montana, Wyoming, and Idaho.[88] The financial impact to Yellowstone National Park tourism was estimated at $21 million in 1988, $13 million in 1989, and $26 million in 1990.[89]

Fire crews attempt to protect facilities at Old Faithful during the 1988 Yellowstone National Park fire season (Photo: NPS).

The 1988 Yellowstone fires illustrate the potential devastation that a large wildfire could have on Park County and local communities. Known for its beautiful scenery and recreational opportunities, Park County has an economy that is increasingly driven by tourism and service-related industries such as retail, lodging, and restaurants. Whereas the Yellowstone fires burned mostly in the backcountry, excluding areas around Gardiner and Cooke City, a large wildfire burning in or near the county's wildland-urban interface (WUI) could have substantial consequences to local landowners, businesses, and governments.

It is therefore worth exploring more deeply the potential economic effects of a large wildfire occurring in Park County. By drawing from examples of wildfire impacts and costs identified in the five case studies, it is possible to extrapolate potential costs for Park County and local communities if a similar wildfire were to occur in the future.

Overview of Park County, Montana

Characterized by vast public lands and scenic viewsheds, Park County has experienced significant socioeconomic shifts since the 1970s. Drawn by the region's recreational and outdoor appeal, people are increasingly moving to areas like Park County for an enhanced quality of life.[90] As more people move into the county, development within wildfire-prone areas—such as homes built in the WUI—increases.

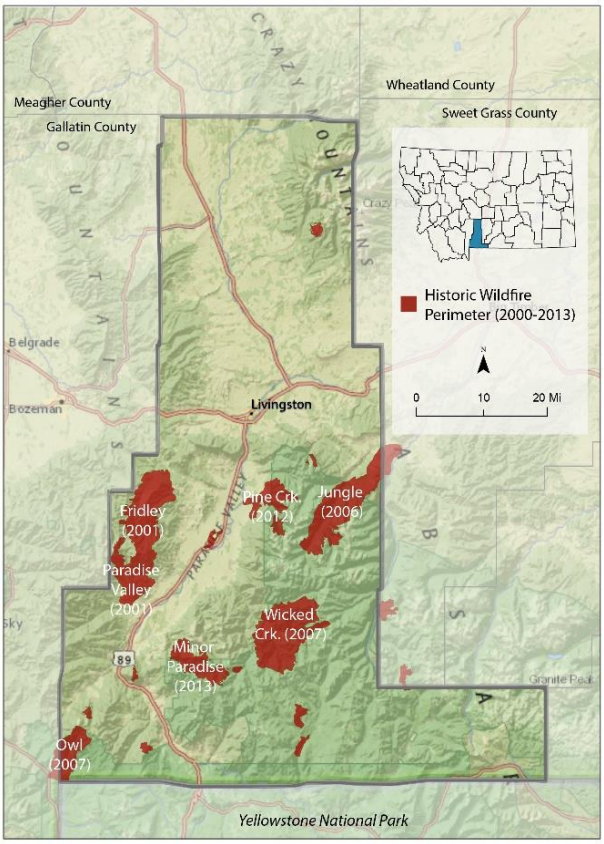
Like the WUI in many places in the West, Park County's WUI is one of the more sought-after locations for new development.[91] Proximity to heavily timbered forests and scenery makes the WUI particularly attractive for landowners who want to live outside town and near environmental amenities.[92] However, these amenities expose homes and new developments to wildfire risks.

In the West, 86 percent of the WUI remains undeveloped; nearly 90 percent of the WUI is undeveloped in Montana. In Park County, a majority (97 percent) of the WUI remains undeveloped, suggesting the county has high potential for continued growth.[93] Further, nearly 56 percent of the development in Park County's WUI is second homes, implying a high presence of seasonal residents and absentee homeowners.[94]

As more people move into Park County, the local economy and employment base are diversifying. Since the 1970s, employment has grown by 115 percent with most new jobs in service-related industries. Self-employment has similarly increased to comprise 40 percent of the total workforce, including contractors, outfitters, recreational guides, artists, and working professionals.[95]

As the employment base continues to expand, Park County's economy is also changing. While farm earnings shrank by as much as 43 percent over recent decades, earnings in service-related industries have increased by more than 60 percent.[96] Yet one of the biggest indicators of the county's transitioning economy has been the growth in non-labor income, or payments received from investments, retirement, Social Security, and other age-related payments such as Medicare. Since 1970, non-labor income in Park County has increased by 357 percent and now accounts for more than half (57 percent) of the county's economy.[97]

Figure 6: Location of Park County, Montana, including historic fire perimeters from 2000-2013.



Park County exemplifies other counties in the West confronted with the dual challenges of population growth coupled with increasing wildfire risks. The county's steady development trends favoring the WUI reflect an ongoing preference to build homes in areas with high scenic amenities. Given its geographic context and recent growth, Park County provides insight for understanding the full impacts of a large wildfire at the community scale.

Projected Wildfire Costs for Park County

To calculate the full costs of a wildfire in Park County, we assume a relatively large wildfire occurring in the future. For this region, a wildfire burning 15,000 acres or more is considered large based on wildfire trends from 1985 to 2013.[98] Over this time period, an average of 16,000 total acres burned annually in Park County. Most wildfires in the county range in size from 1,000 to 5,000 acres, therefore a single wildfire incident burning 15,000 acres would be a large event. The projected total costs for a wildfire of this size in Park County are based on assumed conditions, such as the region's WUI, geography, urban development, and natural resource base. These costs greatly vary with different community characteristics and with wildfire behavior.

Counties similar to Park County in socioeconomic context include Kittitas County, Washington and Lemhi County, Idaho. Estimated costs of wildfires in areas with a heavy population density, strong tourism and recreational base, and conducive terrain—such as Jackson County, Oregon and Teton County, Idaho—will be higher given the impacts to homes, properties, and natural

amenities. The costs cited in this report therefore represent a range of potential wildfire costs and are not ubiquitous for all wildfires across the West.

We draw on existing literature and the five case studies—the Old, Grand Prix, and Padua Complex, Rim, Loma, Schultz, and Hayman fires—to identify possible wildfire impacts and associated costs for Park County. Using suppression costs-per-acre as our baseline, we extrapolated related costs for all other short-term expenses and long-term damages based on their proportional value of total wildfire cost accounting. For instance, analysis of the five case studies suggests suppression costs account for approximately nine percent of total wildfire costs; the remaining 91 percent of wildfire costs are for short- and long-term impacts. If a wildfire costs a total of $100,000, then $9,000 is directed toward suppression and the remaining $91,000 is allocated for other costs such as landscape rehabilitation, relief aid, home and property damage, and other wildfire impacts. Using this cost ratio allows for the calculation of individual expenses and damages.

A number of studies estimate the cost of federal suppression efforts on a per-acre basis. For example, in a review of several wildfires in California in 2008, suppression costs per acre ranged from $168 to $2,055 with an average of $645 per acre.[99] In another study by Thompson et al. (2013), the effectiveness and relationship between fuel treatments on Forest Service land and associated suppression costs was assessed. The authors simulated different fire scenarios and estimated suppression costs at $2,177 per acre.[100] In a study examining suppression costs on a regional basis, Gebert et al. (2007) estimated suppression costs ranging from $106 to $2,114 per acre, depending on which of the eight USDA National Forest System regions the fire occurred.[101] Using these calculations, Gebert et al. estimated average suppression costs for Montana, located in Region 1, totaled $1,088 per acre.

