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**Final Report**

**JFSP Project Number:** 09-1-9-2

**BLM Agreement/Task Order Number (if applicable):**

**Project Title:** A Fire Prevention Effectiveness Assessment for Multiple Ownerships

**Principal Investigator (PI):** Dr. Jeffrey P. Prestemon

**Collaborators:**

Dr. Karen L. Abt, Southern Research Station, USDA Forest Service

Dr. David T. Butry, National Institute of Standards and Technology

Douglas S. Thomas, National Institute of Standards and Technology

Sam Scranton, Bureau of Indian Affairs

Scott L. Goodrick, Southern Research Station, USDA Forest Service

Parker T. Mothershead, Southern Research Station, USDA Forest Service

Terry K. Haines, Southern Research Station, USDA Forest Service

Susan Marzec, Bureau of Land Management

John Owens, Bureau of Land Management

Suzanne Romero, Region 3, USDA Forest Service

Reid Shelley, Region 4, USDA Forest Service

Loren Walker, Region 4, USDA Forest Service

Angela Yearwood, Region 5, USDA Forest Service

## **Abstract**

This study first summarized findings of fire prevention education statistical modeling from the State of Florida from a study originally led by the Principal Investigator and two major collaborators (Karen Abt, USDA Forest Service, and David T. Butry, National Institute of Standards and Technology). The study next measured the statistical effects of wildfire prevention programs occurring on tribal lands administered by the Bureau of Indian Affairs, with primary involvement of major collaborator Sam Scranton (Bureau of Indian Affairs). Using first a binary variable indicating the presence or absence of a wildfire prevention program on lands managed by the tribe or tribal grouping, the second activity revealed that fire prevention programs significantly reduce the occurrence of all categories of wildfires. The largest impacts of these programs are found for campfire escapes, arson, and children ignited wildfires. The overall average reduction in the number of wildfires due to the prevention programs is estimated to be up to 93%. Economic assessments of these impacts are still underway and will be completed as additional data becomes available. Estimates of the statistical effects of specific categories of prevention efforts are still under development and will be completed in the next six months.

## **Background and purpose**

Government agencies devote substantial resources toward reducing the occurrence of unwanted wildfires. Yet limited research has documented the effectiveness of wildfire prevention education or other wildfire prevention efforts (engineering, law enforcement, etc.) that would economically justify the use of such resources. Published research that has confirmed the efficacy of fire prevention is new and focused on Florida for accidentally ignited fires, and arson and on California and Michigan for arson wildfires. Efforts to quantify the effects of wildfire prevention on other ownerships for fires of multiple causes, especially for federally administered lands, are lacking.

Given these facts, the objectives of this research were split into two parts. First, we sought to summarize the wildfire prevention effectiveness identified by the most up-to-date, refereed quality scientific analyses completed for Florida on all ownerships there. This summary revealed the statistical effects of alternative fire prevention strategies on the aggregate of a subset of human-ignited wildfires (those ignited by equipment, children, smoking materials, campfire escapes, and debris burn escapes). Second, we endeavored to quantify the effects of similar efforts on federally managed land in the U.S. on all nine major categories of fire causes (in addition to those above, also lightning, arson, railroad, and miscellaneous).

Accomplishment of the first objective was straightforward. The research in Florida made use of available fire prevention data, reported at the Forest District level in Florida since the early 2000's, combined these data with historical records of wildfire occurrences by causes, weather, socioeconomic variables, fuels management, and law enforcement efforts. The second objective, however, was more challenging because records of wildfire prevention efforts were

inconsistently collected or summarized and/or were not available for long time spans. Incomplete, inconsistent and short time series make statistical modeling difficult. So a principal task in this research has been to initiate the collection of wildfire prevention data for a small subset of federally administered lands in the U.S. This involves the cooperation of multiple collaborators from the Forest Service, the Bureau of Land Management, and the Bureau of Indian Affairs.

