

# *Efficient and Equitable Design of Wildfire Mitigation Programs*

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## *Introduction*

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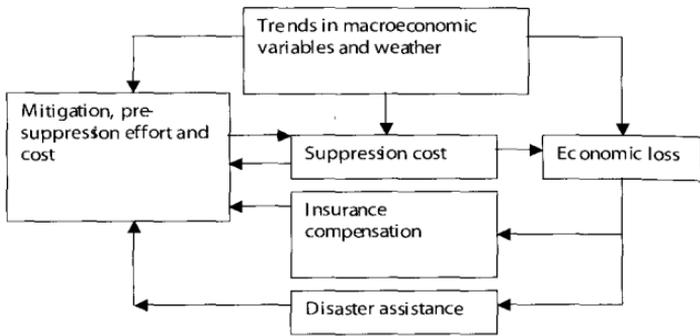
*Natural resource economists* have addressed the economic efficiency of expenditures on wildfire mitigation for nearly a century (Gorte and Gorte 1979). Beginning with the work of Sparhawk (1925), the theory of efficient wildfire mitigation developed along conceptual lines drawn from neoclassical economics. The objective of the traditional least-cost-plus-loss model is to minimize the sum of ex ante expenditures on fire prevention (pre-suppression), the costs of fire suppression, and the ex post costs of economic damages. In the closely related benefit/cost model, the objective is to maximize the sum of damages avoided (the benefits) minus pre-suppression and suppression costs. Both models assume that an increase in pre-suppression expenditures decreases suppression costs and economic damages (Figure 1).

A major obstacle impeding the empirical application of the theoretical model is that the specific functional relationship between costs and economic losses (or damages avoided) is generally unknown. This empirical problem arises because wildfires are dangerous, complex phenomena and experimental control plots, replicating the critical variables existing on burned areas, are almost never available. Thus, it has been extremely difficult to estimate what would have happened on an actual wildfire if pre-suppression and suppression expenditures had been applied at lower or higher levels. Empirical applications of the theoretical model have relied on other approaches such as simulation (Bellinger et al. 1983). Despite this limitation, the theoretical model has been extended to other problems in forest management, such as forest insect control (Herrick 1981), and theoretical refinements continue to be advocated (Donovan and Rideout 2003).

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*Figure 1. An expanded wildfire economic model for use in the wildland-urban interface.*



In this chapter, we examine a second, previously overlooked limitation with traditional microeconomic models of wildfire mitigation. This problem concerns the economic behavior of forest landowners and others living within forested areas referred to as the wildland-urban interface. Because the endpoint of the traditional economic model of wildfire mitigation is the value of timber protected (or lost), and because the frame of reference for the analysis is public forestland, the behavior of private forestland owners in response to wildfire-mitigation incentives has not been adequately addressed.

The rapid escalation of wildfire-suppression costs and financial damages over the past several years led to the National Fire Plan. The major change in federal wildland fire policy reflected in the plan was a shift from a reactive to a proactive approach that emphasizes community-based actions to reduce wildland fires (National Fire Plan 2001). Given this shift in emphasis, it is critical to understand the economic incentives faced by individuals and communities when they are asked to undertake wildfire-mitigation activities. More precisely, we argue that insurance compensation, disaster relief, and wildfire suppression reduce the incentives of homeowners to undertake individual or collective actions to mitigate wildfires (the leftward pointing arrows in Figure 1), and that the issue of who should pay for restoration of capital losses (private insurance, government-subsidized insurance, government disaster relief) does not enter the traditional model. These limitations need to be addressed.

To set the context for the remainder of the chapter, we first provide a historic overview of the development of market (insurance) and social (disaster assistance) responses to natural hazards. Next, we present evidence on the trends in costs and losses from wildfire over the past several decades. This evidence provides the motivation for the ensuing discussion of macroeconomic factors that have influenced the trends in costs and losses, as well as emerging equity impacts (who pays for economic losses). We finish with a summary of the issues and policy implications.

## *Development of Social and Market Responses to Natural Hazards*

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Since antiquity, humans have responded to natural hazards by creating cooperative arrangements to buffer themselves from losses (Kates 1971, McCall 1987). Oliver-Smith (1996) describes how people living in pre-industrial society adapted their behavior to natural disturbance patterns and developed social structures that increased their probability of survival. For example, traditional pastoralists in Africa made rational adaptations to cyclical droughts by creating “protective” social groups, engaging in livestock transfers with members of their group, and migrating with their herds (McCabe 1988). The transfer of livestock from members of the group with abundant cattle to those suffering livestock losses represents a primitive form of social insurance.

