RESEARCH ARTICLE

*J. For.* 113(3):291–297
http://dx.doi.org/10.5849/jof.14-050


economics

# The Economic Foundations of Firefighting Organizations and Institutions

**Dean Lueck and Jonathan Yoder**

This article examines the complex structure of wildland firefighting using the economic theories of contracts, property rights, and organization. We examine historical and cross-sectional case studies and consider the implications for contemporary wildfire management. Wildfires have characteristics that make their management and control complex and seemingly inefficient. Their occurrence has great spatiotemporal variance, and preparation and timeliness are crucial for effective suppression. Fires tend not to coincide with landownership boundaries, which affect private and public incentives to fight fires. Firefighting institutions vary substantially over time and space, ranging from private individual and cooperative action to large-scale centralized government intervention, military style organization, specialization, and prepositioned investments. We examine the implications of how incentives can affect suppression and asset protection decisions in the face of changing land use and land cover and how these changes can affect firefighting costs and other outcomes such as fire size.

**Keywords:** firefighting, organization, economics

> Whether attacked by two smokechasers with hand tools or by dozens of organized crews with sophisticated equipment, every fire requires a certain degree of organization. Certain functions must be performed, and it is a truism that, in some form, all these functions must be done on all fires. Not only do fires require a division of labor, an organization by function; they need an integration of that division, an organization by complexity. (Pyne 1984, p. 372)

Modern wildfire suppression is expensive and organizationally complex. For example, at the zenith of the famous Biscuit Fire in Oregon in late July 2002, there were >2,100 firefighting personnel from 58 crews, 21 helicopters, 95 engines, and 40 bulldozers, dispatched through a military-style hierarchy (US Government Accountability Office 2004). The fire burned nearly 500,000 acres over a 5-month period, including >100,000 acres of backfires and burnouts. The suppression costs alone for this fire were >$150 million.

Federal wildfire suppression spending has been around $1 billion per year over the last decade. Specialized fire crews and firefighting equipment are often moved around the country from one active fire to another, coordinated through the National Interagency Fire Center (NIFC) in Boise, Idaho. This network comprises a bewildering array of laws, policies, and contracts that create a bewildering array of incentives. Scholars and commentators suggest that inefficiencies abound, leading to overinvestment in suppression and underinvestment in prefire risk mitigation (Arno and Allison-Bunnell 2002, Calkin et al. 2005, Ingalsbee 2005, Bradshaw 2012, Yoder 2012, Pyne 2013).

We examine the economic foundation of wildfire suppression organization and institutions, focusing on three driving factors: property rights to assets, the emergency nature of wildfire response, and gains from specialization. Because firefighting is dominated by bureaucratic administration and networks of organizations rather than market allocation, our approach is rooted in the works of Nobel laureate economists Ronald Coase, Douglas North, and Oliver Williamson, as well as newly developing economics of organizations (Gibbons and Roberts 2014), that focus on the underpinnings and effects of organizations, property rights, and contracts.

## Economic Framework

We rely on two pairs of concepts. The first concept pair relates to the fire landscape. The *fireshed* (Lueck 2012) is a well-defined area of land that will occasionally carry a natural fire (Figure 1A).[1] The prototypical fireshed starts at an ignition point and then expands as an ellipse, driven by prevailing winds on flat terrain, although in reality, the size and shape are more variable. A *firescape*

Received May 6, 2014; accepted January 6, 2015; published online February 12, 2015.

Affiliations: *Dean Lueck (lueck@email.arizona.edu), University of Arizona. Jonathan Yoder (yoder@wsu.edu), Washington State University, School of Economic Sciences, Pullman, WA.*

Acknowledgments: *For helpful comments on an earlier version of the article, we thank Terry Anderson, Rob Fleck, Tim Fitzgerald, Randy Rucker, three anonymous reviewers, and two editors. We also acknowledge support from the Property and Environment Research Center (Bozeman, MT) via a Lone Mountain Fellowship, and Washington State University Agricultural Research Center (project #0544).*

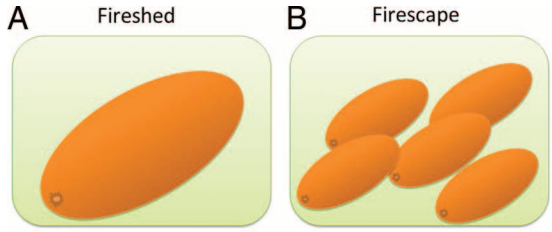


**Figure 1. Fireshed (A) and Firescape (B).**

is a larger landscape in which there are a multitude of firesheds, perhaps overlapping (Figure 1B).

The second concept pair relates to wildfire response. Firefighting effort can be focused on the extensive margin (limiting fire size), which we call *suppression*, or the intensive margin (protecting assets without substantively affecting spatial fire growth), which we call *protection* (Bayham and Yoder 2012). Although this is an artificial dichotomy representing a complex suppression/protection continuum, it is useful to clarify our main points.

## Asset Distribution and Suppression Incentives

Suppose a single landowner owns and controls resources over a single fireshed, and his or her objective is to maximize the economic value of the landholding. Such a landowner will allocate fire suppression resources efficiently over the course of any given wildfire and prepare (invest) for future fires. Figure 1A shows a case in which the fireshed contains a homogeneous diffuse asset, which might represent an even-aged timber stand. If the stand burns, a constant asset value per acre burned would be lost.[2] Here, suppression is economically equivalent to protection: reducing the extent of a fire is equivalent to protecting assets. Indeed, fire size has long been used as a proxy or summary statistic for fire outcomes (Petrovic et al. 2012, Petrovic and Carlson 2012).