### **Study description and location**

The initial spatial scope of our analysis was land managed by three federal agencies: the USDA Forest Service (national forests of Forest Service regions 3, 4, and 5, mainly encompassing New Mexico, Arizona, Utah, Nevada, parts of Wyoming and Idaho, and all of California); the Bureau of Land Management (Utah); and 19 tribal reporting units administered by the Bureau of Indian Affairs. Even after significant, and continuing, efforts, we have been unable to obtain the data we anticipated when the study began. Below we describe the study in three parts, (1) we describe our efforts to obtain prevention data and the eventual outcome, (2) we describe the statistical analysis conducted to date on BIA lands, and (3) we summarize the work we are continuing in this area.

#### *Prevention Activity Data*

The study plan for this work included collaboration from representatives in Regions 3, 4 and 5 of US Forest Service. As of today, we have not been able to obtain data from Regions 3 or 5. Our initial collaborators have been replaced; the task proved more difficult than anticipated; and in a familiar refrain, budget cuts further reduced the time our collaborators had to devote to the data collection and reduced the time field personnel had to enter data.

At our own expense, we hired a temporary employee to seek data from individual forests and state governments in the hope that we would find a usable source of data for analysis. While we have significant amounts of data, the consistency of the data and the lack of multiple years limits what we can do with this data (see attached worksheet). We will further evaluate the state level data to determine if any modeling can be done.

We also reassigned a permanent employee part-time to facilitate the data collection from the BLM-Utah and Region 4, USFS. We do have data that we believe are of adequate detail and range that we can empirically estimate models for the prevention programs in Utah. We expect to develop models on the Utah data over the next year. These models will be based on earlier models used in Florida and for the BIA (discussed below).

Our collaboration with Sam Scranton, BIA provided us with detailed activity data, similar to what was used in the Florida study for 19 BIA units. This data was initially provided for 1996-2009, and the statistical results discussed in the next section focus on this time period. We have

since received the 2010 and 2011 data from BIA, and have also obtained data from BIA on the presence of prevention programs on BIA units nationwide to use in an additional analysis.

### *Statistical Analysis of Tribal Lands*

Our sampling design and estimation methods for tribal ownerships were based on approaches used in the Florida analyses (see discussion of related studies below). There are statistical methods that allow for identification of wildfire prevention effectiveness with the short time series (panel data methods) available in the analyses conducted. However, the time length of the tribal lands analyses were extended to include the years prior to the initiation of an active, large-scale wildfire prevention program on these same 19 units. We are in the process of extending these statistical analyses to tribal units outside of these 19 which will enhance the statistical results.

Data on fire prevention efforts were derived directly from the unit level for the BIA describing the amounts and types of fire prevention activities. Wildfires and acres burned by different causes at fine temporal time scales (e.g., month, quarter, year) were assembled by collaborators on this study. Wildfire occurrence data was derived from the BIA's WFMI databases. Additional data on socioeconomic variables hypothesized to influence preventable wildfire occurrence (e.g., population, economic activities, etc.), law enforcement efforts, fuel class, and climate and weather data were assembled from available local, state, and federal sources, including those of the BIA (especially law enforcement information).

The effectiveness of fire prevention can be measured both in terms of the number of fires prevented per unit of fire prevention applied and in terms of damages averted per unit of fire prevention. Calculating the returns to fire prevention is straightforward and derives directly from equations of fire starts modeled empirically as a function of prevention and a variety of other variables, including fuels management, weather, historical wildfire, and socioeconomic measures. Additionally, it is our ultimate intention to report the value of fire damages averted. In fire economics, this is typically described in the context of a long-run cost plus loss equation. In optimization, the manager seeks levels of fire management inputs that minimize total fire losses (damages) plus costs (prevention budgets) of those inputs.

Wildfire occurrence ( $N$ ) was assumed to be a function of weather, climate, socioeconomic factors, fuels or ecological factors, seasonality of different forms, and interventions such as fuel treatments or wildfire prevention efforts. Monthly observations of tribal unit wildfire and prevention activities were assembled. The effect of prevention was evaluated against seven wildfire causes (escaped campfires, smoking materials, escaped debris fires, arson, equipment, children, and miscellaneous). The study period was from 1996 to 2009. The vector  $x$  included an indicator variable denoting whether a tribal unit had a wildfire prevention program in place (for that month). Prevention programs started at different times, across tribal units; however,

none started before 2005. The vector of free inputs included information on weather, wildfire history, trend variables, and dummy variables for year, month, and tribal unit.