Formal markets for property insurance developed after the Great Fire of London in 1666, which destroyed about 80% of the city (Kovacs 2001). Property insurance works by creating a pool of contributions, known as “premiums,” from members, who can be compensated for contracted losses by the funds collected. This scheme works best where risks are randomly and independently distributed across members of the pool, and where annual losses to individual members are large relative to their assets, but collective losses are small relative to the size of the pool. The law of large numbers guarantees that the annual variation in average losses will decrease as the number of members of the pool increases, thus providing the insurance company with considerable control over annual payouts. Insurers realized from the Great Fire of London that contagion posed a threat to the insurability conditions, and thus required implementation of risk-reduction measures, such as improved building codes and close proximity to a fire brigade, in order to join the pool (Pyne 2001).

Natural catastrophes such as hurricanes, floods, and earthquakes have historically caused problems for the insurance industry because these events damage many or most properties within a geographical area. If risks are spatially correlated, insurance companies need to raise market rates above those that are actuarially fair in order to cover the “social risk” (Hirshleifer and Riley 1979). Under these conditions, consumers may decide not to purchase insurance because of budget constraints or the belief that “it can’t happen to me” (Palm 2003). Where coverage is less than complete, some people remain financially exposed to natural disasters.

Because insurance coverage for natural hazards in the U.S. is less than complete, the federal government has stepped in to provide disaster relief. Although Congress passed the first piece of disaster legislation in

1803, comprehensive (as distinct from disaster-specific) legislation was not forthcoming until the Disaster Relief Act of 1950. During the past half-century, public attitudes toward natural disasters have shifted from fatalistic—disasters are a part of nature that is accepted as part of life—to viewing disaster assistance as an entitlement (Barnett 1999). This change is evidenced by the fact that the federal government provided only 1% of disaster relief in 1953 but more than 70% by the mid-1970s (Clary 1985).

In a bad wildfire year, the need for federal disaster assistance can be great. The California wildfires of 2003 burned over 750,000 acres and destroyed over 3,600 homes. Insured losses from these wildfires were close to \$2 billion (Insurance Information Institute 2005). Because the demand for recovery funds was not completely met by private insurance, the federal government also provided over \$483 million in disaster assistance, an amount equal to roughly 25% of the insured losses (California Fires Coordination Group 2004). Most of this federal relief was in the form of low-interest loans that the Small Business Administration provided.<sup>1</sup>

An increased level of concern with the escalation in federal disaster assistance has caused policymakers to emphasize the linkage between ex post disaster assistance and ex ante community mitigation activities. This shift in policy is characterized by the provisions of the National Flood Insurance Act of 1968, which requires residents of special flood-hazard areas to purchase flood insurance if financing for the property comes from a federal loan or grant or if funds come from an institution that is insured by the federal government (Palm 2003). Provision of flood insurance by the federal government is contingent upon communities undertaking actions that will mitigate potential flood damages.

Rising financial costs of climate- and weather-related disasters have caused unprecedented insurance industry losses and calls for a greater federal role in financing catastrophic relief (Nutter 2002). Insurance companies protect themselves from catastrophic losses, to some degree, by purchasing insurance from re-insurance companies. The re-insurance market attempts to diversify risks from natural catastrophes by pooling risks over large geographic areas, often including international markets. But the potential losses from natural hazards are often so large that the private sector, even supported by the re-insurance industry, has not been willing to shoulder the entire burden. Hence, government-led quasi-private insurance strategies have emerged as stop-gap measures, at the state and federal levels. Some states have created re-insurance pools for hurricane damage (“wind pools”) that help keep rates lower in the private market. Another strategy is for states to create residual markets for homeowners in hurricane- or earthquake-prone locations who cannot obtain coverage in voluntary markets (Nutter 2002).

Floods cause more damage than any other natural hazard in the U.S. and account for the highest levels of federal disaster assistance in most years (Palm 2003). Within the market for private insurance, most insured losses from natural disasters result from hurricanes (33% of total), tornadoes (32% of total), and earthquakes (13%) (Insurance Information Institute 2005). Wildfires have only accounted for about 3% of total insured losses from natural hazards in the United States. Although typical homeowner fire-insurance policies cover losses from wildfires, concern over the rapid rise in insured losses due to wildfires has caused the insurance industry to require wildfire-mitigation activities as a precondition for insurance policies in some regions in California and the Southwest that are at especially high risk of wildfire losses.