Figure 2A adds three concentrated (and typically) high-valued assets (blue boxes), two of which are within the fireshed.[3] If the fire is not extinguished immediately, it may be more efficient to protect the concentrated asset and let the fire burn through the fireshed, especially if it reduces future wildfire risk, or if the diffuse asset is low valued. This implies that efficient suppression will depend on asset distribution and asset values. Diffuse assets call for distributed prepositioning in anticipation of ignitions, and mobile resources are crucial because ignitions are unknown. For concentrated assets, ignition and initial attack at the source matters little, and firefighting resources should be prepositioned to best protect valuable asset points. Further, with concentrated assets, the final fire size matters little economically and as a proxy for fire impact or damage can be misleading, as others have noted (e.g., Reinhardt et al. 2008).

## Contracts and Organization

With zero transaction costs and full information, perfect contracts would be specified so that asset owners and firefighters face the full marginal costs and benefits of their actions (Coase 1937, 1960). Efficient outcomes would result even if wildfires span multiple landholdings, and any contract or organizational structure among asset owners and firefighters would be equally effective at reaching these outcomes. Transaction costs, however, are a part of all human interactions and play a central role in the adoption of alternative organizational regimes and incentives therein (Coase 1937, 1960, Williamson 1985, North 1990).

Even when a landowner completely "owns" a firescape there can be economic gains from specialized firefighting services and technologies that could be attained through contracts or organizations, which necessarily entail transaction costs (Gibbons and Roberts 2014). These costs arise from uncertainty and asymmetric information (Allen 1999). Firefighters are generally not the residual claimants of the assets they are protecting and so have only indirect and generally weak incentives to protect them. While specialized firefighters bring higher productivity, the different incentives of resource owners and suppression decision-makers implies a need for costly monitoring and contract enforcement and even so can lead to inefficient allocation of the firefighting effort.

***Landownership and Public Benefits from Suppression.*** In reality, many landowners have a stake in a single fireshed and thus have impacts on neighbors (Butry and Donovan 2008, Shafran 2008, Lueck 2012). Figure 2B and D have red lines that represent property boundaries. If the owner of the ignition point in the lower left of Figure 2B suppresses a fire before it leaves the property it will save the property of all other landowners in the fireshed and negate the need for the others to invest in firefighting. Acting alone, however, this landowner has weak incentive to invest in suppression. With no concentrated assets on this land, the loss from inaction by the landowner at the ignition point is born primarily by others in the firescape, even though immediate suppression at the ignition point might be the most efficient action for the fireshed as a whole.

## Management and Policy Implications

The organization of wildland firefighting ranges from individual and cooperative action to large-scale centralized government intervention with military-style hierarchy, specialization, and prepositioned investments. Although the modern US firefighting complex has become increasingly effective along many dimensions, it is also criticized as being costly, wasteful, and rife with incentive problems. This article examines the economic foundations of observed firefighting institutions using theories of contracts and economic organization. Gains from specialization and coordination provide a basis for complex transactions among property owners, firefighting specialists, and the public sector, but at the cost of skewed incentives resulting from the economic separation between asset owners and firefighting activity. We bring this economic perspective to historical and cross-sectional case studies and consider the implications for contemporary wildfire management. For example, whereas active suppression may have made economic sense for homogeneous timber assets when rural suppression and exclusion practices were born, the wildland-urban interface calls for very different firefighting organization with emphasis on point protection and portends the decline of fire size and acres burned as a relevant outcome metric. We conclude with a discussion of the implications of a focus on incentives in the context of a changing economic, demographic, and climatic environment.

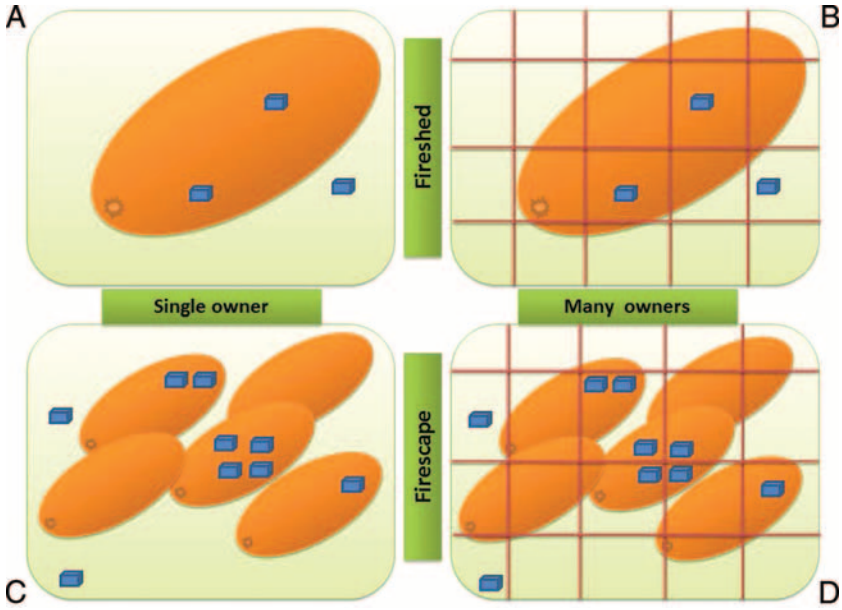


**Figure 2. Firesheds, firescapes, and landownership. (A) Fireshed with a single owner, with diffuse asset values (orange) and concentrated asset values (blue). (B) Fireshed with multiple owners (blue lines are property boundaries). (C) Firescape with multiple firesheds and a single owner. (D) Firescape with multiple firesheds and multiple owners.**