Suppression costs identified in the five case studies concur with the cited literature. Within the range of costs was the Hayman Fire, averaging $314 per acre for suppression, to the Loma Fire which cost nearly $3,700 per acre for suppression. Overall, the average suppression costs among the five case studies averaged $1,125 per acre.

Suppression costs vary according to the size of the fire, the number of threatened homes, rate of spread, and the difficulty of the terrain.[102] As each of these variables increases, the costs of suppression also rise. Yet, as Gebert et al. pointed out, the opposite is true when suppression dollars are disaggregated on a cost-per-acre basis, or as a per-unit cost. In this case, there is an economy of scale and an inverse relationship exists between the size of the wildfire and suppression costs per acre. The larger the wildfire and the more acres burned, the more the costs are spread out across multiple acres so suppression costs on a per-unit basis decrease.[103] Using a cost-per-acre measure can therefore present conflicting results about the true nature of a wildfire.[104]

For the purposes of this report, we use a suppression cost value of $461 per acre to estimate projected wildfire costs in Park County. A suppression cost value of $461 was based on the average suppression costs per acre for wildfires in Park County from 2001 to 2013.[105] While significantly lower than the accepted value of $1,088 referenced by Gebert et al., a suppression cost of $461 is accurate for Park County given historic wildfire trends, past suppression costs, housing density, wildfire potential, and geography.

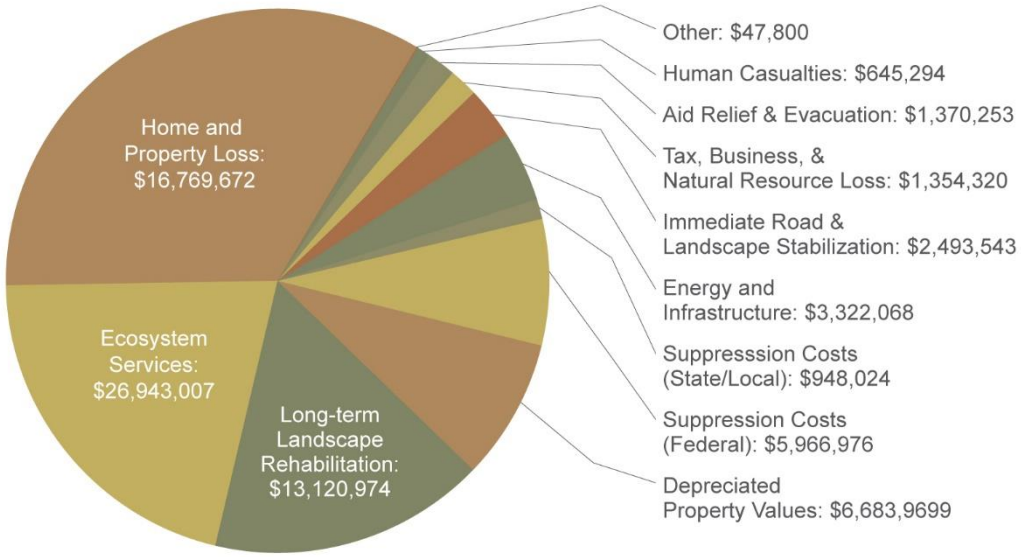
The federal government pays the bulk of wildfire suppression costs (approximately 90 percent) with state and local governments paying the remainder. Assuming a proportional relationship of $461 per acre for suppression costs, or 9 percent of total wildfire costs, indicates an additional $4,997 is spent on other associated costs per acre. Using Gebert et al.'s value of $1,088 per acre for suppression costs suggests that an additional $11,447 is spent on other associated costs per acre. The total costs of a wildfire in Park County are therefore conservatively estimated at $5,311 per acre based on historic average suppression costs, or as high as $12,535 per acre based on Gebert et al.'s accepted suppression value of $1,088 per acre.

We used a wildfire event burning 15,000 acres as a proxy to predict the costs of a moderate-sized wildfire for Park County. Comparable past wildfires in the county include the Fridley Fire (2001), Jungle Fire (2006), and Wicked Creek Fire (2007), with each of these fires burning more than 25,000 acres.[106] Over nearly a 20-year average, wildfires have burned approximately 16,700 acres annually in Park County. A wildfire of 15,000 acres, therefore, is within range of a moderate-sized wildfire for the county. A wildfire of this size burning in the WUI, such as the Wine Glass subdivision outside the town of Livingston, would pose a significant threat to homes, critical resources, and local infrastructure.

Suppression costs for a wildfire of 15,000 acres burning in Park County could be as high as $6.9 million, assuming $461 per acre. Of the total amount estimated for suppression activities, federal agencies pay around $6.2 million, and state and local governments pay around $690,000. Assuming a proportional value of 9 percent for suppression costs suggests overall wildfire costs of nearly $79.7 million.

Using the cost ratios identified in the case studies suggests that a majority of total estimated wildfire costs are spent on long-term damages rather than short-term expenses. In a Park County scenario with an overall wildfire cost of around $80 million, approximately $52 million is projected for long-term damages to ecosystem services, property values, infrastructure and local services, watershed health, recreational sites, and tax and business revenue (Figure 7).

Figure 7: Projected wildfire costs for Park County, Montana, totaling around $80 million.



Of these long-term damages, ecosystem services would be particularly hard hit with estimated costs close to $27 million. Beyond the long-term damages to ecosystem services, other costly long-term damages would include landscape rehabilitation and mitigation ($13 million), depreciated property values ($6.7 million), and energy and infrastructure repairs ($3 million). Losses to local tax and business revenues potentially would total more than $1.4 million.

Beyond suppression costs, potential short-term expenses would include home and property loss adding up to $16.8 million. The repair of roads, slopes, and watersheds to prevent erosion and flooding could cost as much as $2.5 million. Aid relief for evacuees would add another $1.4 million to total wildfire costs.

We drew again on the literature and findings from the five case studies to identify who theoretically pays for these projected wildfire costs in Park County. The bulk of the costs of a 15,000-acre, $80 million wildfire would be borne by communities. Nearly half ($36.8 million) of the wildfire costs would be incurred at the local level. Federal government agencies would potentially pay as much as $19 million (24 percent), with the state and local governments paying an additional $13.4 million (17 percent). Around $9.6 million, or 12 percent, would be shared between all three levels of administration, including local, state, and federal agencies. The remaining $660,000 would be paid for at the state level.

By the numbers—wildfire figures from Park County Sheriff's Office:

Since 2006, the Park County Sheriff's office has responded to more than 290 wildfires. The nine largest wildfires resulted in:

- 4,478 hours worked by personnel
- 17,7550 miles driven
- 109 days of wildfire activities
- $197,000 spent on wildfire evacuation and mitigation efforts ($97,000 was paid for by Park County government;$100,000 was paid for by the federal government)

In a recent study by the University of Montana, wildfires during 2017 cost Montana an estimated $240 million in lost tourism revenue.[107] With more than 1.2 million acres burned, the 2017 wildfire season was one of the state's worst on record. According to the study, for every 100 tourists who planned to visit Montana during the summer, approximately nine canceled their trip because of the wildfires. This added up to around 800,000 fewer visitors and lost revenue to hotels, restaurants, guiding operations, and retail. In addition, Montana paid $62 million in suppression costs, with the federal government spending $340 million on suppression.[108] Together, wildfire suppression costs and the decrease in tourism revenue generated an economic shortfall of $200 million in the state's budget. The study did not project the cost of long-term damages.