### *Trends in Costs and Losses from Wildfires*

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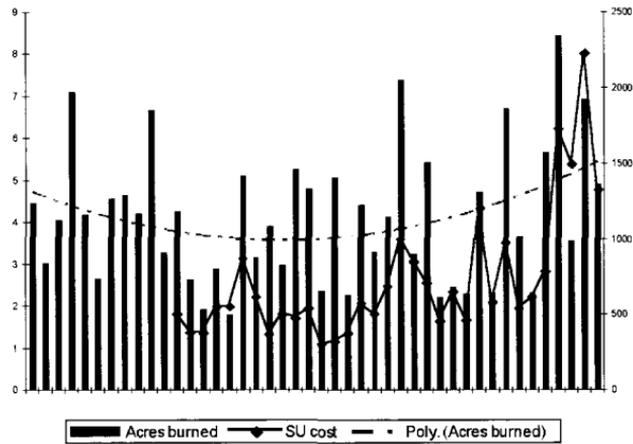
*Wildfire data obtained* from the National Interagency Fire Center (2004) were plotted and a polynomial trend was fitted to the data (Figure 2). The data reveal an increasing trend in total acres burned by wildfire from 1980 to 2003. This rise follows a decreasing trend in total acres burned from 1960 to roughly 1980. The pattern has been partially attributed to a warming trend in the western U.S., causing the snowpack to melt earlier in the spring, and resulting in more severe drought conditions over much of the summer. Continued drought conditions in the western U.S. are anticipated for the foreseeable future (Strategic Issues Panel on Fire Suppression Costs 2004).

The upswing in the number of acres burned by wildfires is reflected in the trend in federal wildfire-suppression cost, adjusted for inflation (SU cost, Figure 2), particularly since 1982. In 1988, wildfire-suppression costs in the U.S. exceeded \$1 billion for the first time. Since the year 2000, the billion-dollar level has been exceeded each year.

Although reliable information on the total financial damages from natural hazards is difficult to obtain, data are available on insured losses (Insurance Information Institute 2005). During the 1970s and 1980s, insured losses from catastrophic wildfires rarely exceeded \$100 million (Table 1). However, the 1991 wildfires in Oakland Hills, California, destroyed nearly 3,200 homes (California Fires Coordination Group 2004) and caused about \$2.3 billion in insured losses. This was the twentieth-most-costly insured loss ever recorded worldwide (Swiss Re 2004).

Since the 1970s and 1980s, insured losses from wildfires have dramatically increased and most catastrophic wildfires occurred in southern California, an area experiencing rapid population growth and escalating property values. This period of escalation in insured losses coincides with the period

*Figure 2. U.S. wildfire history and federal wildfire suppression costs. Sources: NIFC 2004 and Strategic Issues Panel on Fire Suppression Costs 2004.*



of escalation in wildfire-suppression expenditures, providing evidence that overall economic costs (the sum of costs plus losses) are also increasing.

### *Factors Influencing Increased Costs and Losses from Natural Disasters*

We identify several micro- and macroeconomic factors that have contributed to the escalation in costs and losses resulting from natural hazards, including wildfires. Emerging trends in macroeconomic variables (migration, wealth, income, and housing prices) have been compounded by underlying microeconomic behaviors that reflect the incentives that people face when making risk-mitigation decisions. On the other hand, providing timely, believable information about natural-hazard risk helps individuals make rational economic decisions that reduce values at risk. We discuss each of these factors in turn.

#### *Migration*

The escalation in insured losses from natural events might suggest that the natural world is becoming increasingly violent. However, Changnon (2003) shows that the increasing trend of insured losses from catastrophic weather events disappears when loss data are adjusted for population levels and inflation. This leads him to conclude that “Human actions have in many ways caused the economic and environmental losses from natural disasters to become greater than years ago” (p. 287). If more people are migrating to areas that are at risk of natural disasters, such as hurricanes, earthquakes, and wildfires, and if these people are transferring and creating more wealth in these areas, then we would expect that economic losses would likewise increase, even if the rate of natural disasters is constant.

Table 1. Insured losses from catastrophic wildfires in the U.S., 1970-2003.