Suppression and protection also have differential incentives. If the blue cubes are concentrated assets and the orange is valueless fuel, an efficient outcome can occur from noncooperative (i.e., uncoordinated) private action since only point protection is efficient. If the fireshed is instead composed of a homogeneous asset implying gains from contracting among landowners, divided ownership of the fireshed will lead to inefficiently low suppression in the face of transaction costs. At the firescape level, there may also be additional benefits from coordination of firefighting activity, preparedness, and prepositioning. If specialized capital assets are mobile across numerous firesheds, rental and custom contracting markets can arise that reduce down-time for suppression assets (e.g., crews and aircraft) and help pay for fixed costs (Allen and Lueck 2003). These coordination benefits might come from direct complementarities in production under either cooperative landowner firefighting or third-party (public) firefighting.

***Contracting Costs and Their Consequences.*** Contractual solutions depend on the costs of transacting and enforcing agreements (Lueck 1989, Libecap 1990), which in turn depend on the nature of the resource management problem itself, uncertainty and asymmetric information among involved parties, the number and heterogeneity of landowners, technology, and other factors. For example, if the set of landowners within the fireshed in Figure 2B choose to jointly invest in firefighting equipment, they will need to agree on a cost distribution among them and then expend effort to enforce this agreement. In Figures 1 and 2, we implicitly assume that the boundaries of firesheds and firescapes are well known. In reality, these "borders" are uncertain and will depend on weather and fuel conditions that cannot be known with certainty. The presence of uncertainty will increase the costs of contracting by making the stakes that each landowner has in the fireshed or firescape less clear (e.g., Libecap 1990).

With many landowners, the costs of developing, monitoring, and enforcing an agreement can be prohibitive. One solution is to vest wildfire suppression responsibility in a public entity analogous to public water and wildlife management agencies (Lueck 1989, Lueck and Yoder 1997). Transferring wildfire suppression responsibility to a public agency can reduce the number of decisionmakers from many (e.g., all private landowners in a fireshed) to one (e.g., an agency decisionmaker), thereby simplifying the coordination process. It may also allow for economies of scale.[4] However, third-party control further divests the consequences of asset damage from the costs of firefighting, to the extent that public firefighters have no direct stake in the assets being protected.

Public agency authority creates counterproductive incentives that must be weighed against its potential gains. First, public firefighters do not bear the losses from a fire. For example, fire crew members often have direct incentives to obtain overtime and hazard pay (which require active fires), yet they are highly constrained by rules of engagement and incentivized only indirectly through retention and future promotion to account for the product of their labor. Similarly crew bosses and regional/national resource dispatchers are not the residual claimants of their decisions over asset protection and are limited in their time-and-place information about fires over which they are making decisions. The structure of the organization in the face of the emergency nature of suppression may also lead to a situation in which incident commanders and other high-level decisionmakers may also have career advancement incentives to let fires get large much in the same way military leaders have incentives to expand military action. Agency heads and legislators may be unlikely to impose a binding budget constraint on firefighting during the fire season, which can lead to inefficiently high firefighting expenditures.

Second, landowners do not pay the full cost of fire suppression and, absent a binding contract, have weaker incentives to reduce risk before fires (Kousky et al. 2012). Third, agency firefighting personnel do not bear suppression costs themselves (as would a private firefighting firm). Fourth, asset owners may influence the decisions of the public suppression agency to their advantage. Thus, public firefighters face the marginal benefits and costs of their choices mostly indirectly through complex interactions and pressure from interest groups such as asset owners, taxpayers, environmental groups, and others.

## Implications for Wildfire Suppression Organization

Implications follow from our framework. Suppression and/or point protection are more likely when there are higher values at risk and/or when damage reduction is less costly. Point protection is more likely when assets are more heterogeneous; suppression is more likely when assets are more homogeneous. Suppression is less likely and point protection are more likely in fuel environments with rapidly growing fire risk. Smaller landholdings relative to a fireshed size lead to less private suppression and more private

point protection relative to private suppression. Cooperative (or public) suppression is more likely with homogeneous assets and divided landownership. Public suppression is more likely on (or in areas with more) publicly owned land. Larger gains from specialization and larger network economies lead to larger firefighting organization scale. Nonetheless, under divided asset ownership, contract structure and the incentives it creates are always imperfect and depend on the characteristics of information and transaction costs surrounding the fire management environment.

## The Historical Emergence of Organized Wildfire Suppression

Protection of local assets, not suppression, was the standard response in rural settings in North America well into the 1800s (Morton 1637, Stephens and Sugihara 2006). European settlers self-protected against Native American broadcast burning, and settlers cleared vegetation around settlements via the use of backfires and perhaps controlled fires before individual fire threats (Morton 1637, Pyne 1999, Stephens and Sugihara 2006). Native Americans themselves almost certainly self-protected their valuable fixed assets (Anderson 2006). Decentralized local protection and not suppression tended to be the chosen strategy on a sparsely populated frontier. As Pyne (1983) noted, "Free-burning fires belonged with the flaming front of colonizers and pioneers."[5]

Rural suppression organizations date to the late 1800s with two parallel developments in the Northeast and the Northwest. In 1885 and 1886, wildfire control programs were developed for the Adirondacks Reserve in New York and Yellowstone National Park (Chambers 1987). Private forest protection associations also soon developed: first in northeastern forests and shortly after in northwestern states. For example, by 1910 there were around 10 fire protection associations in Idaho (Allen 1910). Typically members paid dues based on the forest acreage that were used to purchase firefighting equipment (water trucks, etc.), build fire lookouts, and pay labor for fire scouts and firefighters (Allen 1910, Bradshaw 2012).

