

## The Effects of Wildfire Prevention Activities

Douglas Thomas<sup>1</sup>, David Butry<sup>2</sup>, and Jeffrey Prestemon<sup>3</sup>

<sup>1</sup>National Institute of Standards and Technology, Applied Economics Office  
100 Bureau Drive, Gaithersburg, MD 20899

<sup>2</sup>National Institute of Standards and Technology, Applied Economics Office  
100 Bureau Drive, Gaithersburg, MD 20899

<sup>3</sup>USDA Forest Service, Southern Research Station  
3041 Cornwallis Road, Research Triangle Park, NC 27709

**Keywords:** fire prevention; human-caused fires; intentional fire; wildfire; unintentional fire; wildland

### ABSTRACT

Eighty percent of wildfires are human caused, so it is important for decision makers and land managers to consider the role of prevention activities that minimize the costs and losses of human-caused wildfires. There have been significant efforts aimed at reducing the impact wildfires have on people and their property, but the efficiency of these efforts often requires a better understanding of the human behavior contributing to the ignition process. This paper discusses three themes related to understanding and reducing the impact of human-caused wildfires: 1) the characteristics of wildfire data; 2) the effects of fire prevention activities; and 3) utilizing spatio-temporal patterns in human-caused fire ignitions to increase the effectiveness of prevention efforts. Research on these issues suggest that social collaboration, crime prevention, and education programs among other efforts may be effective tools in reducing the loss of life and property due to human-caused wildfire ignitions; however, data challenges frequently hinder a complete understanding and analysis.

### INTRODUCTION

Approximately 63 877 wildland fires were human caused in 2011, according to the National Interagency Fire Center (NIFC). These include fires that are mostly reported through county, state, and federal Incident Management Situation Reports. Using data from the National Fire Incident Reporting System (NFIRS) and from the National Fire Protection Association (NFPA), it is estimated that an additional 100 223 human-caused wildland fires were reported by municipal jurisdictions, resulting in an estimated total of 164 100 wildland fires being caused by human activity. These fires destroyed homes, neighborhoods, and communities along with acres of grass and forest land. Because of wildland fire threats, the nation has invested a significant amount of resources in limiting their numbers and consequences.

Unlike indoor-ignited structure fires, which often do not spread beyond the structure of origin, a single wildfire incident can impact thousands of structures. Structure involvement can occur rapidly and simultaneously by direct exposure to flames and to wind-blown embers and firebrands. These fires often grow large enough and fast enough that suppression resources are overwhelmed. Effective wildfire suppression strategies require knowledge of the values at-risk (California Fire Alliance 2001, Haight *et al* 2004).

Eighty percent of wildfires are human caused. Unintentional human-caused fires can be caused by carelessness, failure of equipment, or a number of other factors. A significant proportion of the literature on accidents, in general, focuses on occupational accidents. Approximately 80 % to 90 % of these accidents are thought to be due to human error (Heinrich *et al* 1980, Hale and Glendon 1987, Salminen and Tallberg 1996); thus, the vast majority involves human behavior and not unforeseen acts of nature. Research on occupational accidents has concluded that the best safety and health programs have an established safety culture (Occupational Safety and Health Administration), which includes “shared perceptions of the importance of safety and... confidence in the efficacy of preventive measures” (Health and Safety Commission 1993). Research has further found a significant correlation between reduced accidents and positive safety culture/safety climate in the workplace (Hofmann and Stetzer 1996, Oliver *et al* 2002, Gillen *et al* 2002, Hemingway and Smith 1999, Clarke 2006, Bjerkan 2010, Tomas 1999, Varonen 2000, Lucas 1992). A positive safety culture/climate might be described as an environment where people conform to norms and rules regarding safety. It is plausible, therefore, that communities that recognize the importance of safety and that take preventive measures are also likely to have a lower rate of accidents. In 2009, there were an estimated 6.8 million injuries resulting in 2923 deaths that occurred at personal residences (U.S. Consumer Product Safety Commission 2009). It is likely that these accidents have similar causes to occupational accidents (i.e., human behavior); thus, the effect of careless behavior at home is significant. Many of these injuries may have been prevented by taking safety measures. In regards to accidental fires, it is estimated that 55 % of wildfires between 2002 and 2007 were human caused unintentional fires and, although these accidents are not always related to occupational accidents, they are likely related to careless behavior influenced by a lack of shared perceptions on the importance of safety and prevention.

Intentional fires occur under somewhat different circumstances. Evidence suggests that reducing arson through law enforcement remains a challenge; arson (all types) is cleared at a low rate, similar to other property crimes. Arson was cleared by arrest in a total of 22.5 % of cases for reporting agencies in the United States in 2006 (US Department of Justice 2007). From 1995 to 2006, an average of 22 % of structure, 7.6 % of vehicle based, and 19.4 % of other arson offenses were cleared by arrest. In contrast, non-negligent murders were cleared by arrest in 61 % of cases, forcible sexual offenses in 41 % of reported cases, aggravated assault in 54 %, and robbery in 25 % in 2006 (U.S. Department of Justice, Federal Bureau of Investigation 2007). Although similar to the clearance rate for other property crimes, the low rate for arson highlights both the investigative challenges of arson and the limited law enforcement resources available.

While human-caused ignitions dominate natural-caused ignitions in numbers, they tend to cluster in space and time (e.g., see Genton *et al* 2006, Butry and Prestemon 2005, Prestemon and Butry 2005, Prestemon and Butry 2008, Thomas *et al* 2012), implying a predictability to the ‘when’ and ‘where’ they occur. For instance, they both tend to follow the same daily trends as seen in Figure 1. To the extent that the patterns are predictable it suggests that efforts made to prevent them may be successful. Forecasting the time and place of wildfires in order to prevent them, however, requires reliable and detailed data describing the ignition process. There are opportunities for improvement in data quality on wildland fires.

This paper discusses three themes related to understanding and reducing the impact of human-caused wildfires: 1) the characteristics of wildfire data; 2) the effects of fire

prevention activities; and 3) the utilization of spatio-temporal patterns in human-caused fire ignitions to increase the effectiveness of prevention efforts.

### WILDFIRE DATA

The threat that wildland fires pose to humans and their environment underlines the importance of quantifying the number and extent of fires in the United States. Additionally, in order to effectively prevent wildland fire, it is necessary to have accurate data that provides details on fire incidents and the circumstances under which they occur. Currently, a number of data challenges exist. There does not exist a complete (single, unified) collection of data on wildland fires. Additionally, the current individual datasets are not uniform or standardized, making it difficult to analyze incident details across multiple jurisdictions.

