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Economics of WUI/Wildfire Prevention and Education

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Synonyms

Intervention; Wildfire Mitigation; Wildfire Risk Reduction

Definition and Introduction

Prevention activities are actions designed to reduce the likelihood of an ignition in the wildlands or wildland-urban interface (WUI). Excluded are flame spread and firebrand generation processes, and related mitigation approaches, such as fuels management. This section describes preventable wildfire/WUI ignitions, recent ignition patterns over time in the United States, common prevention activities and approaches, methods for measuring the economic performance of prevention activities, recent studies that measured prevention effectiveness, and current measurement challenges.

Preventable Ignitions

All wildfires not ignited by lightning or other natural heat sources such as geological activities (Table 1) are, in principle, preventable. Recent research (Balch et al. 2016) indicates that human-caused wildfires are expanding their occurrence across geographic extent and time of year, consistent with climate change and growth in human populations and their activity and infrastructure. The vast majority of wildfires that occur in the United States are human-caused, occurring both in the wildlands and WUI. Some preventable wildfires are ignited intentionally to create damage (arson), while others escape from human control when humans intentionally apply a heat source to burn something outdoors (campfires, prescribed fires, debris fires). Other causes of preventable wildfires include those ignited by smoking materials and sparks emitted by equipment (railroads, vehicles, electrical transmitters). Falling outside these broad categories are wildfires ignited by children – and the wildfires that they ignite are sometimes intentional (i.e., arson), while others are the result of unsupervised (by adults) use of smoking materials, fireworks, and cooking or bonfires. There is also a long list of preventable types of wildfires that do not neatly fit within the above list, including wildfires ignited by burning vehicles, burning buildings, and industrial accidents. What all preventable wildfires have in common is that humans are involved

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Economics of WUI/Wildfire Prevention and Education, Table 1 Causes of Wildfire as classified by the United States Department of the Interior and the USDA Forest Service (National Wildfire Coordinating Group 2016, USDA Forest Service 2013)

DOI general cause number	DOI general causes	Examples	USFS statistical cause number	USFS statistical causes	Examples
1	Natural	• Lightning • Rock slide • Volcanic activity	1	Lightning	
2	Campfire		4	Campfire	
3	Smoking		3	Smoking	
4	Fire Use	• Escaped prescribed burn	5	Debris Burning	
5	Incendiary		7	Arson	
6	Equipment		2	Equipment Use	
7	Railroad		6	Railroad	
8	Juveniles		8	Children	
9	Miscellaneous		9	Miscellaneous	• Powerlines • Fireworks • Cutting, welding, and grinding; • Firearms use • Blasting • Structures • Glass refraction/ magnification • Spontaneous combustion • Vehicle fires • Flare stack/ pit fires

in one form or another, and so precautions can be taken to reduce their occurrence.

WUI/Wildfire Ignition Patterns

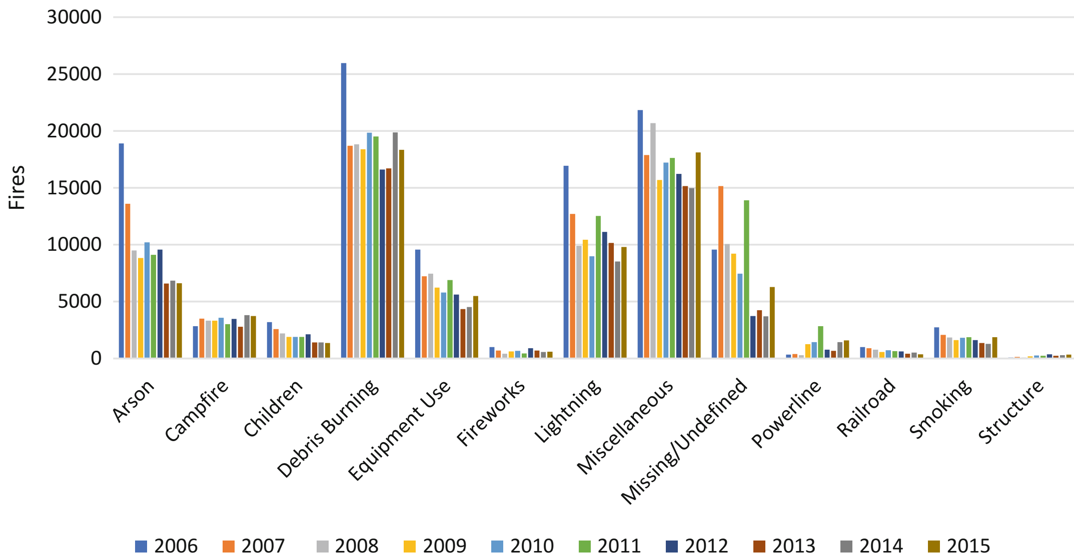
Spatial and temporal patterns of ignitions differ with regard to cause. The data displayed in this section are based on Short (2017). Figure 1 shows the annual pattern of wildfire ignitions, by cause, for the period 2006 to 2015 in the United States. In general, the number of ignitions is falling over this time period, with the exceptions of campfires, fireworks, powerlines, and structures. However, other than campfires, these cause-types represent a small number of total ignitions. The number of campfire ignitions did not show a trend over the period.