Some forests tend to have high-frequency, low-intensity ground fires, and some have a natural tendency to occur in the form of crown fires (Fire Regime Condition Class [FRCC] 2012), such that a primary fuel for the fire was the marketable trees themselves. If a forest is a relatively homogeneous stand of valuable timber, asset protection is functionally equivalent to suppression, and the way to protect timber assets is to suppress crown fires if and when economically viable.

When firesheds span numerous landholdings, suppression efforts on one landholding that extinguish or reduce the extent of a fire may reduce damage to assets and suppression costs on neighboring landholdings, so the incentives for cooperative suppression activity and/or third-party (public) fire suppression become strong. The advent of private timber associations in the late 1800s and early 1900s, as timberland became privatized and timber production was near its zenith (Fernow 1907), is consistent with our economic perspective.

## Geographic Variations

Suppression evolved differently across the country. Organized suppression did not seem to develop in the Southeast as early or as extensively as it did in the northern states until the federal government became actively involved in aggressive suppression. For example, while numerous timber protection associations had developed in the Northeast and Northwest by around 1910, the Florida Forestry Association did not form until 1923.[6] Fire return intervals in the southern United States tend to be shorter, not the least due to active human burning (FRCC 2012). Frequent burning would more often tend to burn the understory, leaving the standing timber unharmed (FRCC 2012). In fact, "light burning," the application of low-intensity fires for vegetation management had been an integral part of these southeastern firescapes since prehistory and continued well beyond initial European settlement (Shea 1940, Pyne 1999, Fowler and Konopik 2007). According to Eldredge (1911), "It is only by chance that any area of unenclosed land [in North Florida] escapes burning at least once in two years" (quoted and cited in Wade et al. 2000). These low-intensity fires were not as often destructive of timber value, so the economic risk of fire is lower than when high-valued vegetation (timber) is at higher risk of burning (e.g., in crown fires).

In the Southeast, the consequences for increasingly intense fires due to fire exclusion was more obvious, and the effects were more immediate than in the northern climates where fire risk growth was slower. Wade et al. (2000) argue that from the early 20th century forward, it was widely believed in the South that light burning was crucial for managing the risks of high-intensity fire in southern pine forests (Shea 1940).[7] Fire suppression in this type of environment not only is less likely to have substantive benefits in terms of current asset value (value of timber in the current year) but also may have detrimental effects on future timber value because fire exclusion increases fire intensity and the risk of crown fires in future years. Under these conditions, local protection of assets and active fuel management such as broadcast burning should dominate suppression as a response to wildfire, and cooperative suppression would be slower or less likely to develop.[8]

## Origins and Evolution of Federal Wildfire Suppression

Major changes in suppression organization occurred early in the 20th century coincident with the expansion of the National Forest System and the US Department of Agriculture (USDA) Forest Service. National forests went from 0 to 175 million acres (about the size of Texas) between 1894 and 1906 (Fernow 1907, USDA Forest Service 2012) and were exclusively in the 13 western states at this time. In 1908, the Forest Fires Emergency Act authorized the Forest Service to spend whatever available funds necessary to combat wildfires and fund fire prevention and control programs in national forests (Forest History Society 2012a). This "blank check" budgeting continued until the 1980s when budgetary limits were imposed, but it was reestablished soon after the 1988 Yellowstone fires and remains more or less intact today.

The Great Burn of 1910 in Idaho and Montana was a large, devastating fire and also a political turning point. The fire burned 3 million acres, killed 85 people, destroyed thousands of buildings, and consumed several towns, most notably Wallace, Idaho. The giant 19th century fires in the Northeast and Great Lakes states provided impetus for the development of private and state-level suppression organizations, but the 1910 Burn dramatically increased federal involvement in wildfire suppression and changed public land-management policy throughout the 20th century (Pyne 1999, Egan 2009, Forest History Society 2012b). By the 1910s, the US Government had become the nation's largest owner/man-

ager of forestland and had been given the authority and funds for aggressive suppression. The 1910 Burn occurred largely on national forests so it is not surprising that the USDA Forest Service developed its own firefighting infrastructure. Further, these were largely valuable old-growth forestland where the valued asset *was* the fuel, so the federal government had the same incentive as the organized private timber associations in northern states to pursue aggressive suppression rather than focus on point protection. Taken together, expansive public landownership, private timberland ownership, and a slower manifestation of the effects of fire exclusion than in the Southeast may have led to a stronger emphasis on suppression and fire exclusion, perhaps leading to more intense and costly fires in the West today (Keane et al. 2002).

