Wildland Fire Suppression and Land Development in the Wildland/Urban Interface

Final Report to the Joint Fire Science Program

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Abstract

This project has explored the hypothesis that public fire suppression in fire-prone areas acts as a subsidy to landowners, incentivizing conversion of land to residential and commercial development. Landowners do not bear the full cost of their choice to build on land in fire-prone areas, since they do not pay for suppression, though they reap all of the benefits, potentially resulting in economically inefficient levels of development.

To test this hypothesis, we performed an econometric analysis of U.S. land use change between 1970 and 2000. Statistically, we identified the impacts of changes in fire suppression policy by exploiting a natural experiment – a major but temporary policy shift toward increased suppression that took place as a result of the significant Yellowstone fires during the summer and fall of 1988 – as well as variation in the benefits of fire suppression based on proximity to federal lands. We also implemented another set of tests based on the fact that the Southeast did not experience this strong return to suppression after the Yellowstone fires. Models control for underlying trends in development over time and across states, and, in most models, within parcels. Results suggest that when federal suppression efforts intensify on public lands, private development accelerates nearby. The main paper produced by the funded research thus shows that public investment in reducing the damages from fire in the short run causes unintended long-run behavioral responses, which may increase future hazard exposure.

The PIs wrote two additional articles, one published as an academic book chapter, and the other published for non-research audiences in the policy community, summarizing the broader implications of the research, and laying out an agenda for future empirical economic research on federal fire policy and private landowner behavior. In addition to informing federal fire suppression policy, our econometric results are directly relevant to ongoing debates over preparedness for and response to hurricanes, droughts, floods, and other events that become natural disasters when they occur in highly populated areas, and that may be expected to occur with increasing frequency due to the changing global climate.

1.0 Background and Project Purpose

Millions of American homeowners have developed new properties in the forests, grasslands, and shrublands of the American West in the past few decades. In 2000, 12.5 million U.S. homes were within the wildland/urban interface (WUI), suburban and exurban areas where homes and other structures mingle with fire-prone vegetation – a 52 percent increase over 1970. A majority of these (65 percent) are in what ecologists describe as high-severity fire regime classes (Theobald and Romme 2007). In California's San Diego County, alone, three out of four homes built since 1990 are within the WUI. Looking forward, U.S. land in developed uses is expected to increase by 70 million acres between 2003 and 2030, with the largest fraction converted from forests (Alig and Plantinga 2004). Little attention has been paid to the role of public policies at the federal or any other level in drawing people and structures into these regions, which have high amenity values but are also prone to wildfire. This project has investigated whether federal fire suppression efforts over many decades have acted as an implicit subsidy, inducing development in risky areas.

The federal government has played a significant role in wildland fire suppression since 1910. While the benefits of development in forested and fire-prone regions are enjoyed by landowners, the costs of fire suppression, when fires occur, are borne by taxpayers at large. Recent trends in public sector spending on fire suppression are striking. U.S. fire suppression expenditures have increased rapidly since 1970 (Calkin et al. 2005). During the decade ending in 1980, the U.S. Forest Service spent $85 million per year, on average, fighting wildfires. For the decade ending in 2005, expenditures averaged $564 million per year, with expenditures in three of those years exceeding $1 billion. Possible contributors to this trend include increases in large fire incidence due to climate change (Westerling et al. 2006) and the effects of decades of suppression, which increases the intensity of fires in some ecosystems through fuel buildup (Prestemon et al. 2002). A recent audit of USFS fire suppression costs suggests that the most significant cause of the increase in suppression expenditures is the agency's "efforts to protect private property in the wildland urban interface" (U.S. Department of Agriculture 2006). New development increases suppression costs because it is more difficult, dangerous, and costly to fight fires when people and structures must be protected.

Viewing the problem through the lens of economics, we examine whether federal fire suppression has induced land development in fire-prone regions in the U.S. West, an important behavioral factor that has been overlooked in discussions of wildfire management. If this is the case, suppression and development may follow each other, in a repeating cycle of increasing social cost. Lessons learned on the ties between land development and public policy regarding fire risk could thus prove useful in thinking about disaster mitigation more broadly, both in terms of current conditions, in which significant populations are already at risk, and for natural hazard policy strategies going forward.