The potential for simultaneity bias (that prevention effort and wildfire ignition starts are simultaneously determined) led to the use of a ‘control function’ regression approach (see Prestemon et al. 2010). These statistical results can then be used in further analyses to calculate cost-benefit ratios for, to the extent the data allows, each prevention activity and fire cause type.

In an economic or financial assessment about whether prevention efforts yield positive net benefits, we can calculate marginal and non-marginal benefit-cost ratios if we are provided, or can estimate, values of both the costs (costs of the prevention programs) and benefits (reduced fire damages and reduced fire suppression expenditures). If we do not know how spending is distributed among different prevention activities, a short-run non-marginal benefit-cost ratio can be calculated, which assumes that all prevention activities change by a constant factor.

### *Continuing Analyses*

Prevention data have been collected for BLM and Forest Service lands in Utah, and a subset of data for the BIA units nationwide. Independent data collection for these geographic areas is underway, and will be followed by statistical analyses similar to those employed for Florida and BIA-20. Additionally, the state level data may provide us with usable time series, and will be evaluated to determine if the detail and scope are adequate for the development of statistical models.

## **Key findings**

***Wildfire prevention efforts on tribal lands that have enacted large-scale fire prevention programs are highly effective.*** The presence of a wildfire prevention program was found to reduce the number of wildfire ignitions for each of the causes evaluated (escaped campfires, smoking materials, escaped debris fires, arson, equipment, children, and miscellaneous). Alternative methods exist for evaluating the effect of prevention on avoided fire starts. To limit the effect of possible data outliers and extreme (rare) events, the marginal effects of prevention on ignition causes were evaluated at the mean (of all other covariates). It is estimated that the presence of a prevention program has reduced the number of wildfire ignitions between 2 to 128 per month on average, for each tribal unit. This represents a reduction in the number of ignitions of from 19% to 93%.

***Wildfire prevention efforts on tribal lands appear to have the largest long-run impacts on campfire escapes, arson, and children ignited wildfires.*** Depending on the method for evaluating the effect of prevention status on ignition cause, the effectiveness ranking changes. Based on counterfactual analysis, the effectiveness ranking declines from highest to lowest, as

follows: escaped campfires, arson, children, escaped debris fires, smoking materials, equipment, and miscellaneous. In general, prevention efforts have (relatively) limited effect on wildfires caused by smoking materials, equipment, and miscellaneous causes. This may be due to the infrequency of these fires (e.g., smoking material), non-specific or numerous underlying causes to the wildfire generation process (e.g., miscellaneous, equipment), or may reflect the current prioritization of prevention objectives.

***Specific wildfire prevention efforts on tribal lands have uncertain impacts, although more research could help to reveal with greater precision their effects on unwanted wildfires.***

Statistical challenges prevented a rigorous analysis of how individual prevention activities (e.g., those listed in National Wildfire Coordinating Group Publication PMS-455 [National Wildfire Coordinating Group 1998], “Wildfire Prevention Strategies”) affect wildfire ignitions by cause. Needed are longer time-series data, detailing prevention activities, and/or additional cross-sectional data, perhaps from other federal agencies.

***Data on wildfire prevention efforts are scarce, incompletely and inconsistently reported across national forests, regions, and Bureau of Land Management lands, but new efforts are underway to better collect such data.***

We have communicated with leaders in fire prevention in the Forest Service, the Bureau of Land Management, and the Bureau of Indian Affairs. As a part of this study, we have reached out to wildfire prevention leaders to provide them with templates for consistent prevention reporting. To our knowledge, these efforts have resulted in consistent data reporting on many tribal units in our study as well as on some national forests in Region 4 and some units of the BLM in Utah.

## **Management implications**

***On tribal lands scattered from the upper Midwest to the West Coast, large-scale fire prevention program efforts are effective at reducing the overall occurrences of wildfires, so it makes sense that expansion of the large-scale prevention efforts to other lands would reduce fire occurrences there.*** Wildfire prevention programs reduce the occurrence of all human-caused ignitions modeled irrespective of the mix of specific prevention activities (e.g., education, engineering, enforcement). This provides support to the idea that specific activities have broad ranging effects and limit the ignitions from multiple wildfire causes.