When suppression is the focus, the initial attack can be crucial. And for some fire regimes, ignition uncertainty suggests there is value in large, complex response structures with an emphasis on preparedness and rapid response when specialized, mobile technology is available for deployment. The organizational structure that arises in emergency settings like this is often similar to that of military or rule-based organizations. Indeed, the USDA Forest Service developed such an organization. During the 1930s and 1940s specialized fire crews and smokejumpers emerged within the USDA Forest Service, along with increased aircraft use. There were large programs to build roads, lay telephone lines, and establish fire lookouts throughout national forests. Such an extensive and complex network of infrastructure and resources requires extensive organization and contracting to coordinate activities. The hierarchical, military-style suppression organization in the United States today was well established by the 1960s, and the NIFC now coordinates wildfire suppression efforts throughout the United States. Our framework implies that the scope of the modern federal firefighting infrastructure is unlikely to have developed to the extent it did were the US government not the owner of extensive tracts of valuable timber.

Fires often span the borders of even the largest landowners, so that landowner coordination problems exist even for the federal fire managers. In general, the initial attack is the responsibility of either the landowners/managers themselves, or, in the case of ignitions on private lands, municipal or county agencies. Extended attack for large fires is usually managed by the USDA Forest Service through formal and informal agreements with other federal land agencies, all states, and local jurisdictions on behalf of private landowners for cooperative suppression and cost-sharing.[9]

As noted, complex suppression networks have both organization costs and economic losses due to weak and skewed incentives for resource allocation relative to private action. These incentives have been the source of many critiques of the current system. Berry (2007) argues that the Forest Fires Emergency Act of 1908 (the blank check policy) provides little incentive for the USDA Forest Service to make the kind of marginal cost/benefit analysis that a private forest owner would and promotes suboptimal suppression. Fire suppression crews have incentives to waste resources, extend the duration of fires, and even start fires (Bradshaw 2012). There is evidence that fire suppression on large fires, especially when they are active, is often ineffective (Rogers 1982, Reinhardt et al. 2008, Gorte and Bracmort 2012), and there are many cases in which the suppression costs far exceed the value of the protected resources (Arno and Allison-Bunnell 2002). In addition, federal suppression crews face minimal fiscal marginal costs of additional effort and face no liability for trespass or damage to private property during the course of active suppression. Indeed, they have near martial law authority (Merrill 2012), which can be justified as needed to support rapid decisions in emergency settings, but substantially disconnects the costs of poor decisions from the decisionmakers. The increasing use of large and costly backfires and burnouts can probably be traced to such incentives (Bradshaw 2012) and incentives to invest in highly visible activity even when their efficacy is questionable (e.g., air tanker delivery of retardant; Bradshaw 2012).

## Implications and Conclusions

Wildfire suppression is governed by a complicated network of organizations and institutions that seem to defy logic. The economics of organization and property rights can reveal these institutions as rational, but imperfect, responses to the unique features of wildfire. This framework stresses the potential gains from a large-scale bureaucratic organization with rule-bound emergency authority set against the weak and often perverse incentives that weaken the connection between the costs and benefits of fire preparedness, protection, and suppression at multiple hierarchical decision points. Still there are serious questions about the efficiency of suppression in the 21st century, both in terms of existing structure and of how firefighting might change (optimally or otherwise) in response to recent environmental and demographic changes. We briefly consider three current issues: increasing federal budgets, expansion of the wildland-urban interface (WUI), and climate change.

The average annual federal suppression expenditures have been roughly $1.5 billion since 1999 and were just $400 million in the prior 15 years, and the USDA Forest Service share of these expenditures has been roughly 75–80% of the total.[10] There is a notable correlation between budgets and aggregate area burned, but almost no correlation between budgets and the number of fires. It is widely recognized that big fires are associated with higher firefighting expenditures and a large fraction of the aggregate firefighting budget. A factor usually ignored is that firefighting incentives play a role, and in the current structure incentives may play a crucial role in allowing fires to get big.

Timber harvest (and associated revenue generation) is now highly constrained on public land because of federal laws such as the Endangered Species Act and the National Environmental Policy Act, so the value of timber as a harvestable asset is very low for public land managers, suggesting that the opportunity cost of large fires in terms of timber losses is small on public lands. Firefighting in this environment represents a replacement revenue source for the USDA Forest Service and now represents more than half of the USDA Forest Service budget (USDA Forest Service 2014). The incentives for the USDA Forest Service to reduce firefighting expenditures seem weak as long as this political and regulatory regime persists, given that it has become such a substantial component of its budget, and actively reducing its expenditures may ultimately have negative impacts on the agency from the perspective of the agency itself.

The growth in WUI has several facets. In our framework, more WUI means more landowners and more asset points and greater incentive problems. Where the WUI abuts federal land, the model suggests that the existing suppression-focused system is misplaced. Although a reduction in timber value suggests that a lower suppression effort may be optimal, growth of the WUI outside

of USDA Forest Service land represents a more complex firefighting environment in which costly point protection is a focus. Further, our model suggests that reductions in timber value on USDA Forest Service land along with the growth of the WUI around it should to lead to both more expensive and larger fires to the extent that firefighting resources are allocated more toward point protection than suppression. One might also hypothesize that a controlled "let-burn" policy on public lands that has to date been applied in fits and starts in the western United States would take a more substantive foothold, but risk of WUI damage after a prescription has been implemented, as well as the complexity of other interest group interests on public lands, may continue to delay such a response.