2.0 Study Description and Location

2.1 Background on the statistical "natural experiment"

Panel data on annual federal fire suppression expenditures are readily available (at least for the USFS, the agency in which the most significant expenditures occur). The simplest approach to testing our hypothesis might be to regress some measure of land development on suppression expenditures. However, this approach would generate biased estimates, due to the endogeneity of suppression expenditures. Development in the WUI increases fire incidence (Cardille et al. 2001), as well as the costs of suppression, conditional on fire occurrence, since firefighting is complicated by development (Gill and Stephens 2009). Thus, while our hypothesis is that suppression expenditures induce development, development also increases suppression expenditures. In addition, many of the factors that make a parcel of land fire prone also make that land appealing to develop (e.g., arid climate, forested landscape, and location on a high ridge). Thus, even in the absence of reverse causality, amenity values – unless perfectly controlled for in the estimation strategy – would be correlated with fire suppression and the unexplained portion of development conversion, biasing estimates.

Seeking an experimental solution to these sources of endogeneity, we turned to the history of federal fire policy. From 1933 through 1978, federal agencies officially followed the so-called "10am policy": they attempted to extinguish any wildland fire, no matter how it started, by 10:00 on the morning after the fire was detected (Carle 2002). If they did not succeed, they continued their effort, with a new goal of extinguishing the fire by 10:00am on the following morning, continuing in this manner until the fire was out. An important exception to this rule concerned fire-prone pine forests in southeastern states. Forest managers in the Southeast adopted the 10am policy along with the rest of the country in 1933. However, rapid buildup of fuel in fire-dependent southern pine forests under the total suppression policy caused a series of catastrophic fires in the late 1930s and early 1940s. In 1943, southern forest

managers seceded from the standard federal policy, a reversal referred to by fire management agencies as the "Treaty of Lake City," as the southern policy was finalized at the Ocala National Forest in Lake City, Florida (Carle 2002). In the meantime, many decades passed during which the policy of total fire suppression remained in place on federal lands in the rest of the United States.

Over time, however, research in the natural sciences produced overwhelming evidence of the downsides of total suppression (Biswell 1989). Several federal agencies, most notably the National Park Service and then USFS, eventually began experimenting with so-called "fire management" policies that allowed some "let burns" and prescribed burns. This shift took place slowly during the early and mid-1970s, and in 1978, total fire management became the policy on all federal lands, officially replacing the 10am policy, and bringing western forest management practices regarding suppression into alignment with southeastern practices (Carle 2002).

In the Summer and Fall of 1988, more than 1 million acres in Yellowstone National Park were affected by a set of massive fires. The largest of these fires was ignited by a carelessly tossed cigarette. There is wide scientific agreement that such major fires were important to the Yellowstone ecosystem, had occurred naturally every 200-400 years, and were overdue. Nonetheless, at least one of the major fires in Yellowstone was an escaped prescribed burn by park managers, and the public was outraged. A New York Times front-page headline on September 22, 1988 claimed: "Ethic of protecting land fueled Yellowstone's fires." Politicians followed the public outcry. Western Congressmen and Senators signed a petition to the president opposing all "let it burn" policies and asking for a permanent abandonment of this approach (Rothman 2005). The Yellowstone fires thus resulted in a backlash against the federal shift to fire management, with an immediate effect on policy. While the fires were still burning, the National Park Service director stopped prescribed burning on all NPS lands (Rothman 2005). Right after the fires, the federal government established a moratorium on fire management, to remain in effect until each park or management area had revised its fire management plan to account for concerns that arose as a result of the Yellowstone fires (Elfring 1989). These actions essentially re-established total fire suppression as federal policy for a few years post-Yellowstone.

The temporary shift back to more intensive fire suppression due to the Yellowstone fires was focused in the west, however. Managers of fire-dependent land in the southeast departed from their western counterparts in their response to the policy change, as they had in the 1940s. For example, in 1990, just over 2,000 acres of prescribed burns occurred in the West but over 70,000 acres were burned in the Southeast, despite the fact that federal land holdings in the west are vastly larger than in the southeast (Rothman 2005).

This history of major changes in federal fire suppression policy suggests several potential natural experiments that might help to identify the impacts of suppression on development. First, if our hypothesis is correct, the drop in public fire suppression from the replacement of the 10am policy with total fire management in the 1970s, all else equal, may have slowed the rate of development on or near lands protected by federal fire suppression efforts. However, this first policy change, while potentially important from a welfare perspective, is simply not temporally "sharp" enough to exploit statistically. In addition, U.S. land-cover data prior to 1970 is not available on a large enough scale to support quantitative analysis of this shift.