While projections of wildfire costs for Park County are hypothetical and are modeled on a worst-case scenario, these cost estimates are within the value range of previously cited wildfire studies. A 15,000-acre wildfire in Park County that totals nearly $80 million in overall wildfire costs suggests total wildfire costs of around $5,300 per acre. By comparison, total wildfire costs per acre for the five case studies ranged from $1,700 per acre for the Hayman Fire to more than $10,000 per acre for Old, Grand Prix, and Padua Complex. The average cost on a per-acre basis for the five profiled wildfires was $6,770. Calculations for total wildfire costs in Park County are therefore conservative estimates but realistic given the region's housing density, geography, development trends, and local economy.

VII. DISCUSSION

One approach to reducing wildfire impacts and associated costs is to control variables within the built environment using land use planning tools. This could help communities mitigate wildfire impacts to homes and structures and reduce their share of wildfire costs, which is nearly half of all wildfire costs. Common land use planning measures such as zoning, regulations, and ordinances can be adopted at the local and state level to better align existing and proposed developments with wildfire threats (Figure 8).[109]

Land use planning can help control how, when, and where development occurs in wildfire-prone areas. With more people building homes in the WUI, the number of structures exposed to wildfires increases, which drives up suppression costs. Gude et al. (2013), for instance, determined that when the number of homes built in high wildfire risk areas doubles (100 percent increase), suppression costs increase by seven percent.[110]

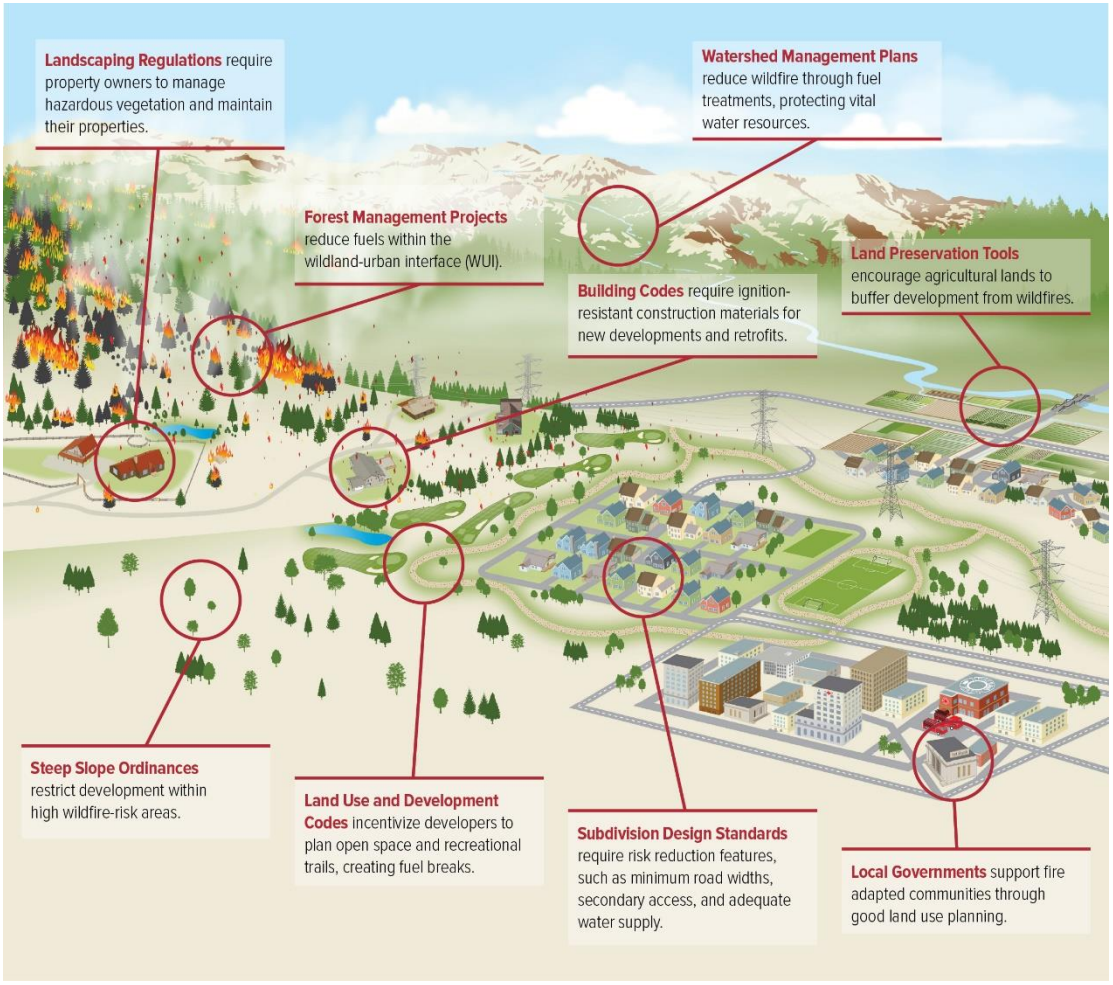
By designing a community to anticipate and live alongside wildfire, impacts and related costs can be mitigated. The placement and layout of roads and infrastructure, for example, can serve as a fuel break to buffer a community from an encroaching wildfire while also assisting with response efforts. Developments built in the WUI can be required to have multiple access routes for the evacuation of residents as well as the arrival of equipment, vehicles, and fire personnel. The location and maintenance of utility poles and transmission lines can also reduce wildfire costs by minimizing opportunities for wildfires to ignite and spread.

Other land use planning tools include regulations and ordinances requiring structures built in especially high-hazard areas to be held to certain wildfire-resistant standards. The required use of ignition-resistant building materials for homes constructed in wildfire-risk areas can reduce costs by increasing the home's resistance to wildfires. Certain decking, siding, roofing, and window materials can be integrated into the design and construction of the home to reduce vulnerability to embers and ignitions.[111]

Alternatively, zoning regulations are a land use planning measure that can steer development away from wildfire-prone areas. An overlay zone is an example of land use regulation limiting the type and location of development in districted areas. In Santa Fe, New Mexico, for instance, an overlay zone is applied to the escarpment area to protect critical viewsheds while also reducing wildfire risks. The overlay zone is applied to all new developments and it limits where structures can be built. Overlay zones offer the dual benefit of protecting critical community assets while also reducing the number of homes vulnerable to wildfires.

Other land use planning options include incentivizing mechanisms to encourage development in areas less likely to burn. Transfer of Development Rights programs, open space initiatives, and clustered housing developments away from the WUI are examples of land use planning strategies for which incentives could be offered to prevent growth in areas of high wildfire risk and redirect homeowners toward safer, less exposed locations. Wildfire-prone areas, which may be heavily vegetated or forested, are thereby preserved and development occurs as infill or a safe distance from the WUI.[112]

Figure 8: Examples of land use planning tools to reduce wildfire risk.



These strategies and other approaches to reduce community wildfire risk should be clearly outlined in land use planning documents, including the Hazard and Mitigation Plan, Comprehensive Growth Plan, Community Wildfire Protection Plan, and other community plans. It is additionally important that these documents speak to one another to address wildfire risk and to ensure there are no discrepancies between the plans. Collectively integrating wildfire risk into the various planning documents allows them to build on one another and creates a more robust approach to wildfire risk reduction.