Many scholars in the natural sciences have argued that climate change implies larger and more catastrophic fires (e.g., Westerling et al. 2006, Fettig et al. 2013), but the empirical literature supporting this claim has not carefully controlled for changes in fire policy, WUI development, and land management, so such conclusions are premature (Johnston and Klick 2012). Although we have focused primarily on suppression incentives, we argue that a sharper focus on incentives for fire prevention, suppression, and protection in fire research, administration, and policy is crucial for understanding and effectively managing fire in a changing economic, demographic, and climatic environment (Newman et al. 2013, Thompson et al. 2013, Reichman et al. 2014).[11]

We have presented a positivist analysis of wildfire that focuses on the economics of institutions and organizations. Federal wildfire suppression has evolved into a bewildering array of networks, laws, policies, and contracts that creates a bewildering array of incentives. Our analysis uses a contract-theoretic approach to help conceptualize the basic structure and evolution of these institutions and organizations into highly complex processes in the face of highly complex environments and objectives and also suggests a potential for improvements and fine-tuning as circumstances change.

## Endnotes

1. Some fire scientists use the term "fireshed" (Bahro and Barber 2004, Ager et al. 2006) although their usage is closer to our idea of a firescape. The term "fireplain" has been used to describe larger scale areas or maximum fire potential across a landscape (e.g., Scott and Thompson 2014). In Figure 1B the boundary of the fireplain would be the outer boundary of all the firesheds in the firescape.
2. The magnitude of the losses will depend on stand age and market prices.
3. While our working definitions of "assets" are intentionally simplistic to clarify our exposition, these assets can represent the gamut from simple, manufactured assets to complex natural assets and ecosystem services, as long as they enter into the calculations of decisionmakers.
4. Such a transfer of responsibility would reduce the incentives for direct landowner investments in suppression capacity. A reviewer suggests, as an example, that many large corporate landowners in Arkansas have divested private suppression capacity and now rely on the Arkansas Forestry Commission, local fire departments and other agencies for wildfire suppression.
5. When households are densely situated within a fireshed, coordinated asset protection is more likely to arise. Urban fires also call for coordinated action. When wood is the primary construction material the area is like a dense, dry, old-growth forest, and every lantern or cigarette is a potential lightning strike. Indeed, since at least Caesar Augustus in Rome two millennia ago, organized fire suppression organizations have existed and persisted in urban environments (Hirst 1884, Winer 2009).
6. A counterexample is the Georgia Forestry Association, which formed in 1907 (Georgia Forestry Association 2015).
7. Kousky and Olmstead (2104) note that on USDA Forest Service land in the Southeast the 10 AM suppression rule only lasted from 1933 to 1943. See also Stanturf et al. (2002) and Waldrop and Goodrick (2012) and references therein for a richer treatment of fire management in the South.
8. Similarly, we have found little or no evidence to date of early organizations developed for rural fire suppression in the Great Plains. Although natural and anthropogenic fire has been an integral part of the ecology of the Great Plains, grass fires tend to be less severe in some ways than forest fires, and grassland ecosystems recover faster and may even respond by increasing biomass growth rates.
9. In California and Texas, there are large state agencies that also have large suppression response areas.
10. These data are from the NIFC website: www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf; last accessed Dec. 22, 2014.
11. Reichman et al. (2014) noted the dramatic rise in prescription burning associations, which are examples of private contracting for fireshed control, in the last decade. Similar contracting for fire management is also starting to emerge in the WUI as well.

## Literature Cited


AGER, A.A., B.B. BAHRO, AND M.A. FINNEY. 2006. Automating fireshed assessments and analyzing wildfire risk with ArcObjects and ArcGIS. *For. Ecol. Manage.* 234S:S215.

ALLEN, D.W. 1999. What are transaction costs? *Res. Law Econom.* 14:1–18.

ALLEN, D.W., AND D. LUECK. 2003. *The nature of the farm: Contracts, risk and organization in agriculture.* MIT Press, Cambridge, MA. 266 p.

ALLEN, E.T. 1910. What protective co-operation did. *Am. For.* 16:641–643.

ANDERSON, M.K. 2006. The use of fire by Native Americans in California. In *Fire in California's ecosystems,* Sugihara, N.G., J.W. van Wagtendonk, K.E. Shaffer, J. Fites-Kaufman, A.E. Thode (eds.). University of California Press, Berkeley, CA.

ARNO, S.F., AND S. ALLISON-BUNNELL. 2002. *Flames in our forest: Disaster or renewal?* Island Press, Washington, DC. 248 p.

BAHRO, B., AND K. BARBER. 2004. *Fireshed assessment: An integrated approach to landscape planning.* USDA For. Serv., RS-TP-17, Pacific Southwest Region, Washington, DC. 2 p.

BAYHAM, J., AND J. YODER. 2012. *Wildfire hazards: A model of disaster response*. Working Pap. 2012-9, Washington State Univ., School of Economic Sciences. Available online at faculty.ses.wsu.edu/WorkingPapers/Yoder/wp2012-9.pdf; last accessed Jan. 27, 2015.

BERRY, A. 2007. *Forest policy up in smoke: Fire suppression in the United States*. Property and the Environment Research Center, Bozeman, MT. 21 p. Available online at www.perc.org/articles/article1004.php; last accessed Jan. 27, 2015.

BRADSHAW, K.M. 2012. Norms of fire suppression among landowners. P. 89–109 in *Wildfire policy: Law and economics perspectives*, Bradshaw, K.M., and D. Lueck (eds.). Resources for the Future, Washington, DC.

BUTRY, D., AND G. DONOVAN. 2008. Protect thy neighbor: Investigating the spatial externalities of community wildfire hazard mitigation. *For. Sci.* 54:417–428.