Similarly, if fire suppression increased after the 1988 Yellowstone fires, our hypothesis would suggest an uptick in the rate of development, which would fall again when policy shifted back toward fire management in the early 1990s. This development increase, however, should be limited to western

states, as the southeast did not experience a policy reversal back to total suppression, giving us an additional source of variation with which to test our hypothesis. The Yellowstone-related policy shift is also appealing for other reasons; it was sudden, unexpected, and plausibly exogenous to other trends in both land development and federal policy. It also occurred in the middle of an available panel data set on U.S. land cover. It is, thus, an ideal candidate for a natural experiment, and we exploit it for this purpose.

Finally, our statistical approach exploits one additional source of spatial variation in the likely effects of federal fire policy shifts. Land closer to federal lands affected by fire suppression (those within the "umbrella" of fire suppression efforts) should have experienced a more significant change in development incentives due to federal policy shifts. Not all federal land is equally affected by the federal suppression effort, however. Five federal agencies receive funds for fire suppression activities: the USFS, National Park Service (NPS), Bureau of Land Management (BLM), Fish and Wildlife Service, and Bureau of Indian Affairs. The most significant federal actors in managing and suppressing wildfire are the first three (USFS, NPS, and BLM); USFS, alone, receives 70 percent of Congressional appropriations for wildfire preparedness and operations.

2.2 Data and methods

Since our focus is development in fire-prone regions near federal lands, we obtained a GIS layer of federal lands from the U.S. National Atlas. We used these data to identify the holdings of the three agencies that comprise the vast majority of federal expenditures on fire suppression, BLM, USFS, and NPS. We then obtained land cover data from the USGS, which has recently developed the Land Cover Trends Database, in cooperation with the U.S. Environmental Protection Agency. The full data comprise a set of randomly-selected sample blocks with an area of 100 km2 (about 24,711 acres) from across the United States (Loveland et al. 2002). These 10 km by 10 km sample blocks are our spatial unit of observation, which we call "parcels". The parcels sampled for the full USGS Land Cover Trends database are depicted as gray squares in Figure 1, which also maps land managed by BLM, USFS, and NPS.

After restricting our sample to the land west of the 100th Meridian, and Southern pine forests (to exploit the policy shifts described above), and dropping parcels entirely in federal land, we are left with 1,053 parcels over 4 periods of observation, creating a panel of 4,212 observations in models that include the full sample (Figure 3). We also use the federal lands data to identify parcels that have any portion within 2.4 km of BLM, NPS, or FS lands, or those within the "umbrella" of federal suppression activity, in accordance with our earlier discussions (as well as 1.2 km and 4.8 km as robustness checks). Finally, we use a GIS layer of state boundaries from the US Census to control for non-time-varying state characteristics.