Of the 15 executive departments in the federal government, four of them are involved with the collection and/or distribution of unprocessed fire data. In addition to these government departments, two private entities also collect and/or distribute unprocessed fire data. Among the most recognized collectors/distributors of data is the U.S. Fire Administration (USFA). As seen in Figure 2, it is an entity of the Department of Homeland Security’s (DHS) Federal Emergency Management Agency (FEMA). The USFA is authorized to gather, analyze, and standardize fire information, and it collects data through the National Fire Incident Reporting System (NFIRS). The National Fire Protection Association (NFPA), also shown in Figure 2, is another entity that is recognized for collecting and distributing fire data. NFPA is a private, nonprofit organization with the mission of reducing the “worldwide burden of fire and other hazards on the quality of life by advocating consensus codes and standards, research, training, and education.” The NFPA gathers data through its annual survey of municipal fire departments. The USFA data and the NFPA data can be combined to create a data set that provides details on the aggregate number of fires within municipal jurisdictions.

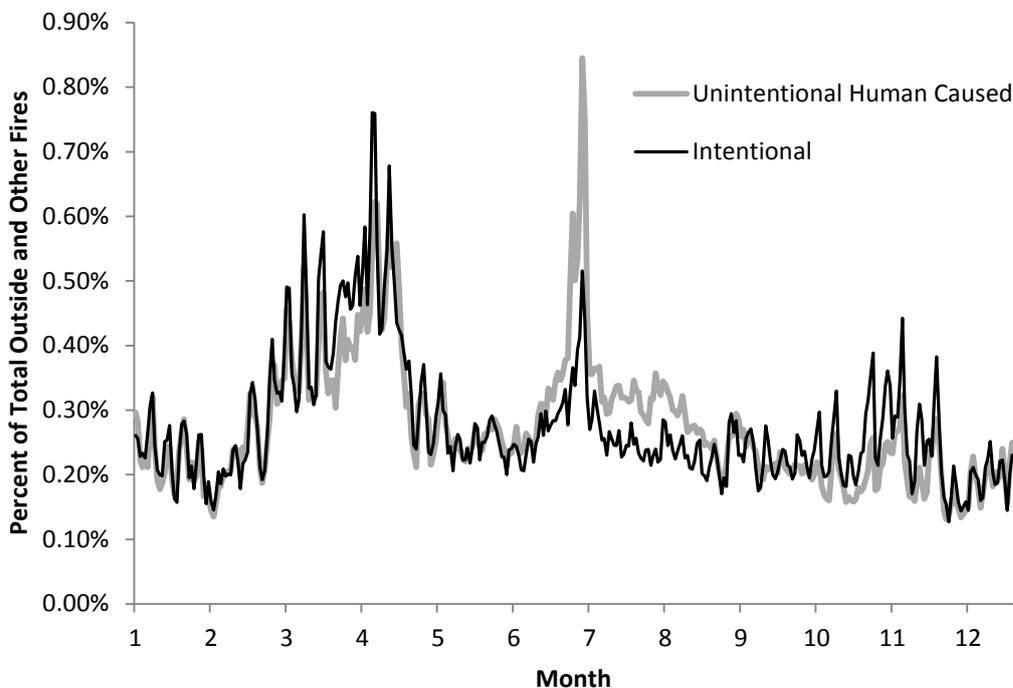


Figure 1: National Daily Percent of Outside Human Caused Fires by Intention Averaged by Day of Week, 2002-2006 (Note: Outside fires includes all fires that are not structural or vehicle fires)  
Data Source: US Fire Administration. National Fire Incident Reporting System. 2012.

As seen in Figure 2, a number of other entities are recognized for collecting wildland fire data; these include the U.S. Forest Service (USFS), an entity of the U.S. Department of Agriculture; Bureau of Indian Affairs (BIA), an entity of the Department of the Interior (DOI); Fish and Wildlife Service (FWS), an entity of DOI; Bureau of Land Management (BLM), an entity of DOI; Bureau of Reclamation (BOR), an entity of DOI; National Park Service (NPS), an entity of DOI; and the National Fire and Aviation Management Web Applications (FAMWEB). Each of these entities is shown in red in Figure 2 along with their parent organizations. FAMWEB is an interagency effort that includes a number of entities, including USFS Fire and Aviation Management (FAM) and the National Association of State Foresters (NASF). The FAMWEB collects and distributes wildland fire data submitted by wildland fire dispatch centers through standardized forms. The National Interagency Fire Center (NIFC) is another interagency body, and it includes the National Business Center's Aviation Management Directorate (NBC-AMD) and the Department of Commerce's (DOC) National Oceanic and Atmospheric Administration (NOAA).

Figure 2 illustrates the complications that are involved with analyzing fire incidents. Additional complexity is added by the fact that data is collected in different formats. A number of the fire collection entities in Figure 2 have their own individualized method, format, and purpose, a diversity of approaches that makes the aggregation of fire data difficult.