Recent wildfires in California demonstrate the high costs of home and property loss. The wildfire season of 2017 was the worst on record for California. In the month of October alone, wildfires burning in the northern part of the state, including the wine country around Napa Valley, resulted in approximately $9.4 billion in insurance claims.[113] Nearly 9,000 structures were burned and more than 100,000 people had to evacuate. The wildfires claimed the lives of 44 people, including civilians and firefighters.[114] Projected long-term costs to local economies, including lost jobs, impacts to tourism, and damages to vineyards, were as high as $85 billion.[115]

As remarkable as these figures seem, they paled in comparison to the costs and damages caused by wildfires burning the southern part of the state. The Thomas Fire surpassed the Cedar Fire of 2003 to become California's largest wildfire on record. Burning more than 280,000 acres, the Thomas Fire destroyed 1,000 structures, killed 15 people, and incurred $110 million in suppression costs alone. Other short-term expenses are estimated at $10 billion.[116]

Future cost analysis of the wildfires in California during 2017 will deepen our understanding of the total impacts and related costs of wildfires. As a historic wildfire season, the financial impact of the wildfires in 2017 will be long-term and affect many sectors of the economy. According to California's Insurance Commissioner, insurance claims for damaged homes and properties was nearing $12 billion by January 2018.[117] Altogether, state and federal suppression costs totaled nearly $1.8 billion.[118] Other preliminary projections suggested the short- and long-term costs from the wildfires will exceed $100 billion.[119]

The staggering costs and devastation of California's 2017 wildfire season are an ominous prelude to what may become standard wildfire conditions. With projected climatic trends and ongoing population growth, California demonstrates a new reality for many places with wildfire risk. The need to rebuild entire communities puts the state in the unique position to consider wildfire risk as part of its planning and recovery efforts. The scale of devastation in California also demonstrates how land use planning must work alongside other risk reduction strategies, and that there is no single approach to alleviate the threat and costs of wildfire.

Conclusion

Wildfires can have significant social, economic, and environmental implications that extend well beyond initial suppression costs. Identifying the broad spectrum of these outcomes, and who pays for them, illustrates the full reach of wildfire devastation.

Our analysis aligns with existing literature and suggests suppression costs comprise around nine percent of total wildfire costs. The remaining costs include short-term expenses, or those costs occurring within the first six months—and long-term damages accruing during many months and years following a wildfire.

Almost half of all wildfire costs are paid for at the local level, including homeowners, businesses, and government agencies. Many local wildfire costs are due to long-term damages to community and environmental services, such as landscape rehabilitation, lost business and tax revenues, and property and infrastructure repairs.

Communities at risk to wildfires can reduce wildfire impacts and associated costs through land use planning. Land use planning is complementary to other wildfire mitigation strategies to reduce wildfire risks and costs. Examples of land use planning tools to reduce wildfire risk include regulations requiring homes located in high-risk areas to be constructed using fire-resistant building materials or incentives for directing new development away from wildfire-prone areas.

ENDNOTES

[1] Combrink, T., Cothran, C., Fox, W., Peterson, J., and Snider, G. 2013. *A Full Cost Accounting of the 2010 Schultz Fire.* Northern Arizona University Ecological Restoration Institute. Available online: http://www.idahoforests.org/img/pdf/FullCostAccounting2010SchultzFire.pdf
[2] Dale, L. 2009. *The True Cost of Wildfire in the Western U.S.* Western Forestry Leadership Coalition. Available online: https://www.blm.gov/or/districts/roseburg/plans/collab_forestry/files/TrueCostOfWilfire.pdf
[3] Zybach, B., Dubrasich, M., Brenner, G., and Marker, J. 2009. U.S. Wildfire Cost-Plus-Loss Economics Project: The "One-Pager" Checklist. *Advances in Fire Practice*. Available online: https://www.wildfirelessons.net/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=9f94b4ed-d5f2-45b8-b198-5677d430e3ae
[4] Dale, L. 2009. *The True Cost of Wildfire in the Western U.S.* Western Forestry Leadership Coalition. Available online: https://www.blm.gov/or/districts/roseburg/plans/collab_forestry/files/TrueCostOfWilfire.pdf
[5] Combrink, T., Cothran, C., Fox, W., Peterson, J., and Snider, G. 2013. *A Full Cost Accounting of the 2010 Schultz Fire.* Northern Arizona University Ecological Restoration Institute. Available online: http://www.idahoforests.org/img/pdf/FullCostAccounting2010SchultzFire.pdf
[6] Zybach, B., Dubrasich, M., Brenner, G., and Marker, J. 2009. U.S. Wildfire Cost-Plus-Loss Economics Project: The "One-Pager" Checklist. *Advances in Fire Practice*. Available online: https://www.wildfirelessons.net/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=9f94b4ed-d5f2-45b8-b198-5677d430e3ae
[7] Thomas, D., Butry, D., Gilbert, S., Webb, D., and Fung, J. 2017. *The Costs and Losses of Wildfires: A Literature Survey*. National Institute of Standards and Technology. Special Publication 1215. Available online: http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1215.pdf
[8] Davis, E. Mosely, C., Nielsen-Pincus, M., and Jakes, P. 2014. The Community Economic Impacts of Large Wildfires: A Case Study from Trinity County, California. *Society and Natural Resources 27*: 983-993. Available online: https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1054&context=esm_fac
[9] Dale, L. 2009. *The True Cost of Wildfire in the Western U.S.* Western Forestry Leadership Coalition (WFLC). Available online: https://www.blm.gov/or/districts/roseburg/plans/collab_forestry/files/TrueCostOfWilfire.pdf
[10] Davis, E. Mosely, C., Nielsen-Pincus, M., and Jakes, P. 2014. The Community Economic Impacts of Large Wildfires: A Case Study from Trinity County, California. *Society and Natural Resources 27*: 983-993. Available online: https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1054&context=esm_fac
[11] Zybach, B., Dubrasich, M., Brenner, G., and Marker, J. 2009. U.S. Wildfire Cost-Plus-Loss Economics Project: The "One-Pager" Checklist. *Advances in Fire Practice*. Available online: https://www.wildfirelessons.net/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=9f94b4ed-d5f2-45b8-b198-5677d430e3ae.
[12] Kent, B., Gebert, K., McCaffrey, S., Martin, W., Calkin, D., Schuster, E., Martin, I., Bender, Holly, Alward, G., Kumagai, Y., Cohn, Patricia, Carroll, M., Williams, D., and Ekarius, C. 2003. *Social and Economic Issues of the Hayman Fire*. USDA Forest Service General Technical Report. RMRS-GTR-114. Available online: https://www.fs.usda.gov/treesearch/pubs/14904
[13] Dale, L. 2009. *The True Cost of Wildfire in the Western U.S.* Western Forestry Leadership Coalition (WFLC). Available online: https://www.blm.gov/or/districts/roseburg/plans/collab_forestry/files/TrueCostOfWilfire.pdf
[14] Ibid.
[15] Howard, P. 2014. *Flammable Planet: Wildfires and the Social Cost of Carbon*. Cost of Carbon Project. Available online: http://costofcarbon.org/reports/entry/flammable-planet-wildfires-and-the-social-cost-of-carbon.
[16] Zybach, B., Dubrasich, M., Brenner, G., and Marker, J. 2009. U.S. Wildfire Cost-Plus-Loss Economics Project: The "One-Pager" Checklist. *Advances in Fire Practice*. Available online: https://www.wildfirelessons.net/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=9f94b4ed-d5f2-45b8-b198-5677d430e3ae.
[17] Dale, L. 2009. *The True Cost of Wildfire in the Western U.S.* Western Forestry Leadership Coalition (WFLC). Available online: https://www.blm.gov/or/districts/roseburg/plans/collab_forestry/files/TrueCostOfWilfire.pdf

[18] Zybach, B., Dubrasich, M., Brenner, G., and Marker, J. 2009. U.S. Wildfire Cost-Plus-Loss Economics Project: The "One-Pager" Checklist. *Advances in Fire Practice*. Available online: https://www.wildfirelessons.net/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=9f94b4ed-d5f2-45b8-b198-5677d430e3ae.