Figure 1. All USGS parcels and selected federal lands

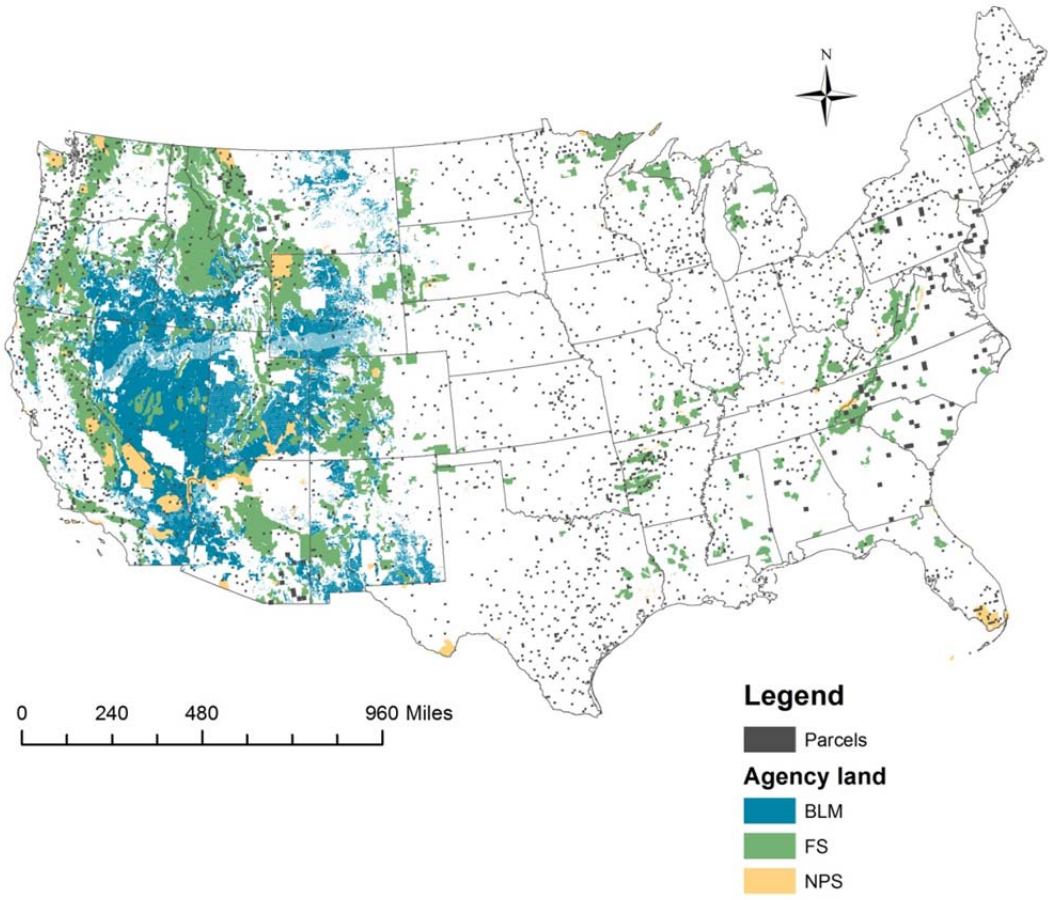
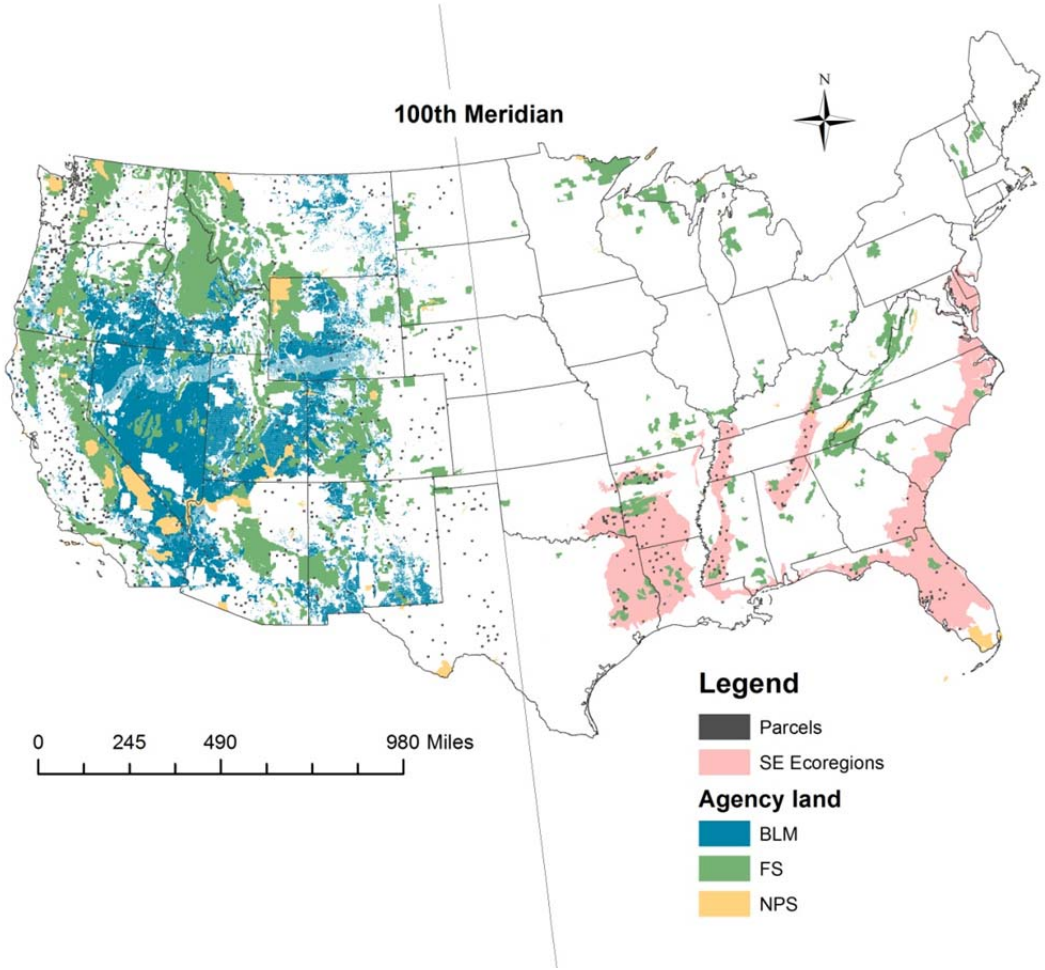


Figure 2. Sample parcels



Using this GIS database, we estimate a set of panel data models to identify the effects of federal fire suppression policy on land development, at first restricting the analysis to the western parcels in the data, and then adding in the additional test of differential impacts of the policy shifts between the West and the Southeast. The methods and model specifications are described in detail in the working paper submitted with this report.