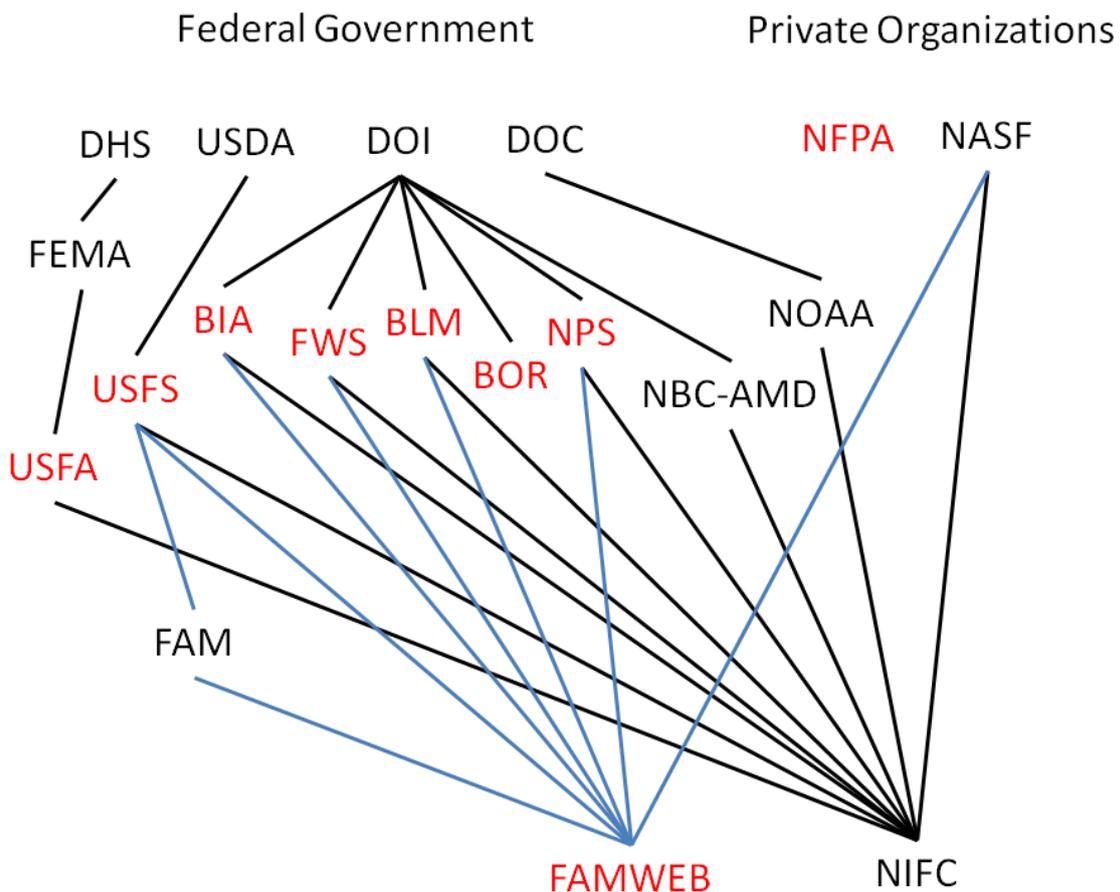


Figure 2: Organizational Chart of Entities Collecting and/or Distributing National Unprocessed Fire Data (distributors/collectors of unprocessed fire data are shown in red)  
 Source: Thomas, D.S. and Butry, D.T. "Tracking the National Fire Problem: The Data Behind the Statistics." National Institute of Standards and Technology. Technical Note 1717.

Advancements in measurement science are needed to accurately quantify and track the U.S. fire burden as well as to characterize the uncertainties of the data (e.g., economic losses, area burned, numbers of fires by cause, ignition time and date) that are gathered. Despite the many organizations involved in data collection, detailed annual statistics characterizing fire burden are not published in a way that can support economic analysis of the U.S. fire problem at the national scale. Without improved accuracy and estimates of uncertainty, it is difficult to assess year-to-year variations (e.g., trends) in key fire statistics, and to evaluate the impact new technologies or fire mitigation strategies might be having on fire losses, injuries, and fatalities, and also to assess their cost-effectiveness.

The U.S. Fire Administration (USFA), NFPA, and the Consumer Products Safety Commission (CPSC) all provide important reports on the fire problem in the United States. The NFPA and CPSC administer surveys to collect data to augment the data provided in NFIRS or to collect data not collected by NFIRS. Because NFIRS is a voluntary (i.e., non-random) data collection system, however, the statistics derived from it may not be representative of the U.S. fire problem. Thus, statistics derived from these data may not be comparable from year-to-year, making the tracking of fire trends difficult. Another challenge is that there is not a method for measuring, or analyzing, the uncertainty (i.e., measurement error) surrounding current fire statistics. These are difficult to create given the non-randomness of the NFIRS sample.

The data challenge can be illustrated in the estimate of human caused wildfires discussed in the introduction. The estimate of 164 100 human caused wildfires in 2011 required three datasets: NIFC data, NFIRS data, and NFPA data. The NIFC data provided a count of wildland fires on state and federal lands with some county lands also included. In order to estimate fires within municipal jurisdictions, fire department data obtained by survey and reported to NFPA are used to scale NFIRS data, which is a partial (non-random) census of fire department activity. Although this is, arguably, the best estimate available, it does not account for reporting bias; it does not fully account for fires that county governments responded to; the combined datasets have different formats, thus, they cannot be broken into more detail; and it is not entirely clear if there is any overlap between the municipal estimates and the NIFC estimates. These challenges make it difficult to conduct meaningful analysis on fire incidents, at least at a national-level.

The NFIRS data provided by the U.S. Fire Administration and the NFPA survey data both contain loss estimates made by fire response personnel. These estimates largely exclude the damage caused by wildfires beyond municipal jurisdictions, and other reporting agencies tend not to provide a dollar loss estimate. Therefore, there is a need to quantify the value of these damages. There is also a need for damage estimates provided to NFIRS and the NFPA to be validated, since they are not necessarily made by those with the expertise to assess the value of fire damages. Although there are a number of shortcomings in the available data on wildfires, some analyses and conclusions can be drawn from them. The following section presents a selection of analyses on the prevention of human caused wildfires.

## **WILDFIRE PREVENTION**

### ***Law Enforcement and Norm Violating Behavior***

Law enforcement affects crime through at least two avenues. There is a direct effect, exercised through fines and incarceration, and there is a secondary effect, deterrence. This secondary effect is supported by Becker's economic model of crime, which proposes that the

'cost' of committing a crime (e.g., fines, fees, or jail time) influences the probability that a would-be criminal engages in illegal behavior (Becker 1968). In more general terms, if an individual perceives that there is a significant cost for participating in a certain behavior, they are less likely to engage in that behavior. This general observation has two implications: 1) negative consequences impact all behavior and not just criminal behavior, and 2) the cost of the behavior only needs to be perceived to influence decision making. The first implication is important because it implies that negative consequences can affect any behavior and not just criminal behavior; thus, careless behavior that causes wildfires can also be impacted. The second implication is important because it is not the actual probability of experiencing negative consequences that affects the decision, but rather it is the perceived probability. Research has shown that just the perception of unpunished criminal activity may influence the probability of engaging in illegal behavior. For instance, Keizer *et al* (2008) showed that individuals were far more likely (69 % vs. 33 %) to litter in the presence of increased social disorder (in the form of graffiti) than without the disorder, *ceteris paribus*. Other, seemingly similar, experiments provided analogous results where individuals violated rules and even police ordinances, such as those that could prevent accidental fires, when in the presence of increased social disorder. The study concluded that "as a certain norm-violating behavior becomes more common, it will negatively influence conformity to other norms and rules" (Keizer *et al* 2008, Wilson and Kelling 1982, Lochner 2007). Thus, individuals in the presence of norm-violating behavior are more likely to commit arson. Additionally, in the presence of norm-violating behavior, individuals are less likely to adhere to fire safe behavior, which relies on conscientious individuals conforming to rules and norms (Butry *et al* 2010; Prestemon *et al* 2010) that reduce the risk of a fire or heat source spreading beyond its intended use. Thus, visible evidence of norm violating behavior encourages further deviation from the norms and rules that prevent accidental fires.

Two studies were conducted to examine the impact that police presence, police effectiveness, and visible evidence of norm violating behavior have on intentional and unintentional wildfire ignitions. The first study, by Thomas *et al* (2011), modeled the incidence of wildland and non-wildland arson ignitions in Michigan from 2001 to 2005. Using NFIRS data, this work found that the elasticity of ignitions with respect to the number of police officers per capita is -0.094, and that the elasticity with respect to the arson arrest rate, a measure of police success, was -0.009 (see Table 1). That is, a 1 % increase in the per capita number of police officers results in a 0.094 % decrease in arson incidents and a 1 % increase in the arrest rate results in a 0.009 % decrease in arson incidents. The arson arrest rate, however, was not statistically significantly different from zero in the model. Further analysis indicates that a 10 % increase in police per capita would result in a 0.98 % decrease in arson incidents. The paper also found that areas marked with physical and social disorder and/or many vacant buildings are at heightened risk of arson, both wildland and non-wildland. A 1 % increase in the building vacancy rate, a proxy for evidence of norm violating behavior, results in a 0.055 % increase in wildland arson ignitions (Table 1). Additional analysis shows that a 10 % decrease in the vacancy rate results in a 7.64 % decrease in wildland arson ignitions.