CALKIN, D., K. GEBERT, G. JONES, AND R. NELSON. 2005. Forest Service large fire area burned and suppression expenditure trends, 1970–2002. *J. For.* 103(4):179–183.

CHAMBERS, J. 1987. The evolution of wildland fire management and policy. *Fire Manage. Notes* 48:5–8.

COASE, R.H. 1937. The nature of the firm. *Economica* 4(16):386–405.

COASE, R.H. 1960. The problem of social cost. *J. Law Econ.* 3:1–44.

EGAN, T. 2009. *The big burn: Teddy Roosevelt and the fire that saved America*. Houghton Mifflin Harcourt, New York. 336 p.

FERNOW, B.E. 1907. *A brief history of forestry in Europe, the United States and other countries.* University Press, Toronto, ON, Canada. 394 p.

FETTIG, C.J., M.L. REID, B.J. BENTZ, S. SEVANTO, D.L. SPITTLEHOUSE, AND T. WANG. 2013. Changing climates, changing forests: A western North American perspective. *J. For.* 111(3):214–228.

FIRE REGIME CONDITION CLASS (FRCC). 2012. *Fire regime condition class*. Available online

at www.frames.gov/partner-sites/frcc/frcc-home/; last accessed Nov. 10, 2012.

Forest History Society. 2012a. *US Forest Service fire prevention and control*. Available online at www.foresthistory.org/ASPNET/Policy/Fire/Prevention/Prevention.aspx; last accessed Jan. 27, 2015.

Forest History Society. 2012b. *The1910 fires*. Available online at www.foresthistory.org/ASPNET/Policy/Fire/FamousFires/1910Fires.aspx; last accessed Jan. 27, 2015.

Fowler, C., and E. Konopik. 2007. The history of fire in the southern United States. *Hum. Ecol. Rev.* 14:165–176.

Georgia Forestry Association. 2015. GRA. Available online at http://gfagrow.org; last accessed Jan. 27, 2015.

Gibbons, R., and J. Roberts (eds.). 2014. *The handbook of organizational economics.* Princeton Univ. Press, Princeton, NJ. 1248 p.

Gorte, R.W., and K. Bracmort. 2012. *Wildfire protection in the wildland-urban interface*. Congressional Res. Serv. Rep. 7-5700, RS21880, Washington, DC. 11 p.

Hirst, J. 1884. *On the methods used by the ancient Romans for extinguishing conflagrations*. London, Exeter, UK. 15 p.

Ingalsbee, T. 2005. The war on wildfire. In *Wildfire: A century of failed forest policy*, Wuerthner, G. (ed.). Island Press, Washington, DC. 340 p.

Johnston, J., and J. Klick. 2012. Fire suppression policy, weather and western wildland fire trends: An empirical analysis. P. 158–178 in *Wildfire policy: Law and economics perspectives*, Bradshaw, K.M., and D. Lueck (eds.). Resources for the Future, Washington, DC.

Keane, R.E., K.C. Ryan, T.T. Veblen, C.D. Allen, J.A. Logan, and B. Hawkes. 2002. *The cascading effects of fire exclusion in Rocky Mountain ecosystems: A literature review*. USDA For. Serv., Gen. Tech. Rep. RMRS-GTR-91, Rocky Mountain Research Station, Fort Collins, CO. 24 p.

Kousky, C., and S. Olmstead. 2014. *Induced development in risky locations: Fire suppression and land use in the American West*. Working Pap., Property and Environment Research Center, Bozeman, MT.

Kousky, C., S. Olmstead, and R. Sedjo. 2012. In harm's way: Homeowner behavior and wildland fire policy. P. 178–199 in *Wildfire policy: Law and economics perspectives*, Bradshaw, K.M., and D. Lueck (eds.). Resources for the Future, Washington, DC.

Libecap, G.D. 1990. *Contracting for property rights*. Cambridge Univ. Press, Cambridge, UK. 144 p.

Lueck, D. 1989. The economic nature of wildfire law. *J. Legal Stud.* 18:291–324.

Lueck, D. 2012. Economics of wildfire suppression organization. P. 71–88 in *Wildfire policy: Law and economics perspectives*, Bradshaw, K.M., and D. Lueck (eds.). Resources for the Future, Washington, DC.

Lueck, D., and J. Yoder. 1997. Federalism and wildlife conservation in the West. P. 89–131 in *Environmental federalism*, Anderson, T., and P.J. Hill (eds.). Rowan and Littlefield, Lanham, MD. 283 p.

Merrill, T. 2012. Property and wildfire. P. 32–49 in *Wildfire policy: Law and economics perspectives*, Bradshaw, K.M., and D. Lueck (eds.). Resources for the Future, Washington, DC.

Morton, T. 1637. *New English Canaan or New Canaan*. Arno Press, New York. 227 p.

Newman, S.M., M.S. Carroll, P.J. Jakes, and T.B. Paveglio. 2013. Land development patterns and adaptive capacity for wildfire: Three examples from Florida. *J. For.* 111(3):167–174.

North, D.C. 1990. *Institutions, institutional change and economic performance*. Cambridge Univ. Press, New York. 159 p.

Petrovic, N., D.L. Alderson, and J.M. Carlson. 2012. Dynamic resource allocation in disaster response: Tradeoffs in wildfire suppression. *PLoS One* 7(4):e33285.