3.0 Key Research Findings

The results of our econometric analysis of the impacts suppression on land development suggest that the temporary shift in federal fire suppression policy due to the Yellowstone fires may, in fact, have induced some land development on private land near federal land affected by fire suppression efforts. Our main models suggest that the conversion of forest, grassland and shrubland to developed uses was 32-44 percent lower (depending on the time period) on parcels near the federal fire suppression "umbrella" when the more liberal fire management policy was in place, relative to a total suppression policy. While this is a large impact in percentage terms, the absolute acreage converted is small, given

the limited development in our sample. As expected, no statistically significant impacts are estimated near federal land in Southeastern parcels, further supporting our hypothesis.

Though we find significant impacts of fire suppression policy on land development in the West, we cannot draw any conclusions from this analysis about the total costs and benefits of fire suppression as federal policy. To fully evaluate any fire suppression policy, one would need estimates of the benefits of suppression, including the benefits to private landowners (both that had been residing in fire-prone regions and those that move in as a result of suppression activities) from their location choice, as well as the costs of firefighting activities, and the cost of damages when fires do occur and are not fully or immediately contained. However, we offer the first empirical evidence that federal fire suppression activity can induce development, and that this effect may be quite large. The paper demonstrates that economic analysis of fire suppression investments must include both the benefits resulting from that induced development, and the costs, since the value of assets at risk when a fire does occur is larger than in the absence of federal suppression efforts.

4.0 Management Implications

An understanding of induced changes in development from suppression is necessary to fully evaluate the benefits and costs of fire management policies. The results of our research suggest that, if and when the benefits and costs of fire management policies are estimated, these calculations must include the benefits and costs of any land development induced by suppression policies in the long run. Induced land conversion may generate many benefits, even if this conversion is unintended. But it may also generate costs, since additional structures and people must now be protected when fires occur (increasing suppression expenditures), and should suppression efforts not succeed completely, additional assets and lives may be lost to future fires. Managers of other natural hazards have long hypothesized that federal protection can draw in more people and structures to hazardous areas; we are able to offer empirical evidence on this phenomenon.

5.0 Relationship to Other Recent Findings and Ongoing Work

Natural and social science research has focused on the increasing incidence of large western wildland fires (Allen et al. 2002, Whitlock 2004,Westerling et al. 2006), and on the rapid rate of growth in development at the wildland/urban interface (WUI) (Radeloff et al. 2005, Vias and Carruthers 2005). Development in the WUI increases fire incidence (Cardille et al. 2001), increases losses when fires occur (Mozumder et al. 2009), and raises suppression costs, since firefighting is complicated by development (Gill and Stephens 2009). Our paper tests a related hypothesis – that fire suppression, itself, has induced some land development in the wildland-urban interface (WUI).

No prior published research investigates the potentially critical link we propose between fire suppression and development. A growing literature models economically optimal public fire pre-suppression and suppression effort (Prestemon et al. 2001, Yoder 2004, Mercer et al. 2007) but does not account for the interaction with development. U.S. land in developed uses is expected to increase by about 70 million acres between 2004 and 2030, with the largest fraction converted from forests (Alig and Plantinga 2004). Identifying the potential role of fire suppression policy in this process is a critical endeavor.

The research is also related to other important questions in economics regarding the effects of public policy and household behavior on land development. Homeowners in fire-prone areas under-invest in

averting activities such as fuel treatment and the development of "defensible space," since these activities provide public goods (Shafran 2008, Amacher et al. 2006). Subsidized insurance and federally-funded risk reduction for other natural hazards, such as floods and droughts, influence land development, particularly for agricultural and residential use (Stavins and Jaffe 1990, Galloway et al. 2006). Similarly, subsidized crop insurance and agricultural disaster payments may increase the amount of land farmers cultivate (Goodwin et al. 2004).