The second paper, by Thomas *et al* (2012), modeled unintentional human caused wildfires also as a function of police force presence, police effectiveness, and factors that can affect the perception of punishment. Similar to the arson model, this analysis found that areas marked with physical and social disorder, and/or many vacant buildings are at risk to accidental wildland fires. The vacancy rate had an elasticity of 0.175 while an additional

Table 1: Elasticity of Factors Impacting Human Caused Wildfires

	Intentional Wildfires			Unintentional Human Caused Wildfires		
	Elasticity	-10%	+10%	Elasticity	-10%*	+10%*
Vacancy Rate	0.553	-7.6%	8.6%	0.175	0.1%	2.9%
Visible Crime	0.007	0.2%	-0.2%	0.022	-1.8%	4.9%
Police per capita	-0.094	1.0%	-1.0%	-0.205	6.8%	-3.0%
Arrest rate	-0.009	0.1%	-0.1%	-0.045	1.9%	1.0%

\* A 10 % increase in the number of vacancies is calculated in place of the vacancy rate

Note: Variables that are greyed out are not statistically significant

Sources: Thomas, Douglas S. David T. Butry, and Jeffrey P. Prestemon. (2011) “Enticing Arsonists with Broken Windows and Social Disorder,” *Fire Technology*. 47(1) 255-273. And Thomas, Douglas S., David T. Butry, and Jeffrey P. Prestemon. (2012) “Social Disorder, Accidents, and Municipal Wildfires.” In the Proceedings of the 3rd Human Dimensions of Wildland Fire,” International Association of Wildland Fire, Missoula, MO. April 17-19, 2012: 11-27.

proxy for norm violating behavior, visible crime, had an elasticity of 0.022. A 10 % decrease in vacancies resulted in a very slight change in accidental fires, while a 10 % decrease in visible crime resulted in a 1.8 % decrease. The study also indicates that the elasticity of arson ignitions with respect to police per capita is -0.205, while the elasticity with respect to the arrest rate was -0.045; however, similar to the arson model, the arrest rate was not significant. Further analysis shows that a 10 % increase in the per capita number of police results in a 3.0 % decrease in accidental wildland fires.

### Prevention Education

Another effort to reduce unintentional wildfires is education. These efforts make individuals aware of the costs of wildfire to both themselves and society while also informing the public about what behaviors and actions increase their likelihood of igniting a fire. Prestemon *et al* (2010) evaluated the impact Florida’s wildfire prevention education program had on the number of human caused wildfires ignitions from 2002 to 2007. Five prevention activities were evaluated: media spots (television, radio, print ads), home visitations, public presentations, distributed number of informational brochures, and community wildfire hazard assessments. Human-caused wildfires included those ignited by escaped campfires, escaped debris fires, cigarettes, and children. Using statistical methods, the number of human caused wildfires was compared to the number of prevention activities occurring within the same month, as well as the number of prevention activities that occurred within the previous six months. The comparisons were made while controlling for weather, climate, previous fuel treatments, previous wildfire activity, population, law enforcement, and regional and seasonal effects. This analysis showed that media public service announcements (TV, radio, and print ads), presentations, and distributing brochures and flyers reduced the incidence of accidental wildfire with elasticities of -0.26, -0.22, and -0.24, respectively. That is, a 1 % increase in public service announcements reduced these fire incidents by 0.26 % while a 1 % increase in presentations and brochures reduced them by 0.22 % and 0.24 %. The net benefits of these efforts were found to vary spatially, suggesting that the optimal use of resources would treat spatial locations individually (Butry et al 2010a, Butry et al 2010b, Prestemon et al 2010).

The results also show that media spots, presentations, brochures, and community hazard assessments were effective at reducing the number of human-caused ignitions in the month they were conducted. In addition, media spots, presentations, and brochures demonstrated a lasting prevention effect up to six months. A benefit-cost analysis was performed to determine the return on investment for additional investment. The marginal benefit-cost ratio was 35-to-1 statewide. (The expected savings are from suppression cost and fire-damage avoidance.)

Butry *et al* (2010a), using the same Florida data, explored the use of a coordinated prevention education program with fuel treatments (prescribed fire) to minimize the sum of human-caused wildfire costs (program costs) plus fire-related damages. (The level of effort exerted to minimize the sum of costs plus losses is considered economically optimal – at the optimum, a dollar spent on either program would result in avoided losses strictly less than the dollar investment.) On economic grounds, the findings supported an expansion of wildfire prevention activities by 168 %, along with an increase in fuel treatments by 74 %. (While the expansions might be economical, they might not be feasible, however.) The net benefit from such a coordinated expansion was estimated at \$24 million – a 7 % savings over the status quo.

Butry *et al* (2010b)—the third paper in the series—further extends the previous analyses by investigating how changes to the timing of prevention messages could be used to reduce human-caused ignitions. Two scenarios were evaluated: (1) a change to the timing of prevention messages; (2) a funding increase AND a change to the timing of prevention messages. The first scenario leveraged only the seasonality of the wildfire season so to get the prevention message ‘out in front.’ Assuming prevention resources could be reallocated over the year, the time change resulted in net benefit of \$3.9 million over a five-year period (statewide). If the costs of reallocation are essentially zero, then this strategy results in an infinite benefit-cost ratio. Accompanying a timing change with an increase in funding (+ \$1 million) would provide net benefits of \$4.4 million

These studies demonstrate that wildfire prevention education programs can have a significant effect on reducing the number and consequence of human-caused ignitions. They also show that the composition of the program (types of activities used) and the message timing matter too. Further, they provide support for coordinating the timing of prevention programs and fuel treatments to jointly reduce wildfire risks. A coupling is advantageous because while fuel treatments provide longer-term protection, prevention programs are generally more flexible in the near-term (e.g., prescribed burns can only be administered at certain times of the year – and not usually during the wildfire season), providing an ability to triage unexpected outbreaks.

### **FUTURE DIRECTIONS IN WILDFIRE PREVENTION**

As discussed in the examination of prevention education, the timing of prevention efforts impacts the effectiveness. One of the reasons that this likely occurs is because clusters of human caused wildfires occur in time and space. Temporal patterns include, but are not limited to, seasonal, weekly, and daily patterns. Prevention efforts, education programs, and law enforcement resources can be targeted during times of high fire risk and at high risk locations to more effectively reduce the likelihood of an ignition or to minimize the consequence of wildfire. Figure 3, which plots the percent of reported fires by month for intentional and unintentional fires, illustrates the seasonal pattern in human caused wildfires.