***Arson fires at an annual temporal scale and a county-level spatial scale are significantly related to socioeconomic and biophysical variables.*** On all lands in North Carolina, South Carolina, and Georgia, population levels are positively, employment rates are negatively, and income variables are related in mixed ways to arson fire counts by spatio-temporal units. The study identified a negative long-term trend in arson fires, which is consistent with other studies

from Florida (e.g., Prestemon and Butry 2005) and Michigan (Thomas et al. 2011). The study also revealed the importance of state of occurrence, ecoregion-related biophysical variables, and long-term climate patterns at explaining observed rates and trends in arson in these states.

***Evaluation of prevention by specific activity, time of occurrence, and geographic location can be used to determine the costs and benefits of prevention programs by public agencies.*** If data are recorded to allow assessment by activity, time and location, economic evaluations of benefits of prevention programs can be made for any geographic area. If these evaluations are made, managers would have the ability to preposition and reposition resources and focus on varying activities during both the fire season and off season. If data are recorded on the costs of prevention programs and/or activities, complete cost/benefit analyses could be conducted to determine how prevention programs can be traded-off with other wildland fire management programs and activities.

### **Relationship to other recent findings and ongoing work on this topic**

Other recent findings: This research is related to earlier efforts to understand human and natural wildfire ignitions on lands in Florida, California, Michigan, and Galicia, Spain. The studies in Florida are highlighted by analyses by Prestemon et al. (2002), Mercer and Prestemon (2005), and Mercer et al. (2007). These studies revealed the differences in fire processes across ignition sources (arson, accidental, lightning), identified the role of socioeconomic variables in predicting such fire occurrences, and identified effects of fuels management at reducing overall costs and losses from wildfires in that state.

Since 2009, Butry and Prestemon have collaborated with Douglas Thomas of the National Institute of Standards and Technology to advance understanding of arson and accidental fire starts in urban and wildland areas of Michigan. Research has been published (Thomas et al. 2011; Thomas et al., forthcoming) and is under development. Those analyses are revealing that law enforcement efforts can reduce accidental fire starts as well as arson fire starts in Michigan. The Thomas et al. (2011) analysis identified a relationship between variables related to crime risk (“Broken Windows” variables) can also help to explain accidental fires. This finding may be useful for specifying improved accidental fire prediction models and associated forecast tools.

Research in review also reveals that arson fire ignition processes in Detroit, evaluated by target, possess temporal autocorrelation that is useful for predicting arson in outdoor settings. A parallel effort, funded through the Department of Homeland Security, will use some of the wildfire prevention data gathered in this study to leverage the development of arson hotspot forecasting tools for tribal lands.

The California study (Prestemon and Butry 2010) focused on national forests and reveals that law enforcement can reduce the occurrences of arson fires on national forests in that state. The analyses also found that socioeconomic variables as well as environmental factors explain variation in fire starts.

New research (Prestemon et al., forthcoming) has revealed the effectiveness of arrests at reducing intentional firesetting in the northwestern Spanish region of Galicia, where half of all fires in Spain originate. The study also showed that intentional fire counts can be forecast with skill out-of-sample, which is evidence that intentional fires can be forecasted, allowing for the development of hotspotting tools for wildland managers and law enforcement in that region. It also indicates that, because similar processes have been identified in the U.S. (Butry and Prestemon 2005, Prestemon and Butry 2005, Prestemon and Butry 2010), similar tools could be successfully deployed in the U.S.

Ongoing work in this area: Ongoing work in this area includes: (1) new models are being developed for all BIA units assessing the benefits of the presence of prevention programs, (2) detailed analyses of BLM/Region 4 data, (3) assessment of the combined impacts of prevention and alternative employment opportunities on BIA units on fire ignitions of all types, (4) development of a general technical report on wildfire ignitions as a result of this work and work on the cohesive strategy, (5) Finally, an extension of work completed by Mothershead (2012) is focused on developing a temporally autoregressive prediction model of arson fires in that state. Pending data on forest areas and law enforcement measures, this will be a manuscript to be submitted to a refereed journal in early 2013.