Petrovic, N., and J.M. Carlson. 2012. A decision-making framework for wildfire suppression. *Int. J. Wildl. Fire* 21:927–937.

Pyne, S.J. 1983. Forged in fire: History, land, and anthropogenic fire. P. 64–103 in *Advances in historical ecology*, Baleé, W. (ed.). Columbia Univ. Press, New York.

Pyne, S.J. 1984. *Introduction to wildland fire*. John Wiley & Sons, New York. 455 p.

Pyne, S.J. 1999. *Fire in America: A cultural history of wildland and rural fire*, 2nd ed. Univ. of Washington Press, Seattle, WA. 654 p.

Pyne, S.J. 2013. From Yosemite to Colorado, our approach to wildfires is all wrong. *Washington Post,* Sept. 13. Available online at www.washingtonpost.com/opinions/from-yosemite-to-colorado-our-approach-to-wildfires-is-all-wrong/2013/09/13/b0aadda6-1968-11e3-8685–5021e0c41964 story.html; last accessed Jan. 27, 2015.

Reichman, J., L. Park, C. Ruffner, and J. Groninger. 2014. Challenges and motivations behind sustaining a volunteer-based forest management organization: A case study of the Southeastern Illinois prescribed burn association. *J. For.* 112(2):215–220.

Reinhardt, E.D., R.E. Keane, D.E. Calkin, and J.D. Cohen. 2008. Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States. *For. Ecol. Manage.* 256:1997–2006.

Rogers, M.J. 1982. Fire management in Southern California. In *Proc. of the symposium on dynamics and management of Mediterranean-type ecosystems, 1981 June 22–26, San Diego, CA.* USDA For. Serv., Gen. Tech. Rep. GTR-PSW-058, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. 664 p.

Scott, J.H., and M.P. Thompson. 2014. Emerging concepts in wildfire risk assessment and management. Presented at the *Large wildland fires conference, 2014 May 21, Missoula, MT.* Association for Fire Ecology, Eugene, OR.

Shafran, A.P. 2008. Risk externalities and the problem of wildfire risk. *J. Urban Econ.* 64: 488–449.

Shea, J.P. 1940. Our pappies burned the woods. *Am. For.* April:159–174.

Stanturf, J.A., D.D. Wade, T.A. Waldrop, D.K. Kennard, and G.L. Achtemeier. 2002. Background paper: Fire in southern forest landscapes. In *Southern forest resource assessment*. USDA For. Serv., Gen. Tech. Rep. SRS-53, Southern Research Station, Asheville, NC. 635 p.

Stephens, S.L., and N.G. Sugihara. 2006. Fire management and policy since European settlement. P. 431–443 in *Fire in California's ecosystems*, Sugihara, N.G., J.W. van Wagtendonk, K.E. Shaffer, J. Fites-Kaufman, and A.E. Thode (eds.). Univ. of California Press, Berkeley, CA.

Thompson, M.P., N.M. Vaillant, J.R. Haas, K.M. Gebert, and K.D. Stockmann. 2013. Quantifying the potential impacts of fuel treatments on wildfire suppression costs. *J. For.* 111(1):49–58.

USDA Forest Service. 2012. *Founding legislation and history of the Forest Service's traditional role*. Available online at www.fs.fed.us/plan/par/2003/final/html/fs_glance/founding_legislation.shtml; last accessed Jan. 27, 2015.

USDA Forest Service. 2014. *The rising cost of fire operations: Effects on the Forest Service's non-fire work*. Available online at www.fs.fed.us/sites/default/files/media/2014/34/nr-firecostimpact-082014.pdf; last accessed Jan. 27, 2015.

US Government Accountability Office. 2004. *Biscuit fire—Analysis of fire response, resource availability, and personnel certification standards*. GAO-04-426. US Government Printing Office, Washington, DC. 41 p.

Wade, D.D., B.L. Brock, P.H. Brose, J.B. Grace, G.A. Hoch, and W.A. Patterson III. 2000. Fire in eastern ecosystems. In *Wildland fire in ecosystems: Effects of fire on flora*, Brown, J.K., and J. Kapler (eds.). USDA For. Serv., Gen. Tech. Rep. GTR-RMRS-42-vol. 2, Rocky Mountain Research Station, Ogden, UT. 257 p.

Waldrop, T.A., and S.L. Goodrick. 2012. *Introduction to prescribed fires in southern ecosystems*. USDA For. Serv., Sci. Update SRS-054, Southern Research Station, Asheville, NC. 80 p. Available online at www.srs.fs.usda.gov/pubs/41316#sthash.sufNEtXK.dpuf; last accessed Jan. 27, 2015.

Westerling, A.L., H. Hidalgo, D.R. Cayan, and T. Swetnam. 2006. Warming and earlier spring increase western US forest wildfire activity. *Science* 313:940–943.

Williamson, O.E. 1985. The economic institutions of capitalism. Simon and Schuster, New York.

Winer, D.H. 2009. *The development and meaning of firefighting, 1650–1850*. PhD thesis, Univ. of Delaware, Newark, DE. 350 p. Available online at gradworks.umi.com/33/60/3360270.html; last accessed Jan. 27, 2015.

Yoder, J.K. 2012. Fuel for the fire: Liability and the economics of wildfire risk. P. 50–70 in *Wildfire policy: Law and economics perspectives*, Bradshaw, K.M., and D. Lueck (eds.). Resources for the Future, Washington, DC.