The pattern in the numbers of wildland fires peaks in March and April with a little resurgence in July, and, for intentional fires, a resurgence in November. The peak corresponds with previous findings showing the peak number of fire department fire runs occurred in March (10.1 %) and April (10.2 %) (USFA 2007). Overall, wildland fires affected the monthly workload of the municipal fire service (i.e., affected the yearly distribution of fire runs). However, wildland fires appear to be highly seasonal, and this seasonality varies across

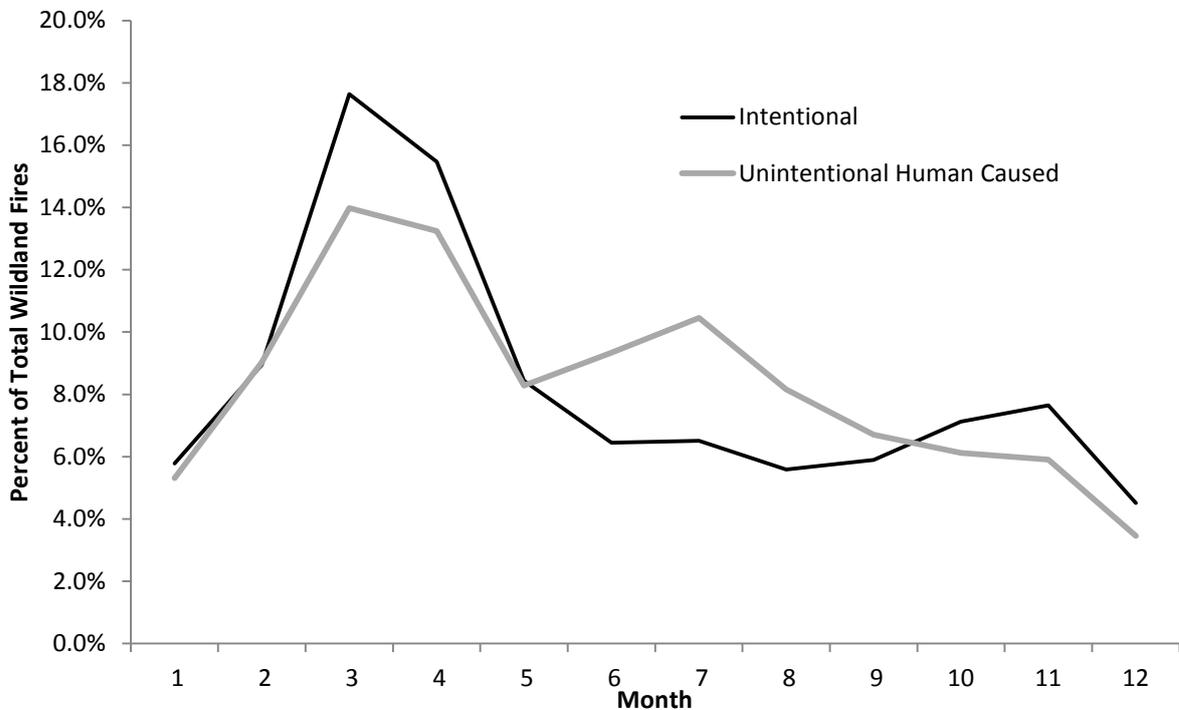


Figure 3. Percent of Reported Wildland Fires in NFIRS by Month and Intention, 2007-2012  
 Data Source: US Fire Administration. National Fire Incident Reporting System. 2012.

space, meaning that planning using forecasting methods might be useful in the future to alleviate potential resource constraints related to fire service response and effectiveness. The seasonality of unintentional human caused fires, furthermore, suggests a mechanism that can be used by fire education specialists in timing their message to communities that are at-risk of being affected by wildland fire (Thomas and Butry 2012).

Additional patterns of ignition, occurring often at even finer time scales, are seen in Figure 1, which, as previously discussed, plots the daily intentional and unintentional human caused fires between 2002 and 2006. There are a number of peaks and increases throughout the graph. Nearly all of the peaks for both types consist of Saturdays, Sundays, or holidays, with the seasonal increase in the springtime being visible. Although it is not shown in this figure, the springtime increase does not occur uniformly, as much of the increase occurs during peak afternoon ignition hours while non-peak hours remain relatively constant. Daily patterns can be seen in the larger graph in Figure 4, which plots the percent of reported fires by hour of the day for both intentional and unintentional human caused wildland fires. Both types demonstrate a very pronounced pattern peaking around 3PM, with very low activity during late night and morning hours. These trends can vary, however, as seen in the smaller graph of Figure 4, which shows the trends for New Year’s Eve, the night before Halloween, and Independence Day. The variation in the time trends illustrates how human activity patterns affect fire incidence. Other events, such as sporting events or political unrest, are likely to have implications for human caused wildfire ignitions, as well. For example, in

1992, after the Chicago Bulls defeated the Portland Trail Blazers in Game 6 of the NBA finals, fans took to the streets to celebrate, but the festivities eventually transformed into a riot that burned 15 buildings and injured numerous people. The 2002 soccer World Cup finals in Russia ended with riots and arson that killed one person and injured 27 (CNN 2002). Many events are associated with fireworks and other celebrations that are likely to result in