[19] Graham, Russell T., Technical Editor. 2003. *Hayman Fire Case Study*. Gen. Tech. Rep. RMRSGTR-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 396 p. Available online: https://www.fs.usda.gov/treesearch/pubs/5587

[20] Kent B, Gebert K, McCaffrey S, Martin W, Calkin D, Schuster E, Martin I, Bender HW, Alward G, Kumagai Y, Cohn PJ, Carroll M, Williams D, and Ekarius C. 2003. Social and Economic Issues of the Hayman Fire. *In* Graham RT, ed. 2003. *Hayman Fire Case Study*. Gen. Tech. Rep. RMRS-GTR-114. Ogden, UT: USDA Forest Service Rocky Mountain Research Station. Available online: https://www.fs.fed.us/rm/pubs/rmrs_gtr114/rmrs_gtr114_315_395

[21] Lynch DL. 2004. What Do Forest Fires Really Cost? Journal of Forestry 102(6): 42-49. (The author served as a reviewer on the socioeconomic chapter of the report referenced above. His paper draws heavily from that report.)

[22] Ibid.

[23] Ibid.

[24] Dunn, A. 2005. *The Old, Grand Prix, and Padua Wildfires: How Much did these Fires Really Cost? A Preliminary Report on Expenditures and Discussion of Economic Costs Resulting from the 2003 Old, Grand Prix, and Padua Wildfire Complex.* US Forest Service. San Bernardino National Forest. Available online: http://www.wildfire-economics.org/Library/Dunn_et_al_2005.pdf

[25] Ibid.; InciWeb: Incident Information Systems. Accessed on Aug. 21, 2017. Available online: http://www.incidentcontrol.com/oldfire/

[26] Dunn, A. 2005. *The Old, Grand Prix, and Padua Wildfires: How Much did these Fires Really Cost? A Preliminary Report on Expenditures and Discussion of Economic Costs Resulting from the 2003 Old, Grand Prix, and Padua Wildfire Complex.* US Forest Service. San Bernardino National Forest. Available online: http://www.wildfire-economics.org/Library/Dunn_et_al_2005.pdf

[27] Koestner K, Youberg A, and Neary DG. 2011. Field Trip Guide to the 2010 Shultz Fire Burn Area. Flagstaff, AZ: Arizona Hydrological Society. Available online: https://www.fs.fed.us/rm/pubs_other/rmrs_2011_koestner_k001.pdf

[28] Ibid.

[29] Combrink, T., Cothran, C., Fox, W., Peterson, J., and Snider, G. 2013. *A Full Cost Accounting of the 2010 Schultz Fire*. Northern Arizona University Ecological Restoration Institute. Available online: http://www.idahoforests.org/img/pdf/FullCostAccounting2010SchultzFire.pdf

[30] Ibid.

[31] Batker, D., Christin, Z., Schmidt, R., and de la Torre, I. 2013. *Preliminary Assessment: The Economic Impact of the 2013 Rim Fire on Natural Lands*. Earth Economics. Tacoma, WA. Available online: https://www.energyenvironmentallaw.com/files/2014/01/Earth-Economics-Rim-Fire-Report-11.27.20131.pdf

[32] Ibid.

[33] InciWeb Incident Information System. Available online: https://inciweb.nwcg.gov/incident/3660/

[34] Sierra Nevada Conservancy. *The Rim Fire: Why investing in forest health equals investing in the health of California.* Auburn, CA: State of California. Available online: http://www.sierranevada.ca.gov/factsheets/10.31rimfirefactsheet.pdf

[35] State of California. 2016. *Loma Fire: Watershed Emergency Response Team Final Report.* Pub. No. CA-SCU-006912. Available online: http://www.fire.ca.gov/communications/downloads/Watershed_reports/20161026_LomaWERT_FINAL.pdf

[36] Christin, Z., Mojica, J., Cousins, K., and Chadsey, M. 2017. *The Economic Impact of the 2016 Loma Fire. Earth Economics*. Tacoma, WA. Available online: https://www.openspaceauthority.org/system/documents/The%20Economic%20Impact%20of%20the%202016%20Loma%20Fire%20FINAL%2020170505_2.pdf

[37] Davis, E. Mosely, C., Nielsen-Pincus, M., and Jakes, P. 2014. The Community Economic Impacts of Large Wildfires: A Case Study from Trinity County, California. *Society and Natural Resources 27*: 983-993. Available online: https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1054&context=esm_fac; Gebert, K., Calkin, D., and Yoder, J. 2006. Estimating suppression expenditures for individual large wildland fires. *Western Journal of Applied Forestry*. *22*(3): 188-196. Available online: https://www.fs.usda.gov/treesearch/pubs/27726