#### *Citations from this section*

Butry, D.T., and J.P. Prestemon. 2005. Spatio-temporal wildland arson crime functions. Paper presented at the Annual Meeting of the American Agricultural Economics Association, July 26-29, 2005, Providence, Rhode Island. 18 p. Published on the Internet, <[http://agecon.lib.umn.edu/cgi-bin/pdf\\_view.pl?paperid=16442&ftype=.pdf](http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=16442&ftype=.pdf)>.

Mercer, D.E., and J.P. Prestemon. 2005. Comparing production function models for wildfire risk analysis in the Wildland-Urban Interface. *Forest Policy and Economics* 7(5):782-795.

Mercer, D.E., J.P. Prestemon, D.T. Butry, and J.M. Pye. 2007. Evaluating alternative prescribed burning policies to reduce net economic damages from wildfire. *American Journal of Agricultural Economics* 89(1):63-77.

Prestemon, J.P., J.M. Pye, D.T. Butry, T.P. Holmes, and D.E. Mercer. 2002. Understanding broad scale wildfire risks in a human-dominated landscape. *Forest Science* 48(4):685-693.

Prestemon, J.P., and D.T. Butry. 2005. Time to burn: modeling wildland arson as an autoregressive crime function. *American Journal of Agricultural Economics* 87(3):756-770.

Prestemon, J.P., and D.T. Butry. 2010. Wildland arson: a research assessment. P. 271-283 In Pye, J.M., H.M. Rauscher, Y. Sands, D.C. Lee, and J.S. Beatty (eds.), *Advances in Threat Assessment and their Application to Forest and Rangeland Management*. Gen. Tech. Rep. PNW-802. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 708 p. (2 volumes).

Prestemon, J.P., M.L. Chas-Amil, J. Touza Montero, and S.J. Goodrick. [In Press]. Forecasting intentional wildfires using temporal and spatiotemporal autocorrelations. *International Journal of Wildland Fire*.

### **Future work needed**

Work is needed to gather long, consistently reported time series of wildfire prevention efforts for multiple ownerships and subunits in the United States. This can be facilitated by requiring national forest managers, Bureau of Land Management district managers, and potentially encouraging state agencies to begin such a data gathering effort. This effort could allow for more statistically robust assessments of recommended activity levels for fire prevention across landscapes.

Additional study is needed into how all categories of wildfires may be forecasted at alternative spatial and temporal scales. Some work, led by the collaborators in this Joint Fire Science Program study, has revealed that such forecasts are possible and are superior to alternative, simpler or naïve approaches used today by managers or not used at all. These models would be further enhanced by the inclusion of wildfire prevention intervention activity measures, which could reveal how such prevention actions can affect the temporal and spatio-temporal patterns of fires, with potential benefits for managers, society, and valued environmental goods and services.

Research emerging from this Joint Fire Science Program funded study has the potential to allow for updating of existing software tools, such as RAMS. Parameters estimated in this study to date, and those to emerge in the coming months through non-JFSP-funded efforts, could allow for better fire prevention planning especially on public ownerships.

Research completed to date by this study's collaborators has shown that the effects of fire prevention efforts may vary over time. However, little is known about the time dynamics associated with fire prevention, especially how durable such efforts in reducing human-ignited wildfires. Longer time series of fire prevention data, such as could be assembled for tribal lands

in the near future and in Florida even today, could allow for a more comprehensive evaluation of these questions. Such research would advance education planning and allow for better targeting of prevention education messages and other prevention measures in the times when such efforts yield maximum benefits.

**Deliverables**

As of June 28, 2012, all available deliverables have been uploaded.