6.0 Future Work Needed

As the PIs discuss in the book chapter published from this project, while empirical economic analysis should have much to contribute to the challenging questions regarding the interaction of wildfire risk and household behavior, the existing literature on the topic is thin. From our perspective, there are at least four key economic issues regarding household behavior that, if examined empirically in greater depth by economists, have the potential to provide useful input to federal wildland fire policy: (1) the possible incentive for development provided by fire suppression, (2) the links between information disclosure about fire hazard and household location decisions, (3) the importance of private insurance markets in generating efficient fire policy outcomes, and (4) free-riding in household private mitigation expenditures. The working paper drafted from this project examines the first question, though further research in this area would continue to be useful. The remaining three areas are important areas for future work.

Regarding topic (2), several states have enacted policies that disclose fire hazard information to homeowners. For example, following the 1991 Oakland Hills fire, California required its Department of Forestry and Fire Protection (CalFIRE) to identify Very High Fire Hazard Severity Zones (VHFHSZs). Maps designating these zones were made in 1996 and updated in 2008. A disclosure law passed in 1998 addressing multiple natural hazards requires sellers of property in VHFSZs to disclose to buyers the fire risk. As another example, under Oregon's Forestland-Urban Interface Fire Protection Act, sellers must disclose if a property is located in a forestland-urban interface area. The Act may also require landowners to create fuel breaks along property lines and roadsides, the size of which varies by fire risk classification, which ranges from "low" to "extreme." Several other states have developed fire hazard rating systems that can be applied by local land-use and fire-management officials to map fire risk within their communities. The extent to which this information is easily available to landowners varies by state, an interesting source of variation that could be exploited for empirical analysis of the effectiveness of such policies. Similar information provision programs have been used in a wide range of other areas to try and influence homeowner behavior, some more successfully than others. In the realm of hazards, there is research support that disclosure of flood risk is capitalized into property values. More research is needed on the role of information provision regarding wildfire risk on housing prices, development patterns, and homeowner willingness to invest in mitigation activities, however, in order to inform the development and use of information policies going forward.

On topic (3), many homeowners at risk of wildfires may choose to insure their property against damage. In most places, wildfire damage will be covered under a traditional homeowners policy. In very high risk areas, homeowners may instead need to purchase a specific wildfire policy. Premiums will generally be higher in the highest risk areas, and many insurers may make coverage conditional on certain mitigating actions or offer discounts to homeowners who reduce risks. Inspectors can be sent to homes to ensure compliance. Economic theory predicts that a risk-averse homeowner, maximizing their expected utility (the sole function of which is wealth), will fully insure when the premium of the insurance equals the expected loss. Of course, in practice, private insurance costs more than the expected loss, but levels of

risk aversion are often high enough to cover this difference. Further, homeowners insurance is usually required by mortgage lenders. For these reasons, theory would predict that the cost of insurance is internalized by homeowners when making location decisions (assuming they are aware of the rates before purchase). In areas where the risk of damage from wildfire is greater, policies will cost more, reflecting that higher level of risk. This should lead to higher prices and different development patterns than in low-risk areas, all else equal.

In some cases, however, the rates homeowners face may not adequately reflect the level of wildfire risk, distorting decision-making in ways similar to the case of inadequate information or subsidized suppression. Insurance prices are regulated by the states, and some insurance commissioners may artificially compress rates — allowing less spatial differentiation than a company may desire — introducing some cross-subsidization into insurance markets. They may also suppress rates, capping the premiums insurance companies can charge. Some very high risk areas for other perils, such as Gulf Coast areas at risk of hurricanes, have seen problems in insurance markets when states restrict the ability of insurers to charge prices they think reflect the risk or when homeowners balk at high prices in risky locations. In many of these instances, the state has stepped in, offering insurance-of-last-resort to homeowners, often at artificially low prices. State policies for wildfire are available in California in designated high risk areas, but there has been little empirical work on the influence this has had on development patterns or property values. More empirical research is needed on the influence of state insurance programs and state insurance regulations on development and homeowner mitigation activities in the WUI.

Further social science research on topic (4) would consider the actions that homeowners can and do take to reduce the risk of fire damage to their home. These include clearing areas of defensible space around the home and choosing fire-resistant building materials. At the community level, actions such as making roads easily accessible to fire-fighting crews can also reduce the risk of damage. Risk-reducing activities like these generate both private goods (in the form of reduced risk of personal damage from fire) and public goods (in the form of reduced risk to one's neighbors). Public goods are non-excludable, meaning it is impossible to prevent others from consuming the good, and non-rival, meaning one person's consumption does not diminish another's. Economic theory predicts that individuals will under-invest in public goods, "free-riding" on the investment of others.