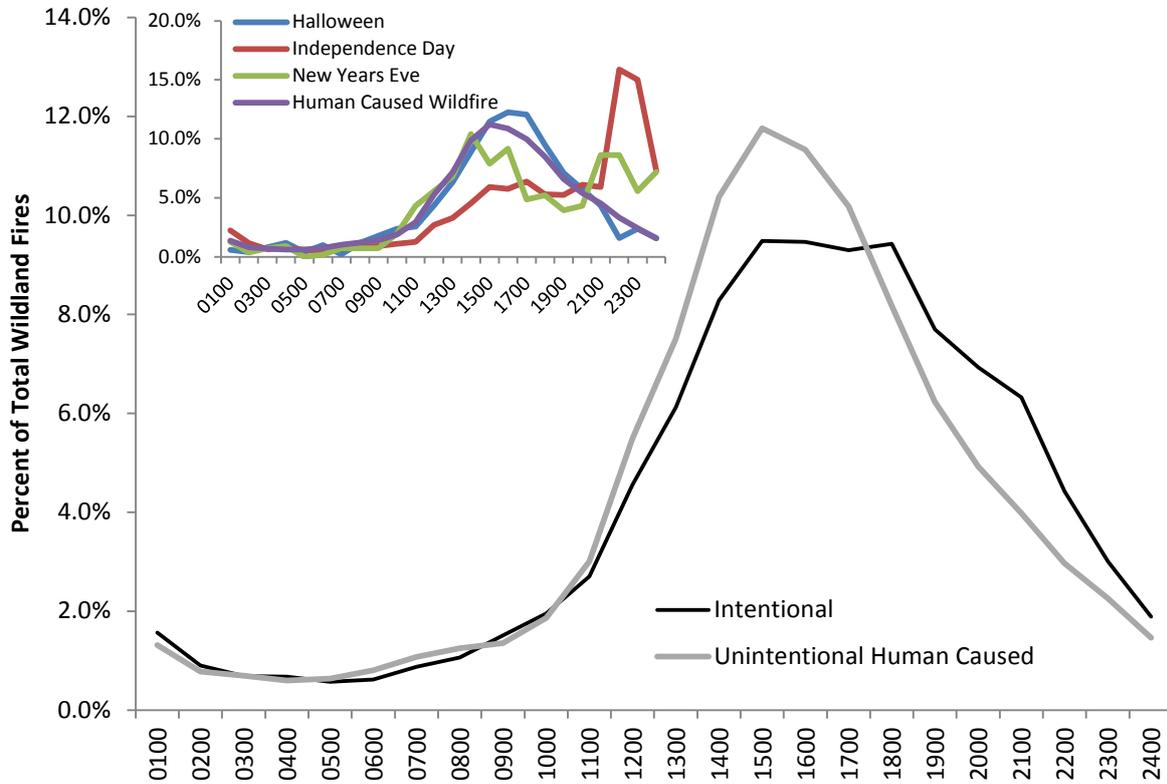


Figure 4. Percent of Reported Human Caused Wildland Fires in NFIRS by Time of Day and Intention. Data Source: US Fire Administration. National Fire Incident Reporting System. 2012.

accidental ignitions as well. Civil unrest, such as those following the trial of the officers accused of beating Rodney King, can also cause arson clusters (National Geographic 2009).

In addition to temporal clusters, spatial clusters of human-caused wildfires can also be illustrated, as seen in Figure 5, which shows a density plot of human caused fires in Jacksonville, FL. These spatial trends can be used to prevent human caused wildfire ignitions by prepositioning resources near high risk locations. It is logical that clusters of human caused wildfires would occur where high levels of human activity and wildland intermingle; however, in addition to this trend, evidence suggests that behavior trends vary within these areas. Devil’s Night in Detroit provides a good illustration. Devil’s Night had been known in Detroit as an evening of pranks the night before Halloween, at least until the early 1980’s. By the early 1980’s, Devil’s Night had morphed into a multiple evening affair, beginning the night of October 29 and ending Halloween evening, marked by rampant intentional fire setting throughout the city (Center for Disease Control 1997). Detroit, a city noted for its economic struggles (e.g., a 14.3 % unemployment rate (Bureau of Labor Statistics 2008)) is no stranger to crime and arson. But, in 1984 there were 810 fires, with nearly 600 intentional or suspicious fires set, during the three evenings of Devil’s Night. Arsonists targeted abandoned buildings, cars, trash containers, and “whatever would burn” (The New York

Times 1996). Year after year, arsonists returned to concentrated areas (see Figure 6), run-down and littered with vacant buildings and abandoned cars. Many of these arsons clustered spatially, as illustrated in Figure 6. A closer examination of arson by census tract using Poisson models confirms that spatial clusters of arson do occur in Detroit (Prestemon *et al* 2013).

Understanding, and manipulating, the relationship between arson fire and neighborhood conditions, law enforcement effort, and the spatio-temporal characteristics of intentional firesetting can be used to mitigate fire risk. Detroit's response to Devils Night provides an example of a community successfully using prepositioned resources to prevent arson. Following the height of Devil's Night in Detroit in the early 1980's, the city responded to these arson incidents in subsequent years by (1) strategically pre-positioning firefighters throughout the city; (2) eliminating arson targets by towing abandoned vehicles, demolishing vacant buildings, and removing large trash containers; (3) recruiting neighborhood volunteers to guard abandoned buildings and patrol streets; (4) administering a public relations campaign; and (5) sponsoring structured activities for teenagers and youths in the area (Center for Disease Control 1997). The total number of intentional and suspicious fires fell precipitously. It appears that the city's effort had the largest effect on the number of fires deliberately set by children. The Devil's Night example demonstrates that intentional and suspicious fires exhibit both spatial and temporal correlation, much of which can be explained by neighborhood characteristics (e.g., the presence of abandoned vehicles and buildings) and the time of year, and are affected by different mitigation strategies (not just policing). Detroit successfully used fire ignition trends to prevent arson fires in subsequent years and illustrates the potential success of these types of efforts.

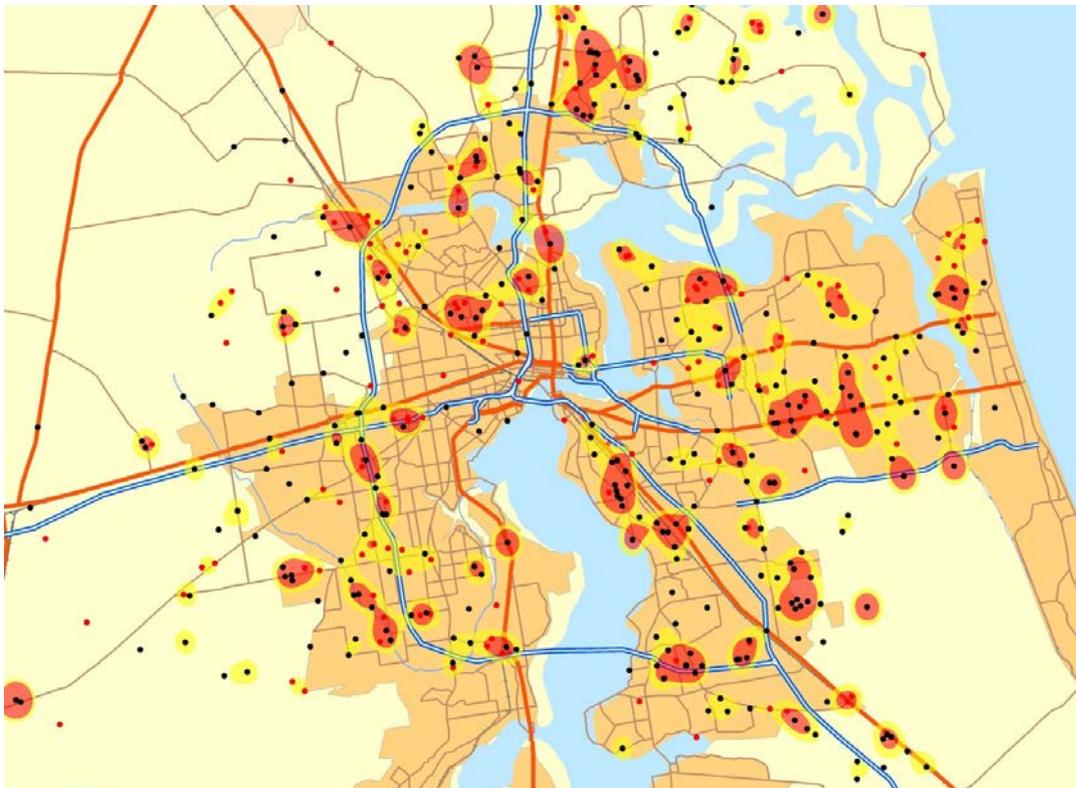


Figure 5: Density of Intentional and Unintentional Human Caused Wildland Fires Reported in Jacksonville, FL Between 2007 and 2011 (black points represent accidental ignitions while red points represent intentional ones) Data Source: US Fire Administration. National Fire Incident Reporting System. 2012.