Prevention Approaches

Approaches to limit the number of WUI/wildfire ignitions can be grouped into engineering, management, and financial categories.

Engineering approaches resist ignition through physical methods that have been designed for this purpose. Engineering approaches include spark arrestors (for off-road vehicles and railcars), campfire rings, lightning rods, safety lighters, fire standard compliant cigarettes, landscaping materials and design, and the use of fire-resistant building materials and practices (building codes and standards).

Management approaches use procedures or processes. Management approaches include education and awareness (e.g., public service announcements, school or community events, leaflets or flyers), policing (e.g., patrolling,



Economics of WUI/Wildfire Prevention and Education, Fig. 1 The number of ignitions, by cause, by year (2006–2015), United States

arrests, deterrence), inspection programs (e.g., inspections of powerlines, forestry equipment, off-road vehicles), and use of burn permits and burn bans.

Financial approaches leverage incentives affecting monetary gain or loss. Those include civil penalties, including fire trespass laws, and legal liability (negligence).

Table 2 maps each prevention approach to the wildfire causes it is expected to limit. The “Miscellaneous” and “Missing” types are the only cause types affected by each intervention. This is because these wildfires are a subset of the other causes.

Methods for Measuring the Economic Performance of Prevention

Methods for measuring the economic performance of prevention compare the benefits of prevention with the costs. The benefits of wildfire prevention – i.e., ignition prevention – include avoided losses from wildfire damage and avoided costs of wildfire suppression. All else equal, preventing a wildfire will have a larger economic value than limiting its flame spread. Benefit-cost analysis is a method used to evaluate the economic performance of wildfire prevention efforts. The benefit-cost ratio (BCR) is specified as the ratio of discounted benefits to discounted costs:

$$\mathrm{BCR} = \frac{\sum_{t=0}^{T} B_t/(1+r)^t}{\sum_{t=0}^{T} C_t/(1+r)^t},$$

where B_t and C_t are the benefits and costs, respectively, occurring in time period t, T denotes the study period length, and r is the discount rate per period. Benefits and costs are measured in dollars. The discount rate, which is used to account for the “time value of money,” normalizes values occurring in different time periods into a present (current) value. An r equaling 0.05 means \$1.00 in period $t = 0$ is valued equivalent to \$1.05 in period $t = 1$. A larger (smaller) discount rate weights future dollars less (more) than a smaller (larger) discount rate.

Benefits can be decomposed into:

$$B_t = \left(W_t^0 - W_t\right) * L_t,$$

Economics of WUI/Wildfire Prevention and Education, Table 2 Mapping prevention approaches to wildfire cause types

	Arson	Camp	Child	Debris	Equip	Fireworks	Lightning	Misc	Missing	Powerline	Rail	Smoking	Structure
Engineering													
Campfire Rings		X						X	X				
Lightning Rods							X	X	X				
Spark Arrestors					X			X	X		X		
Safety Lighters			X					X	X			X	X
FSC Cigarettes								X	X			X	
Building Codes and Stds			X			X		X	X				X
Landscaping			X			X	X	X	X			X	X
Management													
Education		X	X	X		X		X	X			X	
Training								X	X				
Policing and Patrolling	X	X	X	X		X		X	X			X	
Inspections													
Utility Equipment								X	X	X			
Forestry Equipment					X			X	X				
OHV					X			X	X				
Building Codes and Stds								X	X				X
Permits & Burn Bans				X				X	X			X	
Financial													
Liability and Civil Penalties	X			X				X	X				

where W^0 is the number of wildfires in the absence of prevention, W is the number of wildfires with prevention, and L is the value (in dollars) of the avoided wildfire damage. The benefit equation could be further refined to allow the damages avoided to vary by wildfire cause:

$$B_t = \sum_j^J \left(W_{j,t}^0 - W_{j,t}\right) * L_{j,t},$$

where j indexes cause and J is the total number of causes.