Though none of the research topics we cover in this section have received significant attention from empirical economists, the question of private homeowner investment in fire risk mitigation has generated more research than the other three future research topics discussed in this section. For example, economists have noted the propensity for homeowners in fire-prone areas to under-invest in averting activities, and a key explanation appears to the be the public good nature of these investments. However, future research could illuminate the interactions between federal and state fire suppression and these kinds of investments by homeowners – are public expenditures complements to, or substitutes for, private expenditures, and how can public policy be designed so as not to skew homeowners' incentives to invest in fire risk mitigation?

7.0 Deliverables

This work has resulted in a working paper currently in submission to a peer-reviewed general economics journal. The PIs also co-authored a published book chapter on the broader topic of the need for additional empirical social science research on the interactions between federal fire management policy and household behavior, important barriers to such research, and how some of these challenges might

be overcome. The funding also supported development of an article aimed at policymakers and others outside of the research community, published in RFF's *Resources* magazine. Finally, the PIs presented research funded by the project in 11 academic seminars and 5 conference and workshop presentations between September 2010 and November 2011.

Table 1. Deliverables Crosswalk Table

Proposed	Delivered	Status
2 papers for publication	Kousky and Olmstead working paper (1)	In review
	Kousky, Olmstead and Sedjo book chapter (2)	In print
1 non-academic publication discussing results, aimed at policymakers	Kousky and Olmstead article in *Resources* magazine (3)	In print
Presentations	11 academic seminars 5 conference presentations	Completed between Sept. 2010 and Feb. 2012, slides available by request from PIs.

(1) Kousky, Carolyn, and Sheila Olmstead. 2012. Induced development in risky locations: Fire suppression and land use in the American West. Working paper, Resources for the Future, Washington, DC. (*In submission, uploaded to JFSP website.*)

(2) Kousky, Carolyn, Sheila Olmstead, and Roger Sedjo. 2011. In harm's way: homeowner behavior and wildland fire policy. In: *Wildfire Policy: Law and Economics Perspectives*, ed. Karen M. Bradshaw and Dean Lueck. New York: Taylor and Francis for RFF Press. (*Published*.)

(3) Kousky, Carolyn, and Sheila Olmstead. 2012. Unnatural disasters? *Resources* 179: 21-23, February. Available online at: http://www.rff.org/Publications/Resources/Pages/179-disasters.aspx.

7.1 Research presentations given, in reverse chronological order

Working paper presentations:

- University of Virginia, Batten School of Public Policy, Charlottesville, VA, Feb. 2012
- Virginia Polytechnic University, Agricultural and Applied Economics Department, Blacksburg, VA, Nov. 2011
- Pennsylvania State University, Agricultural and Resource Economics Department, State College, PA, Oct. 2011
- Society for Benefit-Cost Analysis Annual Conference, Baltimore, MD, Oct. 2011
- Association of Environmental and Resource Economists Summer Conference, Seattle, WA, June 2011
- Environmental Defense Fund, Washington, DC, May 2011
- University of California, San Diego, Economics Department, April 2011

- Resources for the Future, Washington, DC, Feb. 2011
- University of Pennsylvania Law School-Wharton Risk Regulation Seminar, Philadelphia, PA, Jan. 2011
- Arizona State University, Economics Department, Phoenix, AZ, Nov. 2010
- Harvard University, Kennedy School of Government, Cambridge, MA, Oct. 2010
- Colby College, Economics Department, Waterville, ME, Sept. 2010
- University of Maryland, Agricultural and Resource Economics Department, College Park, MD, Sept. 2010

Presentations related to book chapter:

- Comments on Frisvold's "Insurance, Incentives, and Wildfire". Discussant presentation at Wildfire: Economics Law and Policy Symposium, University of Arizona, Tucson, AZ, 12-13 November.
- Comments on Yoder's "Fuel for the fire: liability and the economics of wildfire risk". Discussant presentation at Wildfire: Economics Law and Policy Symposium, University of Arizona, Tucson, AZ, 12-13 November.
- Comments on Johnston and Klick's "Climate change and economic forces in wildfire". Discussant presentation at Wildfire: Economics Law and Policy Symposium, University of Arizona, Tucson, AZ, 12-13 November.

8.0 References Cited

Alig, Ralph J., and Andrew J. Plantinga. 2004. Future forestland area: impacts from population growth and other factors that affect land values. *Journal of Forestry*. 102: 19-24.

Allen, C.D., M. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman, and J.T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. *Ecological Applications*. 12: 1418-1433.

Amacher, G.S., A.S. Malik, and R.G. Haight. 2006. Reducing social losses from forest fires. *Land Economics*. 82: 367-383.

Biswell, H. 1989. Prescribed burning in California wildland vegetation management. Berkeley: University of California Press.