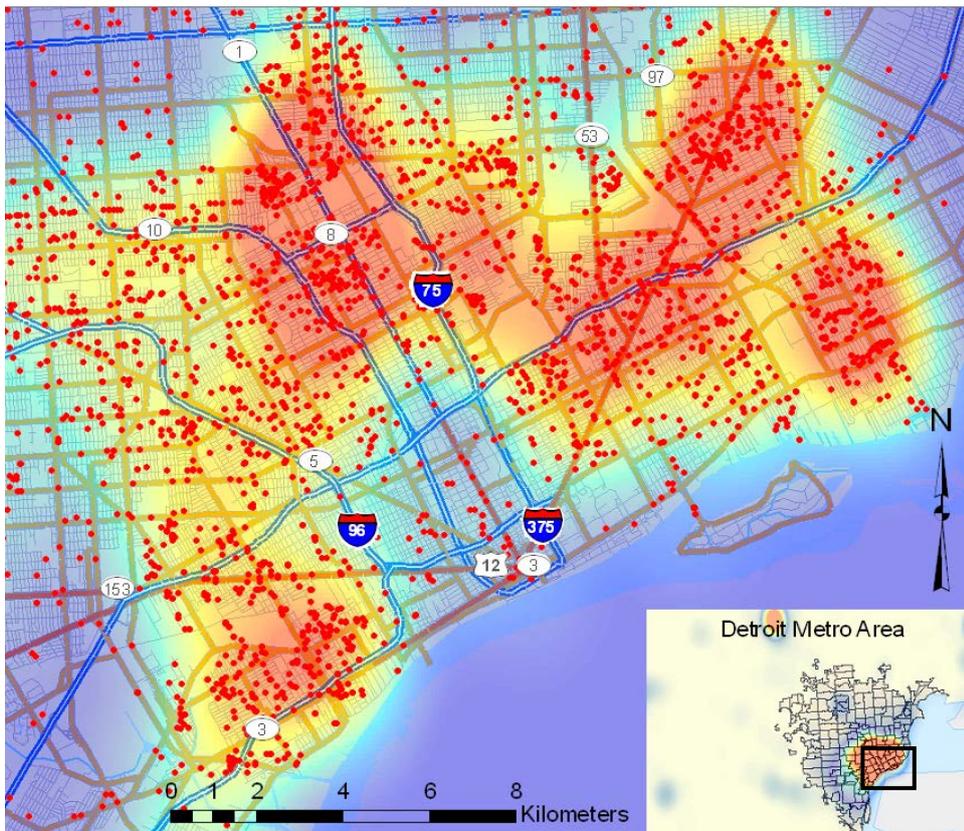


Figure 6: Density of Devil's Night Fires (wildland and non-wildland), Detroit 1985-1998. Areas in red distinguish high levels of fire; red points denote fire incidents  
Data Source: US Fire Administration. National Fire Incident Reporting System. 2012.

### CONCLUDING REMARKS

With scarce and limited resources, it is important to optimize expenditures on fire prevention and response. In order to achieve this goal, it is necessary to understand the extent of fire occurrence, the costs and losses related to fire, and the spatio-temporal trends. That is, it is important for decision makers and land managers, who invest in mitigation techniques and strategies to minimize the cost and losses of fire, to understand the extent of fire occurrence and the costs and losses that actually occur. As previously discussed, there are some limitations of existing wildfire data. Advancements in measurement science are needed to accurately measure, describe the uncertainty, and track the U.S. fire burden. Despite the many organizations involved in data collection, detailed annual statistics characterizing fire burden are not published in a way to support economic analysis of the entire U.S. fire problem, nor are associated measures of uncertainty provided.

A simple examination of the data that are available on human caused wildland fires reveals that these incidents occur in clusters in both time and space. Temporal patterns include, but are not limited to, seasonal, weekly, and daily patterns. These characteristics make human caused wildfires often predictable, thus implying they are preventable. Prevention efforts, education programs, and law enforcement resources can be targeted in space and time to more effectively reduce the risk of fire ignition, while fire response resources can be prepositioned to mitigate the damage that fires cause.

The surroundings of an individual can have implications on their behavior, as illustrated in two separate models: one of intentional wildland fires and one of unintentional wildland fires. Each models the incidence of wildland fire ignitions in Michigan from 2001 to 2005 as a function of police presence, police effectiveness, and visible evidence of norm violating behavior. These analyses found that areas marked with physical and social disorder, and/or many vacant buildings are at risk to human caused wildland fires. Additionally, the results suggest that a 1 % increase in police presence can reduce intentional fires by 0.09 % and unintentional fires by 0.21 %.

Research on the effects of wildfire prevention education suggests that education efforts can successfully be used to reduce accidental fire ignitions. A 1 % increase in public service announcements reduced accidental fire incidents by 0.26 % while a 1 % increase in presentations and brochure distribution reduced them by 0.22 % and 0.24 %.

### **Acknowledgement**

The Department of Homeland Security Science and Technology Directorate funded the production of the work presented in this material under Interagency Agreement No. HSHQDC-11-X-00565 with the National Institute of Standards and Technology (NIST).