A BCR greater than or equal to 1 means the investment produces at least as much benefit as it costs. A BCR less than 1 means the investment costs outweigh the benefits. The BCR can be used to calculate the return-on-investment (ROI). An ROI, measured in percent terms, is calculated as:

$$\text{ROI} = 100\% * (\text{BCR} - 1) .$$

While BCR and ROI are useful measures of economic performance, they do not consider the overall magnitude of the benefits and costs. A $1 million investment that produces $10 million in benefits yields the same BCR and ROI as does a $100 million investment that produces $1 billion in benefits.

A more interesting case is the comparison between investments that differ in BCR and magnitude. For example, a tradeoff exists between an investment that yields a BCR of 5, from $5000 in benefits for $1000 in costs, and another investment that yields a BCR of 2, from $1 million in benefits for $0.5 million in costs. The first project computes a larger BCR, but the second project produces net benefits (i.e., benefits minus costs) that are 125 times the size of the first.

The present value net benefit (PVNB) is another economic method used to evaluate investments. The PVNB of a wildfire prevention effort is computed as:

$$\text{PVNB} = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}.$$

A PVNB greater or equal to zero means the investment produces at least as much benefits as it costs. A PVNB less than zero means the investment costs outweigh the benefits.

The PVNB equation can also be used to measure the internal rate of return (IRR) of an investment. The IRR of an investment is the value of r that yields an PVNB of exactly zero. The IRR is similar to the BCR and ROI metrics in that it does not consider magnitude. However, the IRR provides a measure of economic performance without having to specify a discount rate.

Measured Effectiveness of Wildfire Management Approaches

Wildfire prevention education has been shown to be effective by three studies. These have narrowly focused on education programs offered by the State of Florida (Butry et al. 2010a; Prestemon et al. 2010) and on tribal land units administered by the Bureau of Indian Affairs of the US Department of the Interior (Abt et al. 2015). Law enforcement effort has been found to be effective in analyses of both unintentional and intentionally ignited wildfires in the states of Florida, California, and Michigan, on tribal lands in the United States, and on all lands in the region of Galicia, Spain (Butry 2005, Prestemon and Butry 2005, Thomas et al. 2011, Prestemon et al. 2012).

Wildfire Education

In the Florida studies, each dollar of prevention education spending yielded an average of $35 in avoided wildfire suppression expenditures ($5.36) and avoided wildfire damages ($29.64). Values ranged from $10 to $99, depending on the region in Florida. The Florida studies showed statistically that the most effective prevention education activities were focused on media (TV, radio, newspapers), brochures distributed, presentations offered to targeted audiences (e.g., schools, community organizations), and wildfire hazard assessments done by wildfire prevention and mitigation specialists in targeted Florida communities. The statistical models were used to estimate ignition rates under a counterfactual scenario assuming no prevention activity. The avoided ignitions were converted into losses avoided based on average wildfire damage loss estimates. The statistical models estimating wildfire ignition rates, from unintentional human-causes, were developed using data on prevention activity, weather and climate, recent wildfire activity, fuels management, and locational and time effects.

On tribal lands, each dollar spent on wildfire prevention programs (including law enforcement) was associated with averted suppression expenditures of $5 to $38 (Abt et al. 2015); if losses from these averted human-ignited wildfires are included, returns would be higher. Similar to the Florida studies, the statistical models estimating wildfire ignition rates were developed using data on prevention activity, weather and climate, recent wildfire activity, fuels management, and locational and time effects. However, individual statistical models were developed by ignition type (escaped campfire, smoking, escaped fire-use, juvenile, incendiary, equipment). Thus, the economic returns to prevention activity were calculated regionally, and returns varied across regions due to differences in suppression expenditures per fire.

The timing of prevention activities can exploit the temporal variation in wildfire ignitions to "get ahead" of the wildfire season and times of heavy ignition activity and limit damages. Leveraging the statistical models developed in Butry et al. (2010a) and Prestemon et al. (2010), Butry et al. (2010b) simulate the change in wildfire ignitions rates due to strategic increases in prevention activities over the fire season. Targeting specific months was shown to increase the net benefits from prevention by $3.6 million in Florida (Butry et al. 2010b). This finding suggests that the BCR for prevention activities can be increased at no cost.