<i>Year</i>	<i>Location</i>	<i>Insured losses (\$millions 2003)</i>
2003	San Diego and San Bernardino Counties, CA	2,035
2002	Rodeo-Chediski Complex, AZ	123
2000	Cerro Grande, NM	150
1993	Los Angeles and Orange Counties, CA	923
1991	Oakland and Alameda Counties, CA	2,297
1990	Santa Barbara County, CA	373
1985	Florida	56
1982	Los Angeles, Ventura, and Orange Counties, CA	31
1980	Several Counties, Southern CA	132
1979	Hollywood Hills, CA	13
1978	Los Angeles and Ventura Counties, CA	42
1977	Santa Barbara, Montecito, CA	61
1970	Oakland-Berkley Hills, CA	118

Source: Insurance Information Institute 2005

Of particular relevance in the overall trend in losses due to natural disasters has been the migration to coastal areas, particularly in the southern and southeastern states, which are particularly prone to hurricanes. The National Oceanic and Atmospheric Administration reports that U.S. coastal areas experienced a population increase of 41% from 1960 to 1990, demonstrating a growth rate 3% higher than the nation as a whole (Ross & Lott 2003; U.S. Census Bureau 2004a)<sup>3</sup>. In total, 53% of the national population resides in coastal counties that account for 17% of the U.S. landmass (National Oceanic and Atmospheric Administration 1998).

Migration trends also appear to influence the escalation of economic costs and losses attributable to wildfires. Recent studies have shown that rural population growth in the U.S. has largely resulted from the attractiveness of natural environments, including forested areas (Deller et al. 2001; English et al. 2000). Johnson and Beale (1994) reported that, during the 1990s, the fastest-growing counties in the United States were nonmetropolitan counties that were destinations for retirement-age migrants or were outdoor-recreation centers.

### *Housing prices*

A second factor contributing to the escalation in costs and losses attributable to natural hazards is the trend in housing prices. A rise in the general price level over time—inflation—increases the price of vulnerable human capital as the value of all goods and services rises. For example, from 1960 to 2000 the general price level rose by 482% (U.S. Department of Commerce 2002)<sup>4</sup>.

Housing price inflation may be particularly acute in locations with favorable environmental amenities. English et al. (2000) found in a study of 1990 house values that the average house was worth nearly \$13,000 more in tourism-dependent counties than in non-tourism counties. The scarcity of real property can result in higher at-risk values, as the price for land and housing is bid up in areas with desirable natural amenities. In most areas, the supply of available private land is nearly fixed, constrained by physical features and jurisdictional rules. Against a nearly fixed supply, rising demand due to increases in real wealth per capita and population create rapid property-value increases. Relatively rapid population growth in wildland-urban interface areas with attractive natural amenities combined with an increase in the real value of housing stock might reasonably explain much of the trend in increasing losses from wildfires.

### *Wealth and income*

Wealth represents the accumulation of capital over time. Household wealth is created by savings from personal income after consumption expenditures and tax payments have been deducted. During the twentieth century, the household savings rate in the U.S. has been relatively stable at approximately 15-20% of disposable personal income, and the proportion of disposable personal income that is saved for retirement ("life-cycle saving") nearly tripled over the same period (Lee 2001). Investments in real estate are an important type of wealth accumulation and, during the period from 1945 to 1990, real-estate investments averaged about 4.4% per annum of disposable personal income (more than double the rate for the period 1897-1929) (Lee 2001). In the U.S., per capita incomes, adjusted for inflation, rose by 148% between 1960 and 2000 (U.S. Census Bureau 2004a, 2004b; U.S. Department of Commerce 2003). Thus, income growth and the accumulation of wealth through investment in real estate have placed an increasing amount of capital at risk of loss from natural hazards. This problem may be particularly acute for retirees who have migrated to the wildland-urban interface and invested life-cycle savings in real estate.

Although the overall trend in wealth has been upward in the U.S., over the past two decades income inequality has been increasing as well (Aghion et al. 1999). Chevan and Stokes (2000) argue that this trend may be due in part to the "McDonald's effect," whereby unionized, highly paid blue-collar jobs have been replaced by non-unionized lower-paying service jobs. Income inequality may be important in tourism-dependent communities within the wildland-urban interface because the tourism sector is dependent on service jobs. Although population growth has been rapid in tourism-dependent communities (Johnson and Beale 1994), income inequality in

such communities may create different economic stresses for people within different economic strata.

Natural disasters may also create poverty traps. Although the linkages between poverty and natural disasters have been discussed primarily in the context of low-income countries (e.g., Morduch 1994), Fothergill and Peek (2004) have argued that even in the U.S. the poor are more vulnerable to natural catastrophes because of where they live and their poorer quality of housing. Thus, natural disasters may be among the factors that prevent people living in poverty from bettering their lives economically. Because people living below or near the poverty line, who rent or own poor-quality housing, are less able to afford investments in mitigation or insurance, they rely more heavily on governmental compensation when a disaster strikes. Thus, increasing income inequality could lead to increased recovery costs.