[38] Dunn, A. 2005. *The Old, Grand Prix, and Padua Wildfires: How Much did these Fires Really Cost? A Preliminary Report on Expenditures and Discussion of Economic Costs Resulting from the 2003 Old, Grand Prix, and Padua Wildfire Complex.* US Forest Service. San Bernardino National Forest. Available online: http://www.wildfire-economics.org/Library/Dunn_et_al_2005.pdf
[39] InciWeb: Incident Information Systems. Accessed on Aug. 21, 2017. Available online: https://inciweb.nwcg.gov/incident/2069/
[40] U.S. Department of Interior. Bureau of Reclamation. 2013. *Summary Report: Santa Ana Watershed Basin Study*. Available online: https://www.usbr.gov/lc/socal/basinstudies/OWOWReferences/FinalReport/Summary%20Report.pdf
[41] Santa Ana Watershed Project Authority. 2003. *Old, Grand Prix, and Padua Fires (October 2003) Burn Impacts to Water Systems and Resources.* Available online: http://www.sawpa.org/wp-content/uploads/2013/10/2003-12-05-complete-report.pdf; Dunn, A. 2005. *The Old, Grand Prix, and Padua Wildfires: How Much did these Fires Really Cost? A Preliminary Report on Expenditures and Discussion of Economic Costs Resulting from the 2003 Old, Grand Prix, and Padua Wildfire Complex.* US Forest Service. San Bernardino National Forest. Available online: http://www.wildfire-economics.org/Library/Dunn_et_al_2005.pdf
[42] Dale, L. 2009. *The True Cost of Wildfire in the Western U.S.* Western Forestry Leadership Coalition (WFLC). Available online: https://www.blm.gov/or/districts/roseburg/plans/collab_forestry/files/TrueCostOfWilfire.pdf
[43] Combrink, T., Cothran, C., Fox, W., Peterson, J., and Snider, G. 2013. *A Full Cost Accounting of the 2010 Schultz Fire*. Northern Arizona University Ecological Restoration Institute. Available online: http://www.idahoforests.org/img/pdf/FullCostAccounting2010SchultzFire.pdf
[44] Dunn, A. 2005. *The Old, Grand Prix, and Padua Wildfires: How Much did these Fires Really Cost? A Preliminary Report on Expenditures and Discussion of Economic Costs Resulting from the 2003 Old, Grand Prix, and Padua Wildfire Complex.* US Forest Service. San Bernardino National Forest. Available online: http://www.wildfire-economics.org/Library/Dunn_et_al_2005.pdf
[45] Graham, Russell T., Technical Editor. 2003. *Hayman Fire Case Study*. Gen. Tech. Rep. RMRSGTR-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 396 p. Available online: https://www.fs.usda.gov/treesearch/pubs/5587
[46] Combrink, T., Cothran, C., Fox, W., Peterson, J., and Snider, G. 2013. *A Full Cost Accounting of the 2010 Schultz Fire*. Northern Arizona University Ecological Restoration Institute. Available online: http://www.idahoforests.org/img/pdf/FullCostAccounting2010SchultzFire.pdf
[47] Ibid.
[48] Youberg, A. *Wildfire, rain and floods: A case study of the June 2010 Schultz wildfire, Flagstaff, Arizona*. Arizona Geology. Arizona Geological Society. Available online: http://www.azgs.az.gov/arizona_geology/winter10/article_feature.html
[49] Ibid.
[50] Dunn, A. 2005. *The Old, Grand Prix, and Padua Wildfires: How Much did these Fires Really Cost? A Preliminary Report on Expenditures and Discussion of Economic Costs Resulting from the 2003 Old, Grand Prix, and Padua Wildfire Complex*. US Forest Service. San Bernardino National Forest. Available online: http://www.wildfire-economics.org/Library/Dunn_et_al_2005.pdf
[51] Batker, D., Christin, Z., Schmidt, R., and de la Torre, I. 2013. *Preliminary Assessment: The Economic Impact of the 2013 Rim Fire on Natural Lands*. Earth Economics. Tacoma, WA. Available online: https://www.energyenvironmentallaw.com/files/2014/01/Earth-Economics-Rim-Fire-Report-11.27.20131.pdf
[52] Christin, Z., Mojica, J., Cousins, K., and Chadsey, M. 2017. *The Economic Impact of the 2016 Loma Fire. Earth Economics*. Tacoma, WA. Available online: https://www.openspaceauthority.org/system/documents/The%20Economic%20Impact%20of%20the%202016%20Loma%20Fire%20FINAL%2020170505_2.pdf
[53] Loomis, J. 2004. Do nearby forest fires cause a reduction in residential property values?" *Journal of Forest Economics 10*(30): 149-57. Available online: https://www.sciencedirect.com/science/article/pii/S1104689904000340; Stetler, K., Venn, T., and Calkin, D. 2010. The effects of wildfire and environmental amenities on property values in northwest Montana, USA. *Ecological Economics 69*(11): 2233-2243. Available online: https://www.fs.usda.gov/treesearch/pubs/37469
[54] Donovan, G, Champ, P., and Butry, D. 2007. Wildfire risk and housing prices: A case study from Colorado Springs. *Land Economics 83*(2): 217-233. Available online: https://www.fs.fed.us/rm/value/docs/wildfire-risk-housing-prices-colorado-springs.pdf
[55] Dunn, A. 2005. *The Old, Grand Prix, and Padua Wildfires: How Much did these Fires Really Cost? A Preliminary Report on Expenditures and Discussion of Economic Costs Resulting from the 2003 Old, Grand Prix,*

and Padua Wildfire Complex. US Forest Service. San Bernardino National Forest. Available online: http://www.wildfire-economics.org/Library/Dunn_et_al_2005.pdf

[56] Christin, Z., Mojica, J., Cousins, K., and Chadsey, M. 2017. *The Economic Impact of the 2016 Loma Fire. Earth Economics*. Tacoma, WA. Available online: https://www.openspaceauthority.org/system/documents/The%20Economic%20Impact%20of%20the%202016%20Loma%20Fire%20FINAL%2020170505_2.pdf; Tostado, M., 2016. Santa Clara County: PG&E Crews Restore Power after Wildfire Damages Power Lines and Poles. *Currents*. URL: http://www.pgecurrents.com/2016/10/07/santa-clara-county-pge-crews-restore-power-after-wildfiredamages-power-lines-and-poles/

[57] Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Synthesis*. Island Press. Washington, D.C. Available online: https://www.millenniumassessment.org/documents/document.356.aspx.pdf

[58] Boyd, J., Ringold, P., Krupnick, A., Johnston, R., Weber, M., and Hall, K. 2015. *Ecosystem services indicators: Improving the linkage between biophysical and economic analyses.* Discussion Paper, RFF DP 15-40. Resources for the Future. Available online: http://www.rff.org/files/document/file/RFF-DP-15-40.pdf

[59] Everard, M. 2017. *Ecosystem Services: Key Issues*. Routledge. Milton Park, Abingdon, Oxon.

[60] Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Synthesis*. Island Press. Washington, D.C. Available online: https://www.millenniumassessment.org/documents/document.356.aspx.pdf

[61] Christin, Z., Mojica, J., Cousins, K., and Chadsey, M. 2017. The Economic Impact of the 2016 Loma Fire. Earth Economics. Tacoma, WA. Available online: https://www.openspaceauthority.org/system/documents/The%20Economic%20Impact%20of%20the%202016%20Loma%20Fire%20FINAL%2020170505_2.pdf;

[62] Batker, D., Christin, Z., Schmidt, R., and de la Torre, I. 2013. *Preliminary Assessment: The Economic Impact of the 2013 Rim Fire on Natural Lands*. Earth Economics. Tacoma, WA. Available online: https://www.energyenvironmentallaw.com/files/2014/01/Earth-Economics-Rim-Fire-Report-11.27.20131.pdf

[63]Christin, Z., Mojica, J., Cousins, K., and Chadsey, M. 2017. The Economic Impact of the 2016 Loma Fire. Earth Economics. Tacoma, WA. Available online: https://www.openspaceauthority.org/system/documents/The%20Economic%20Impact%20of%20the%202016%20Loma%20Fire%20FINAL%2020170505_2.pdf; California Environmental Protection Agency. 2016. California Cap-and-Trade Program. Summary Results. Available online: https://www.arb.ca.gov/cc/capandtrade/capandtrade.htm

[64] Combrink, T., Cothran, C., Fox, W., Peterson, J., and Snider, G. 2013. *A Full Cost Accounting of the 2010 Schultz Fire*. Northern Arizona University Ecological Restoration Institute. Available online: http://www.idahoforests.org/img/pdf/FullCostAccounting2010SchultzFire.pdf

[65] Butry, D., Mercer, D., Prestemon, J., Pye, J., and Holmes, T. 2001. What is the price of catastrophic wildfire? *Journal of Forestry 99*(11): 9-17. Available online: https://www.researchgate.net/profile/Jeffrey_Prestemon/publication/233578214_What_Is_the_Price_of_Catastrophic_Wildfire/links/0c9605304e984e7a6d000000.pdf

[66] Graham, Russell T., Technical Editor. 2003. Hayman Fire Case Study. Gen. Tech. Rep. RMRSGTR-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 396 p. Available online: https://www.fs.usda.gov/treesearch/pubs/5587

[67] Ibid.