Law Enforcement

In Florida, law enforcement presence (average spatial density of sworn law enforcement officers) was shown to reduce especially the occurrence of arson wildfires (3.75% for each 1% increase in officers) (Prestemon and Butry 2005). A statistical model was developed relating the number of daily arson ignitions to police presence, economic measures, previous wildfire activity, fuels management, weather, temporal effects, and prior days' arson activity. The temporally autoregressive structure of the model implies that police presence also limits arson ignitions indirectly: police efforts that result in the removal of serial and copycat arsonists lead to reduced ignition rates over time.

On California national forests, each 1% increase in sworn law enforcement officers was associated with a 0.4% reduction in arson wildfires (Prestemon and Butry 2010). A statistical model was developed relating the number of daily arson ignitions to the per capita number of sworn law enforcement officers, economic measures, climate variables, and prior wildfire activity. This research generally supports the earlier Florida studies, including the finding that arson ignitions are clustered in time.

In Michigan, each 1% increase in law enforcement would decrease arson wildfires by 0.3% (Thomas et al. 2011). A statistical model was developed relating the annual number of arson ignitions to the number of police, arrest data, weather, economic and demographic factors, and measures of social disorder. An additional finding is that crime begets crime – i.e., areas with other, lesser crimes were correlated with increased arson risk.

On tribal lands, law enforcement was found effective at limiting incendiary wildfires and those set by equipment (Abt et al. 2015). No statistical relationship was found with escaped campfires, smoking, fire-use, or juveniles causes. An additional sworn law enforcement officer was estimated to reduce incendiary ignitions by 3.13% per month and equipment ignitions by 2.80% per month.

In Galicia, Spain, each 1% increase in arrests would decrease intentionally ignited wildfires by 0.9% (Prestemon et al. 2012). The statistical approach employed was similar to Prestemon and Butry (2005), accounting for the autoregressivity (in time) of ignitions. The forward-looking aspect of the model, facilitating the ability to predict future ignitions, potentially allows for improvement in the efficacy of prevention and suppression resources.

Measured Effectiveness of Wildfire Engineering Approaches

One evaluation of the effectiveness of engineering approaches focused on less fire-prone cigarettes marketed in the United States (Butry et al. 2014). "Fire Standard Compliant" (FSC) cigarettes were mandated in a rolling fashion across US States between 2004 and 2012. The effectiveness evaluation found that FSC cigarettes were associated with an overall 23% reduction in smoking-caused wildfires in national forests of the states studied. By contrast, a 9% reduction in smoking-caused wildfires was found due to a decline in adult smoking rates, and a 48% reduction in smoking-caused wildfires occurred to changes in wildfire cause determination methods. The reduction in smoking fires due to FSC cigarettes resulted in an estimated $3.5 million in avoided suppression expenditures.

Challenges

There are a few challenges in accurately measuring the economic performance of wildfire prevention efforts. Quantifying the benefits and costs of prevention can be difficult. The benefits of wildfire prevention – avoided wildfires – are not directly observable. This necessitates the use of observational, rather than experimental, statistical methods to model the counterfactual (if prevention had not occurred). While prevention costs are observable, they can be difficult to measure due to recordkeeping. In the absence of costs, often prevention is tracked in terms of "effort" or "activities," which presents challenges to aggregate data because they can be tracked in different units (e.g., flyers distributed versus schools visited).

Unreported Fires

Research by Holmes et al. (2004) provides evidence that in Florida a large share of small lightning wildfires goes unreported. If wildfires are distributed log-linearly in size-frequency space, then data on numbers of reported wildfires by size classes support a contention that the smallest wildfires go unreported to official reporting agencies. Butry and Thomas (2017) offer statistical evidence of underreporting, as well. Holmes et al. (2004) speculate that small fires would be underreported if they are never witnessed or self-extinguish quickly. Additionally, small fires would be under-reported if nearby humans quickly extinguish a wildfire without calling for official assistance. Whether such underreporting is important from a societal or a fire service standpoint is a question that merits research attention. For example, if small wildfires are viewed by nearby people as "manageable" using resources at hand, then these wildfires perhaps may present a hazard. Furthermore, trends in the number of unreported small fires, if accurately assessed, might be used as indicators of wildfire prevention education needs, failures, and successes, making their roles in microscale ecological processes better appreciated.