*Deliverables table from the study plan:*

<b>Deliverable Type</b>	<b>Description</b>	<b>Proposed Delivery Dates</b>	<b>Actual Delivery Dates</b>
Non-refereed Publication	Initial Prevention Efficacy Parameter Estimates from a Florida Prevention Study	July 31, 2009	July 23, 2009
Non-refereed Publication	Estimates of the effectiveness of spending on fire prevention, on each cause of preventable fire (Part I results), provided to JFSP and associated collaborating agencies (USDA-FS, BLM, BIA) documenting fire prevention parameter estimates for western national forests, Utah BLM Districts, and up to 41 BIA Reservations	July 31, 2010	June 30, 2012
Non-refereed Publication (Final Report Supplement)	A report provided to JFSP and associated collaborating agencies (USDA-FS, BLM, BIA) describing an optimal fire prevention spending allocation model. This will describe how, holding other kinds of fire management variables constant, alternative levels of fire prevention spending on each national forest, included BLM District, and BIA unit would lead to changes in expected wildfire occurrence costs and losses due to wildfire.  (Actual Reference:  Model Estimates, Generated for Bureau of Indian Affairs Tribal Units Data. 2012. David T. Butry, Karen L. Abt, Jeffrey P. Prestemon,	March 31, 2011	June 28, 2012

	Samuel Scranton, Douglas Thomas, and Scott L. Goodrick. Report submitted to the Joint Fire Sciences Program, in partial completion of JFSP Study 09-1-9-2, "A Fire Prevention Effectiveness Assessment for Multiple Ownerships", 47 pages.)		
Refereed Publication	At least one manuscript, prepared for a refereed scientific journal, describing the net effects of fire prevention on fire occurrence, costs, and losses, on our study sites.  Abt, K.L., D.T. Butry, D.T., K.L. Abt, J.P. Prestemon, S. Scranton, D. Thomas, and S. Goodrick. 2012. Fire prevention efficacy on tribal lands of the United States.	March 31, 2011	Manuscript under development. Anticipated date: FY 2013

*Additional Deliverables:*

<b>Product Type</b>	<b>Product Title</b>	<b>Proposed Delivery Date</b>	<b>Actual or Anticipated Delivery Date</b>
Non-Refereed Publication	Hermansen-Báez, A., J.P. Prestemon, D.T. Butry, K.L. Abt, and R. Sutphen. 2011. The Economic Benefits of Wildfire Prevention Education. Southern Research Station Fact Sheet, 2 p.	na	September 8, 2011
Masters Thesis	Mothershead, Parker T. 2012. Geo-spatial Analysis of Socioeconomic Risk Factors Affecting Wildfire Arson Occurrence in the Southeastern United States. Masters Thesis, Department of Forest and Environmental Resources, North Carolina State University. 66 pages.	na	June 28, 2012
Data	Descriptive Statistics, Generated for Bureau of Indian Affairs Tribal Units Data. 2012. David T. Butry, Karen L. Abt, Jeffrey P. Prestemon, Samuel Scranton, Douglas	na	June 28, 2012

	Thomas, and Scott L. Goodrick. Report submitted to the Joint Fire Sciences Program, in partial completion of JFSP Study 09-1-9-2, "A Fire Prevention Effectiveness Assessment for Multiple Ownerships". Excel spreadsheet converted to pdf.		
Data	David T. Butry, Karen L. Abt, Jeffrey P. Prestemon, Samuel Scranton, Douglas Thomas, and Scott L. Goodrick. 2012. Marginal Effects Estimates, BIA Units. Report submitted to the Joint Fire Sciences Program, in partial completion of JFSP Study 09-1-9-2, "A Fire Prevention Effectiveness Assessment for Multiple Ownerships". Excel spreadsheet, converted to pdf.	na	June 28, 2012
Data	Mothershead, P.T., David T. Butry, Karen L. Abt, and Jeffrey P. Prestemon. 2012. Data on fire prevention efforts for other selected locations in the U.S. Report submitted to the Joint Fire Sciences Program, in partial completion of JFSP Study 09-1-9-2, "A Fire Prevention Effectiveness Assessment for Multiple Ownerships". Excel spreadsheet, converted to pdf.	na	June 28, 2012
Refereed Publication	Mothershead, P. T. and J. P. Prestemon. Geo-spatial Analysis of Socioeconomic Risk Factors Affecting Wildfire Arson Occurrence in the Southeastern United States.	na	Manuscript under development