[68] Ibid; McCrimmon, Katie K. 2002. Politics on front line at fires. Rocky Mountain News. [Denver, CO], June 15.

[69] Santa Ana Watershed Project Authority. 2003. *Old, Grand Prix, and Padua Fires (October 2003) Burn Impacts to Water Systems and Resources*. Available online: http://www.sawpa.org/wp-content/uploads/2013/10/2003-12-05-complete-report.pdf

[70] Dunn, A. 2005. *The Old, Grand Prix, and Padua Wildfires: How Much did these Fires Really Cost? A Preliminary Report on Expenditures and Discussion of Economic Costs Resulting from the 2003 Old, Grand Prix, and Padua Wildfire Complex*. US Forest Service. San Bernardino National Forest. Available online: http://www.wildfire-economics.org/Library/Dunn_et_al_2005.pdf

[71] Lynch, D. 2004. What do forest fires really cost? *Journal of Forestry 102*(6): 42-49. Available online: https://academic.oup.com/jof/article/102/6/42/4613189

[72] Lucas, A. M., 2015. *Flagstaff Watershed Protection Project: Creating Solutions through Community Partnerships*. Northern University Ecological Restoration Institute. September 2015. Available online: https://www.flagstaffwatershedprotection.org/wp-content/uploads/2015/11/FWPP-Creating-Solutions-Through-Community-Partnerships.pdf

[73] EPA website: https://www.epa.gov/environmental-economics/mortality-risk-valuation

[74] Viscusi, W.K. and Aldy, J. 2002. *The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World*. Discussion Paper No. 392. Harvard Law School. Available online: http://lsr.nellco.org/cgi/viewcontent.cgi?article=1180&context=harvard_olin
[75] Ibid.
[76] Ibid.
[77] US Department of Transportation. 2016. *Revised Departmental Guidelines 2016: Treatment of the value of preventing fatalities and injuries in preparing economic analyses*. Available online: https://cms.dot.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20a%20Statistical%20Life%20Guidance.pdf; EPA Website: https://www.epa.gov/environmental-economics/mortality-risk-valuation
[78] Healy, J. 2013. "Firefighters' Survivor Benefits Value Some Lives Over Others" *New York Times.* Available online: http://www.nytimes.com/2013/08/19/us/for-families-of-dead-firefighters-a-fight-over-compensation.html
[79] Lynch, D. 2004. What do forest fires really cost? *Journal of Forestry 102*(6): 42-49. Available online: https://academic.oup.com/jof/article/102/6/42/4613189
[80] Ibid.
[81] Combrink, T., Cothran, C., Fox, W., Peterson, J., and Snider, G. 2013. *A Full Cost Accounting of the 2010 Schultz Fire*. Northern Arizona University Ecological Restoration Institute. Available online: http://www.idahoforests.org/img/pdf/FullCostAccounting2010SchultzFire.pdf
[82] Romero, C.J. 1986. The Economics of Volunteerism: A Review. *Productive Roles in an Older Society*. National Academies Press. Washington DC.
[83] Combrink, T., Cothran, C., Fox, W., Peterson, J., and Snider, G. 2013. *A Full Cost Accounting of the 2010 Schultz Fire*. Northern Arizona University Ecological Restoration Institute. Available online: http://www.idahoforests.org/img/pdf/FullCostAccounting2010SchultzFire.pdf
[84] Butry, D.T., Mercer, D.E., Prestemon, J.P., Pye, J.M., Holmes, T.P., 2001. What is the price of catastrophic wildfire? *Journal of Forestry 99*(11), 9–17. Available online: https://www.fs.usda.gov/treesearch/pubs/4446; Martin, W.E., Brajer, V., Zeller, K., 2007. Valuing the health effects of a prescribed fire. In: Martin, W.E., Raish, C., Kent, B. (Eds.). *Wildfire Risk: Human Perceptions and Management Implications. Resources for the Future*. Washington, DC, pp. 244–261; Moeltner, K., Kim, M.K., Zhu, E., Yang, W., 2013. Wildfire smoke and health impacts: a closer look at fire attributes and their marginal effects. *Journal of Environmental Economics and Management 66*(3): 476–496. Available online: http://dx.doi.org/10.1016/j.jeem.2013.09.004.
[85] Moore, D., Copes, R., Fisk, R., Joy, R., Chan, K., and Brauer, M. 2003. Population health effects of air quality changes due to forest fires in British Columbia in 2003. *Canadian Journal of Public Health 97*(2): 105-108. Available online: https://www.ncbi.nlm.nih.gov/pubmed/16619995
[86] Kochi, I., Champ, P., Loomis, J., and Donovan, G. 2016. Valuing morbidity effects of wildfire smoke exposure from the 2007 Southern California wildfires. *Journal of Forest Economics 25*: 29-54. Available online: https://www.sciencedirect.com/science/article/pii/S1104689916300174
[87] Community Wildfire Protection Plan. 2014. Park County, Montana. Available online: http://www.parkcounty.org/pdfs/FW/2014%20PC%20CWPP%20FINAL%20PDF.pdf
[88] Rothermel, R., Hartford, R., and Chase, C. 1994. *Fire Growth Maps for the 1988 Greater Yellowstone Area Fires*. USDA General Technical Report INT-304. Available online: https://www.fs.fed.us/rm/pubs_int/int_gtr304.pdf
[89] Polzin, P., Yuan, M., and Schuster, E. 1993. *Some Economic Impacts of the 1988 Fires in the Yellowstone Area*. USDA General Technical Report INT-418. Available online: https://ia800306.us.archive.org/17/items/someeconomicimpa418polz/someeconomicimpa418polz.pdf
[90] Rudzitis, G. 1999. Amenities Increasingly Draw People to the Rural West. *Rural Development Perspectives* 14(2): 9-13. Available online: https://www.colorado.edu/AmStudies/lewis/west/amenities.pdf; Rasker, R. and Hansen, A. 2000. Natural Amenities and Population Growth in the Greater Yellowstone Region. *Human Ecology Review* 7(2): 30-40. Available online: http://www.montana.edu/hansenlab/documents/downloadables/raskerhansen2000.PDF
[91] Gude, P., Jones, K., Rasker, R., and Greenwood, M. 2013. Evidence for the effect of homes on wildfire suppression costs. *International Journal of Wildland Fire 22*(4): 537-548. Available online: https://headwaterseconomics.org/wp-content/uploads/CAfire_Manuscript_July11.pdf
[92] Rasker, R. and Hansen, A. 2000. Natural Amenities and Population Growth in the Greater Yellowstone Region. *Human Ecology Review* 7(2): 30-40. Available online: http://www.montana.edu/hansenlab/documents/downloadables/raskerhansen2000.PDF; Gude, P.H., A.J. Hansen, R. Rasker, and B. Maxwell. 2006. Rates and Drivers of Rural Residential Development in the Greater Yellowstone. *Landscape and Urban Planning 77*(2006): 131-151. Available online: http://www.montana.edu/hansenlab/documents/downloadables/Gudeetal06.pdf