### *Moral hazard*

If we wish to understand the economic rationality of actions that people take to protect themselves and their property from natural hazards, we must consider the full range of incentives and opportunities faced by property owners. The transfer of risk from the individual to the principal (i.e., insurance company) via insurance affects the incentives faced by the individual (McCall 1987). The major factor linking protective actions of individuals to private insurance is known as “moral hazard.” If individuals who purchase private insurance contracts are not inclined to undertake protective measures that would reduce either the probability of loss (self-protection) or the magnitude of loss if it did occur (self-insurance), and if insurance companies cannot perfectly monitor the actions of the policyholder, a moral hazard is created for the insurance company (Kotowitz 1987). Viewed the other way around, if insurance prices do not reflect efforts at self-protection or self-insurance, then individuals will not have an incentive to adopt risk-reduction measures (Hirshleifer and Riley 1979). Ehrlich and Becker (1972) showed that market insurance is a substitute for self-insurance, and as the price of market insurance increases (decreases), people will spend more (less) on self-insurance.

### *Samaritan's dilemma*

The expectation that the government will provide disaster assistance in the wake of a natural disaster causes people to under-invest in protective measures, a phenomenon known as “the Samaritan's dilemma.” Lewis and Nickerson (1989) argued that the decision by consumers to underinsure is rational given the expectation that the government will provide compensation for losses that exceed the limits set by an insurance contract.

Kelly and Kleffner (2003) confirmed this and showed how government disaster assistance can reduce mitigation expenditures by individuals. Coate (1995) argued that the fundamental problem stems from the fact that the government cannot commit *ex ante* to a fixed level of support should a disaster occur. Experimental evidence has shown that a disaster-recovery program of financial aid lowers most forms of wildfire risk-mitigation expenditures (McKee et al. 2004).

These theoretical and empirical studies suggest that self-protection and self-insurance measures such as those advocated by community wildfire-mitigation programs (e.g., reducing vegetation close to the home and using fire-resistant materials in roofs and gutters) may not be adopted by homeowners for rational economic reasons. If the government were to commit *ex ante* to provide disaster relief only to homeowners living in communities that have implemented measures to reduce the risk of wildfire, then the incentives to take protective action would be increased.

### *Risk information*

A basic economic tenet is that people make decisions based on the information that is available to them. If information is incomplete or is of dubious quality, then people may rationally decide not to act on that information or may make seemingly irrational decisions. Uncertainty regarding the extent to which community-based wildfire-mitigation activities reduce wildfire risk may explain why some people are reluctant to invest in these activities.

A number of economic studies have shown that, when reliable information is available regarding the risk of natural hazards, individuals use that information in making economic choices. Brookshire et al. (1985) investigated California housing markets in areas subject to earthquakes. What these researchers discovered is that people are willing to pay higher (lower) real estate prices for houses in lower (higher) earthquake risk zones. These authors concluded that a 1974 law passed by the state of California requiring earthquake risk information be available to consumers allowed individuals to self-insure by trading off risk and price. Similar results were reported by Troy and Romm (2004). They found that the average home located on floodplains across California sold for 4.2% less than comparable non-floodplain homes after passage of the California Natural Hazard Disclosure Law, but that no difference in price was found before passage of that law. The provision of timely, believable information about the risk of catastrophic events may be a critical factor in individual decisions to self-insure.

## *Discussion and Policy Implications*

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*Over the past two decades*, the upward trend in the number of acres burned by wildfires has been matched by growth in wildfire-suppression costs, insured economic losses, and disaster assistance. A number of macroeconomic factors have contributed to the trends in wildfire-suppression costs and losses within the wildland-urban interface, including in-migration to scenic areas, increasing wealth, and an escalation in real estate values. As greater wealth is placed at risk, more money is spent by the federal government to protect it from wildfires and provide assistance for losses. Research is clearly needed to systematically document and analyze the trends in population growth, migration, and the accumulation of capital in wildfire risk areas within the wildland-urban interface.