### **REFERENCES**

- Butry, D.T., Prestemon, J.P., Abt, K.L., and Sutphen, R. 2010a. "Economic Optimisation of Wildfire Intervention Activities." *International Journal of Wildland Fire* 19: 659-672.
- Butry, D.T., Prestemon, J.P., and Abt, K.L. 2010b. "Optimal Timing of Wildfire Prevention Education." In G. Perona and C.A. Brebbia (eds.), *Modelling, Monitoring and Management of Forest Fires II*. WIT Press, Southampton.
- Butry, D.T. and Prestemon, J. P.. 2005. "Spatio-Temporal Wildland Arson Crime Functions." Selected Paper Presented at the American Agricultural Economics Association Annual Meeting. Providence, RI.
- Bjerkan, A.M. 2010. Health, Environment, Safety Culture and Climate – Analysing the Relationships to Occupational Accidents." *Journal of Risk Research*. 13: 445-477.
- California Fire Alliance. 2001. "Characterizing the Fire Threat to Wildland-Urban Interface Areas in California." <[http://frap.cdf.ca.gov/projects/wui/525\\_CA\\_wui\\_analysis.pdf](http://frap.cdf.ca.gov/projects/wui/525_CA_wui_analysis.pdf)>
- Center for Disease Control. 1997. "Urban Community Intervention to Prevent Halloween Arson – Detroit, Michigan, 1985-1996." *MMWR Weekly* 46(14):299-304.
- Clarke, S. 2006. Safety Climate in an Automobile Manufacturing Plant. *Personnel Review*. 35: 413-430.
- CNN. June 9, 2002. 'Russia Soccer Riot Leaves one Dead.'. <<http://www.cnn.com>>
- Consumer Product Safety Commission. National Electronic Injury Surveillance System (NEISS). <<http://www.cpsc.gov/library/neiss.html>>
- Genton, M.G., Butry, D.T., Gumpertz, M.L., and Prestemon, J.P. 2006. Spatio-Temporal Analysis of Wildfire Ignitions in the St Johns River Water Management District, Florida. *International Journal of Wildland Fire* 15: 87-97.
- Gillen, M., Baltz, D., Gassel, M., Kirsch, L., Vaccaro, D. 2002. Perceived Safety Climate, Job Demands, and Coworker Support Among Union and Nonunion Injured Construction Workers. *Journal of Safety Research*. 33: 33-51.

- Haight, R.G., Cleland, D.T., Hammer, R.B., Radeloff, V.C., and Rupp, T.S. Oct/Nov 2004. "Assessing Fire Risk in the Wildland-Urban Interface." *Journal of Forestry*. 41-48
- Hale, A.R., Glendon, A.I. 1987. *Individual Behaviour in the Control of Danger*. Elsevier. Amsterdam.
- Health and Safety Commission (HSC). 1993. Third report: organizing for safety. ACSNI Study Group on Human Factors. HMSO, London.
- Heinrich H.W., Petersen, D., Roos, D. 1980. *Industrial Accident Prevention*. 5<sup>th</sup> Edition. McGraw-Hill. New York.
- Hemingway, M.A., Smith, C.S. 1999. Organizational Climate and Occupational Stressors as Predictors of Withdrawal Behaviours and Injuries in Nurses. *Journal of Occupational and Organizational Psychology*. 72: 285-299.
- Hofmann D.A., Stetzer, A. 1996. A Cross-Level Investigation of Factors Influencing Unsafe Behaviors and Accidents. *Personnel Psychology*. 49: 307-339.
- Lochner, L. 2007. "Individual Perceptions of the Criminal Justice System." *American Economic Review*, 97(1): 444-460.
- Lucas, D. 1992. Understanding the Human Factor in Disasters. *Interdisciplinary Science Reviews*. 17: 185-190.
- National Geographic. 2009. *The Final Report: LA Riots*. <[http://channel.nationalgeographic.com/series/final-report/2770/Overview#tab-Videos/02283\\_00](http://channel.nationalgeographic.com/series/final-report/2770/Overview#tab-Videos/02283_00)>
- The New York Times. November 3, 1996. "Civic Angels Curb Detroit 'Devil's Night' Fire."
- Oliver, A., Cheyne, A., Tomas, J.M., Cox, S. 2002. The Effects of Organizational and Individual Factors on Occupational Accidents. *Journal of Occupational Psychology*. 75: 473-488.
- Prestemon, J.P., Butry, D.T., Abt, K.L., and Sutphen, R. 2010. "Net Benefits of Wildfire Prevention Education Efforts." *Forest Science* 56(2): 181-192.
- Prestemon, J.P. and Buttry, D.T.. 2005. "Time to Burn: Modeling Wildland Arson as a Autoregressive Crime Function." *American Journal of Agricultural Economics* 87(3): 756-770.
- Prestemon, J.P. and Butry, D.T. 2008. "Wildland Arson Management." In Holmes, T.P., Prestemon, J.P., and Abt, K.L. 2008. *Economics of Forest Disturbances: Wildfires, Storms, and Invasive Species*. Springer: Dordrecht, The Netherlands.
- Prestemon, J.P. Butry, D.T., and Thomas, D.S. 2013. "Exploiting Autoregressive Properties to Develop Prospective Urban Arson Forecasts by Target." Unpublished white paper.
- Salminen, S., Tallberg, T. 1996. Human Errors in Fatal and Serious Occupational Accidents in Finland. *Ergonomics*. 39, 980-988.
- Thomas, D.S. and Butry, D.T. 2011. "Tracking the National Fire Problem: The Data Behind the Statistics." National Institute of Standards and Technology. Technical Note 1717.
- Thomas, D.S., and Butry, D.T. 2012. "Wildland Fires Within Municipal Jurisdictions." *Journal of Forestry*. 110(1): 34-41.
- Thomas, D.S. Butry, D.T., and Prestemon, J.P. 2011. "Enticing Arsonists with Broken Windows and Social Disorder," *Fire Technology*. 47(1): 255-273.
- Thomas, D.S., Butry, D.T., and Prestemon, J.P. 2012. "Social Disorder, Accidents, and Municipal Wildfires." In the Proceedings of the 3rd Human Dimensions of Wildland Fire," International Association of Wildland Fire, Missoula, MO. April 17-19, 2012: 11-27.

Thomas, R. September 29, 2000. "Leicester Make Bitter Exit." *Guardian*. <<http://www.guardian.co.uk>>

Tomas, J.M., Melia, J.L., and Oliver, A. 1999. A Cross-Validation of a Structural Equation Model of Accidents: Organizational and Psychological Variables as Predictors of Work Safety. *Work and Stress*. 13: 49-58.

US Department of Justice, Federal Bureau of Investigation. 2007. Uniform Crime Reporting Program Data (United States): County-Level Detailed Arrest and Offense Data, 2000-2005. ICPSR. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [producer and distributor].

US Department of Justice, Federal Bureau of Investigation. . 2007. "Crime in the United States, 2006." <[http://www.fbi.gov/ucr/cius2006/about/variables\\_affecting\\_crime.html](http://www.fbi.gov/ucr/cius2006/about/variables_affecting_crime.html)>

US Fire Administration. 2004. All Structure Fires in 2000. Topical Fire Research Series

US Fire Administration. 2005. Fatal Fires. Topical Fire Research Series

US Fire Administration. 2007. Fire Department Fire Run Profile. Topical Fire Report Series.

US Fire Administration. 2008. Civilian Fire Injuries in Residential Buildings in 2005. Topical Fire Report Series.

Varonen, U., Mattila, M. 2000. "The Safety Climate and its Relationship to Safety Practices, Safety of the Work Environment and Occupational Accidents in Eight Wood-Processing Companies." *Accident Analysis and Prevention*. 32: 761-769.

Wilson, J.Q., and Kelling, G.L. March 1982. "The Police and Neighborhood Safety: Broken Windows." *The Atlantic* v. 249(3): 29-38.