[93] Gude, P., Rasker, R., and van den Noort, J. 2008. Potential for Future Development on Fire-Prone Lands. *Journal of Forestry 106*(4): 198-205. Available online: https://www.colorado.edu/geography/class_homepages/geog_4430_f10/Gude_WUI%20development_JFor08.pdf ; U.S. Department of Commerce. 2011. TIGER/Line 2010 Census Blocks and 2010 Summary File 1, Washington, D.C.
[94] Ibid.
[95] U.S. Department of Commerce. 2016. Bureau of Economic Analysis. Regional Economic Accounts. Washington, D.C. Table CA30.
[96] U.S. Department of Commerce. 2016. Bureau of Economic Analysis. Regional Economic Accounts. Washington, D.C. Table CA05.
[97] U.S. Department of Commerce. 2016. Bureau of Economic Analysis. Regional Economic Accounts. Washington, D.C. Tables CA05, CA05N, and CA35.
[98] Community Wildfire Protection Plan. 2014. Park County, Montana. Available online: http://www.parkcounty.org/pdfs/FW/2014%20PC%20CWPP%20FINAL%20PDF.pdf; Sites, A. 2018. Wildfire statistics (name, year, acres burned, suppression costs per fire) for Park County. Gallatin-Custer National Forest Service. Personal Communications.
[99] Large-Cost Fire Independent Review Panel. 2009. Fiscal Year 2008 Large-Cost Fire Independent Review. Washington, D.C.: U.S. Secretary of Agriculture.; Buckley, M., N. Beck, P. Bowden, M. E. Miller, B. Hill, C. Luce, W. J. Elliot, N. Enstice, K. Podolak, E. Winford, S. L. Smith, M. Bokach, M. Reichert, D. Edelson, and J. Gaither. 2014. "Mokelumne watershed avoided cost analysis: Why Sierra fuel treatments make economic sense." A report prepared for the Sierra Nevada Conservancy, The Nature Conservancy, and U.S. Department of Agriculture, Forest Service. Sierra Nevada Conservancy. Auburn, California. Available online: http://www.sierranevadaconservancy.ca.gov/mokelumne.
[100] Thompson, M., Vaillant, N., Haas, J., Gebert, K., and Stockmann, K. 2013. Quantifying the potential impacts of fuel treatments on wildfire suppression costs. *Journal of Forestry 111*(1): 49-58. https://www.fs.fed.us/rm/pubs_other/rmrs_2013_thompson_m001.pdf
[101] Gebert, K.M., Calkin, D.E., and Yoder, J. 2007. Estimating suppression expenditures for individual large wildland fires. Western Journal of Applied Forestry 22(3), 188-196. Available online: https://www.fs.usda.gov/treesearch/pubs/27726
[102] Gude, P., Jones, K., Rasker, R., and Greenwood, M. 2012. "Evidence for the effect of homes on wild- fire suppression costs." International Journal of Wildland Fire. 22 (4): 537-548.
[103] Gebert, K.M., Calkin, D.E., and Yoder, J. 2007. Estimating suppression expenditures for individual large wildland fires. *Western Journal of Applied Forestry 22*(3), 188-196. Available online: https://www.fs.usda.gov/treesearch/pubs/27726
[104] Strategic Issues Panel on Fire Suppression Costs. 2004. Large Fire Suppression Costs: Strategies for Cost Management. Report for the Wildland Fire Leadership Council. Available online: https://www.fs.fed.us/fire/ibp/cost_accounting/costmanagement_aug_04.pdf
[105] Sites, A. 2018. Wildfire statistics (name, year, acres burned, suppression costs per fire) for Park County. Gallatin-Custer National Forest Service. Personal Communications.
[106] Ibid.
[107] Sage, J. and Nickerson, N. 2017. *The Montana Expression 2017: 2017's Costly Fire Season*. University of Montana. Institute for Tourism and Recreation Research. Available online: https://scholarworks.umt.edu/cgi/viewcontent.cgi?article=1364&context=itrr_pubs
[108] Haack, M. 2017. "Forest Service faces wildfire budget crisis." NBC Montana. Sept. 26, 2017. Available online: http://www.nbcmontana.com/news/keci/forest-service-faces-wildfire-budget-crisis-1/626796489
[109] Rasker, R. 2009. *Solutions to the Rising Costs of Fighting Fires in the Wildland-Urban Interface*. Headwaters Economics. Available online: https://www.google.com/url?q=https://headwaterseconomics.org/wp-content/uploads/HeadwatersFireCosts.pdf&sa=U&ved=0ahUKEwiJxdeE1JbYAhWn5oMKHbsiDEEQFggEMAA&client=internal-uds-cse&cx=007398610912929186557:6dtcogozopw&usg=AOvVaw3p45FpyVMfZ96olTZaBdO7; Radeloff, V., Helmers, D., Kramer, H., Mockrin, M., Alexandre, P., Bar-Massada, A., Butsic, V., Hawbaker, T., Martinuzzi, S., Syphard, A., and Stewart, S. 2018. Rapid growth of the US wildland-urban interface raises wildfire risk. *PNAS.* Available online: http://www.pnas.org/content/early/2018/03/06/1718850115
[110] Gude, P., Jones, K., Rasker, R., and Greenwood, M. 2013. Evidence for the effect of homes on wildfire suppression costs. *International Journal of Wildland Fire 22(4):* 537-548. Available online: http://www.publish.csiro.au/wf/WF11095

[111] Quarles, S., Valachovic, Y., Nakamura, G., Nader, G., De Lasaux, M. 2010. Home survival in wildfire-prone areas: Building materials and design considerations. *University of California Agriculture and Natural Resources*. Publication 8393. Available online: https://anrcatalog.ucanr.edu/pdf/8393.pdf

[112] Syphard, A., Massada, A., Butsic, V., and Keeley, J. 2013. Land use planning and wildfire: Development policies influence future probability of housing loss. *PLOS*. Available online: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0071708

[113] California Department of Insurance. 2017. Insured losses from October 2017 wildfires: Statewide claims. Available online: http://www.insurance.ca.gov/0400-news/0100-press-releases/2017/upload/nr135Statewideclaims.pdf

[114] Dobuzinskis, A. 2017. "Death toll from California blazes rises to 43, after teen dies." *Reuters*. October 30, 2017. Available online: https://www.reuters.com/article/us-california-fire/death-toll-from-california-blazes-rises-to-43-after-teen-dies-idUSKBN1D004Z

[115] Lada, B. 2017. "Devastating California wildfires predicted to cost US economy $85 billion; Containment may take weeks." Accuweather News. Available online: https://www.accuweather.com/en/weather-news/devastating-california-wildfires-predicted-to-cost-us-economy-85-billion-containment-may-take-weeks/70003000

[116] Chavez, N. 2017. "Thomas Fire is the largest blaze in California history." CNN News. December 23, 2017. Available online: http://www.cnn.com/2017/12/23/us/thomas-fire-california/index.html

[117] California Insurance Commissioner. 2018. "California statewide wildfire insurance claims nearly $12 billion." Press Release. January 31, 2018. Available online: https://www.insurance.ca.gov/0400-news/0100-press-releases/2018/release013-18.cfm

[118] Associated Press. 2018. "California spent nearly $1.8 billion last year fighting major wildfires." *Los Angeles Times*. March 1, 2018. Available online: http://www.latimes.com/local/lanow/la-me-wildfire-costs-20180301-story.html

[119] AccuWeather. 2017. "AccuWeather predicts 2017 California wildfire season cost to rise to $180 billion." Available online: https://www.accuweather.com/en/weather-news/accuweather-predicts-2017-california-wildfire-season-cost-to-rise-to-180-billion/70003495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