A fundamental issue facing policy makers is the prevalent social attitude that the federal government should and will provide assistance during a disaster (such as wildfire suppression) and that governmental relief will be forthcoming in the aftermath of a catastrophe. Although few would argue against the need for some level of federal disaster aid, federal assistance is commonly viewed as an entitlement even when those needing assistance chose not to invest in insurance or mitigation measures beforehand. Economic theory suggests that if property owners believed that disaster relief would not be forthcoming from the federal government unless effective risk-mitigation measures had been implemented beforehand, then their incentives for self-protection would be enhanced. These actions may reduce the probability of damages, may reduce future migration to, or rebuilding in, risky locations, and might begin to shift the responsibility of protection from the federal government to individuals and neighborhoods who share the risk. Research is needed to systematically evaluate the economic efficiency of mandatory and voluntary wildfire-mitigation programs.

Making disaster assistance conditional on *ex ante* mitigation, however, would have severe consequences for the poor. There is evidence that natural disasters are felt more acutely by the poor than the more wealthy for a variety of factors, including the likelihood that the poor live and move to risk-prone areas, have relatively low-quality housing, and possess less ability to travel the bureaucratic pathways necessary to claim disaster assistance. Because the poor are less able to purchase insurance or make investments in self-protection, they rely more heavily on federal disaster assistance to help them recover from natural disasters. Research into the impact of wildfires on people living in poverty, or close to the poverty line, is sorely needed.

Property owners use reliable information about risk in making choices regarding both purchase and provision of self-insurance. If wildfire risk

factors are capitalized into property values, as has been demonstrated for earthquake and flood risks, then risk-adjusted property values may provide a degree of financial self-insurance for property owners, because they would have less wealth at risk. In addition, private insurance costs may be more affordable for risk-adjusted property owners, again because the value of the property at risk would be lower. This can only occur if wildfire risks are adequately mapped in the wildland-urban interface and the information made readily available to consumers.

Many community action programs aimed at lowering wildfire risk have been established throughout the wildland-urban interface. However, we would emphasize that the success of wildfire risk-reduction programs depends to a large degree on understanding the economic incentives that people face when making risk-reduction choices, and incorporating the proper incentives into program implementation.

## NOTES

1. Most, but not all, of the loans are repaid by property owners. The net present value (NPV) of direct federal disaster relief expenditures comprises interest rate subsidies and the costs of loan defaults, and these averaged 27% of the insured losses during the mid-1990s (Barnett 1999). Applying this average to the 2003 California wildfires yields an estimated NPV of direct costs to the government of \$130.4 million. It has been estimated that, during the period FY 1980-96, the NPV of direct costs to the federal government for all natural disasters averaged \$535 million per year (Barnett 1999).
2. Suppression-cost data shown in Figure 2 were obtained from the report published by the Strategic Issues Panel on Fire Suppression Costs (2004). USDA Forest Service data include expenditures for initial attack and suppression, whereas those for Department of Interior agencies only include suppression expenditures. Because Department of Interior data were only reported beginning in 1985, estimates were back-cast to 1970 based on the ratio of DOI to Forest Service expenditures during the period 1985-2003.
3. The total U.S. population increased from 181 million to 249 million between 1960 and 1990 (U.S. Census Bureau 2004a); in 2000, it was estimated at 282 million (U.S. Census Bureau 2004b).
4. It should be recognized that published reports of loss-value trends sometimes do not adjust for general price inflation.

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Cite individual chapters by author or authors. Fictitious example:

Flame, W. W. 2007. Wildland Fire Events: Dealing with the Consequences. In T. C. Daniel, M. S. Carroll, C. Moseley, and C. Raish (eds.), *People, Fire, and Forests: A Synthesis of Wildfire Social Science*. Corvallis: Oregon State University Press, Pp. 100-135.

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The paper in this book meets the guidelines for permanence and durability of the Committee on Production Guidelines for Book Longevity of the Council on Library Resources and the minimum requirements of the American National Standard for Permanence of Paper for Printed Library Materials Z39.48-1984.

### Library of Congress Cataloging-in-Publication Data

People, fire and forests : a synthesis of wildfire social science / edited by Terry C. Daniel ... [et al.].

p. cm.

Includes bibliographical references and index.

ISBN-13: 978-0-87071-184-8 (alk. paper)

ISBN-10: 0-87071-184-9 (alk. paper)

1. Wildfires--Social aspects--United States. 2. Fire ecology--United States. 3. Fire management--United States. 4. Wildfires--Prevention and control--Social aspects--United States. I. Daniel, Terry C.

SD421.3.P46 2007

363.37'9--dc22

2006039350

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First published in 2007 by Oregon State University Press

Printed in the United States of America



Oregon State University Press

500 Kerr Administration

Corvallis OR 97331-2122

541-737-3166 • fax 541-737-3170

<http://oregonstate.edu/dept/press>