Calkin, David E., Krista M. Gebert, J. Greg Jones, and Ronald P. Neilson. 2005. Forest service large fire area burned and suppression expenditure trends, 1970-2002. *Journal of Forestry*. 103: 179-183.

Cardille, Jeffrey A., Stephen J. Ventura, and Monica G. Turner. 2001. Environmental and social factors influencing wildfires in the upper Midwest, United States. *Ecological Applications*. 11: 111-127.

Carle, David. 2002. Burning questions: America's fight with nature's fire. Westport, CT: Praeger.

Cordes, J. J., and A. M. J. Yezer. 1998. In harm's way: does federal spending on beach enhancement and protection induce excessive development in coastal areas? *Land Economics*. 74: 128-145.

Cross, J. A. 1989. Flood insurance and coastal development. *The Florida Geographer*. 23: 22-45.

Elfring, Chris. 1989. Yellowstone: fire storm over fire management. *Bioscience*. 39: 667-672.

Gill, A. Malcolm, and Scott L. Stephens. 2009. Scientific and social challenges for the management of fire-prone wildland–urban interfaces. *Environmental Research Letters*. doi:10.1088/1748-9326/4/3/034014.

Goodwin, Barry K., Monte L. Vandeveer, and John L. Deal. 2004. An empirical analysis of acreage effects of participation in the Federal crop insurance program. *American Journal of Agricultural Economics*. 86: 1058-1077.

Gorte, Ross W. 2006. Forest fire/wildfire protection. CRS Report for Congress RL30755. U.S. Congressional Research Service, Library of Congress, Washington, DC.

Krutilla, J. V. 1966. An economic approach to coping with flood damage. *Water Resources Research*. 2: 183-190.

Loveland, T.R., Sohl, T.L., Stehman, A. L., Gallant, A. L., Sayler, K. L., and D. E. Napton. 2002. A Strategy for Estimating the Rates of Recent United States Land-Cover Changes. *Photogrammetric Engineering and Remote Sensing*. October: 1091-1099.

Mercer, D. Evan, Jeffrey P. Prestemon, David T. Butry, and John M. Pye. 2007. Evaluating alternative prescribed burning policies to reduce net economic damages from wildfire. *American Journal of Agricultural Economics*. 89: 63-77.

Mozumder, P., R. Helfor, and R. P. Berrens. 2009. Provision of a wildfire risk map: informing residents in the wildland urban interface. *Risk Analysis*. 29: 1588-1600.

Prestemon, Jeffrey P., D. Evan Mercer, John M. Pye, David T. Butry, Thomas P. Holmes, and Karen L. Abt. 2001. Economically optimal wildfire intervention regimes. Paper presented at the American Agricultural Economics Association Annual Meeting, Chicago, IL.

Prestemon, Jeffrey P., John M. Pye, David T. Butry, Thomas P. Holmes, and D. Evan Mercer. 2002. Understanding broadscale wildfire risks in a human-dominated landscape. *Forest Science*. 48: 684-693.

Radeloff, V.C., R.B. Hammer, S.I. Stewart, J.S. Fried, S.S. Holcomb, and J.F. McKeefry. 2005. The wildland-urban interface in the United States. *Ecological Applications*. 15: 799-805.

Rothman, H. K. (2005). A Test of Adversity and Strength: Wildland Fire in the National Park System. Washington, DC, National Park Service, Department of the Interior.

Shafran, A.P. 2008. Risk externalities and the problem of wildfire risk. *Journal of Urban Economics*. 64: 488-495.

Stavins, Robert N., and Adam B. Jaffe. 1990. Unintended impacts of public investments on private decisions: the depletion of forested wetlands. *American Economic Review*. 80: 337-352.

Theobald, David M., and William H. Romme. 2007. Expansion of the US wildland-urban interface. *Landscape and Urban Planning*. 83: 340-354.

U.S. Department of Agriculture, Office of the Inspector General, Western Region. 2006. Audit Report: Forest Service Large Fire Suppression Costs. Report No. 08601-44-SF. November.

Vias, A.C., and J.I. Carruthers. 2005. Regional development and land use change in the Rocky Mountain West, 1982-1997. *Growth and Change*. 36: 244-272.

Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. *Science*. doi: 10.1126/science.1128834.

Whitlock, C. 2004. Forests, fires and climate. *Nature*. 432: 28-29.

Yoder, J. 2004. Playing with fire: endogenous risk in resource management. *American Journal of Agricultural Economics*. 86: 933-948.