Summary

Not all wildfires in the United States are preventable, but most, in principle, can be avoided. Strategies for reducing preventable wildfires include engineering, management, and financial approaches. Most recent research has focused on engineering and management approaches to reducing their occurrence and, therein, wildfire damages. In engineering, Fire Standard Compliant cigarettes have been shown to reduce smoking caused wildfires and their damages on national forests of the United States. In management, research has centered on the effects of law enforcement and wildfire prevention education efforts. Law enforcement efforts lead to reduced numbers of preventable wildfires, while education efforts have been shown to generate substantial positive net benefits. Data limitations constrain advancement in our understanding of the effectiveness of financial approaches to reducing preventable wildfires. Lack of reporting of wildfires also limits scientific assessment of alternative strategies for reducing overall wildfire losses.

Cross-References

- ▶ Cost of Retrofitting Existing Construction WUI Communities
- ▶ Cost of Suppression
- ▶ Cost of Wildland Fuel Treatments
- ▶ Fire data
- ▶ Firebrand and Embers
- ▶ Ignition
- ▶ Ignition Source
- ▶ Models to Estimate Suppression Costs
- ▶ Public Education
- ▶ Technical Education

References

Abt KL, Butry DT, Prestemon JP, Scranton S (2015) Effect of fire prevention programs on accidental and incendiary wildfires on tribal lands in the United States. Int J Wildland Fire 24(6):749–762

Balch JK, Bradley BA, Abatzoglou JT, Nagya RC, Fuscod EJ, Mahooda AL (2016) Human-started wildfires expand the fire niche across the United States. Proc Natl Acad Sci 114(11):2946–2951

Butry DT, JP Prestemon (2005) Spatio-temporal wildland arson crime functions. Selected Paper Presented at the American Agricultural Economics Association Annual Meeting. Providence, RI

Butry DT, Thomas DS (2017) Under-reporting of wildland fires in NFIRS: California. Int J Wildland Fire 26(8):732–743. https://doi.org/10.1071/WF17004

Butry DT, Prestemon JP, Abt KL, Sutphen R (2010a) Economic optimisation of wildfire intervention activities. Int J Wildland Fire 19:659–672

Butry DT, Prestemon JP, Abt KL (2010b) Optimal timing of wildfire prevention education. In: Perona G, Brebbia CA (eds) Modelling, monitoring and management of forest fires II. WIT Press, Southampton, pp 197–206

Butry DT, Prestemon JP, Thomas DS (2014) Investigation of the decline in reported smoking-caused wildfires in the USA from 2000 to 2011. Int J Wildland Fire 23(6):790–798

Holmes TP, Prestemon JP, Pye JM, Butry DT, Mercer DE, Abt KL (2004) Using size-frequency distributions to analyze fire regimes in Florida. In: Engstrom RT, de Groot WJ (eds) Fire in temperate, boreal and montane ecosystems, Proceedings of the tall timbers 22nd fire ecology conference. Tall Timbers Research Station and the Canadian Forest Service, October 15–18, 2001, Kananaskis Village, Alberta, Canada, pp 88–94

National Wildfire Coordinating Group (2016) Guide to wildland fire origin and cause determination. PMS 412/NFES 1874

Prestemon JP, DT Butry (2005) Time to burn: Modeling wildland arson as an autoregressive crime function. Am J Agric Econ 87(3):756–770

Prestemon JP, Butry DT (2010) Wildland arson: a research assessment. In: Pye JM, Rauscher HM, Sands Y, Lee DC, Beatty JS (eds) Advances in threat assessment and their application to forest and rangeland management, Gen. Tech. Rep. PNW-802. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, pp 271–283

Prestemon JP, Butry DT, Abt KL, Sutphen R (2010) Net benefits of wildfire prevention education efforts. For Sci 56(2):181–192

Prestemon JP, Chas-Amil ML, Touza Montero J, Goodrick SJ (2012) Forecasting intentional wildfires using temporal and spatiotemporal autocorrelations. Int J Wildland Fire 21(6):43–54

Short KC (2017) Spatial wildfire occurrence data for the United States, 1992–2015 [FPA_FOD_20170508], 4th edn. Forest Service Research Data Archive, Fort Collins. https://doi.org/10.2737/RDS-2013-0009.4

Thomas DS, Butry DT, Prestemon JP (2011) Enticing arsonists with broken windows and social disorder. Fire Technol 47(1):255–273

USDA Forest Service (2003) FIRESTAT User's Guide, version 5.4. Available at https://fam.nwcg.gov/fam-web/helpdesk/firestat/firestat_54/firestat_users_guide_2003_1117.pdf. Accessed 2 Jan 2018