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The economic benefits of planning before the fire

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Abstract

Wildfire suppression expenditures in the United States regularly exceed a billion dollars and are expected to continue rising due to climate change, high fuel loads, and a growing wildland urban interface. Risk management research suggests that pre-fire planning reduces uncertainty and may lead to better wildfire management outcomes including lower suppression costs, less damage to values at risk and improve safety outcomes. One form of pre-fire planning in US National Forests is known as potential operating delineations (PODs) whereby stakeholders collaboratively identify area on the landscape where wildfire can be safely and effectively engaged. Moreover, the area defined by the PODs are classified based on the level of urgency to suppress fire.

The objective of this paper is to test whether fires that have occurred within areas that have undergone the POD process are systematically different from fires that have not undergone PODs. We evaluate the following wildfire outcomes: final fire cost, final fire size, cost per acre, and duration. We employ statistical matching methods to find comparable non-POD fires that serve as “control” units for our POD “treated” fires. Our results suggest that POD fires cost $373 per acre less than non-POD fires, and that the POD fires cost per acre is comparable to prescribed burning cost per acre in the Southwestern US. These results imply that pre-fire planning like the POD process may reduce suppression costs to a level comparable with prescribed burning facilitating the long-standing recommendation from fire ecologists to “restore fire to the landscape.”

1. Introduction

Billions of dollars are spent on wildland fire management in the United States each year. These costs are a result of decisions to commit resources to manage and suppress fire. Climate change, a growing wildland urban interface, and the accumulation of fuels are expected to drive increased fire activity necessitating additional resources that will likely increase costs. For decades, the default response had been to suppress all fire as quickly as possible. This strategy has led to an accumulation of fuels that currently contribute to large costly incidents (Thompson et al., 2013). Risk management offers insights that when applied to wildfire management can improve effectiveness, reduce costs, and increase safety (Thompson et al., 2011, 2019). Risk management involves planning in advance of an incident to identify risks and make informed decisions.

The wildfire community has recognized the importance of planning in advance of incidents. The process to identify and characterize potential operational delineations (PODs) is an attempt to plan in advance of the incident (Dunn et al., 2020). PODS summarize wildfire risk before ignitions occur and may guide operations as fires progress. In cases where a fire is burning in a POD with a low risk rating, managers may employ less aggressive suppression strategies that may reduce cost. While less aggressive suppression may result in larger fires, they may provide ecological benefits and reduce the risk of firefighter injury.

Fuel treatments are another tool used to mitigate the impacts of fire. Fuel treatments are an important tool to reduce fuel loads thereby reducing the risk of uncontrollable wildfire. However, fuel treatments can be costly (US Forest Service, 2015). Mechanical treatments involve considerable machinery and labor. Prescribed burns carry political risk and generate smoke that impose additional costs on society (Navaro et al., 2018). Managing wildfire to achieve the benefits of fuel treatment may represent a less costly method for mitigating fuels and the potential for future fire damage.

We investigate the impact of the POD process on economic and operational aspects of fire management. Our approach is to compare fires that occur in forests that have developed PODs to statistically similar fires that occur in forests that have not developed PODs. After controlling for numerous factors that may influence fire outcomes, we attribute differences in fire outcomes to the POD process. We find that POD fires have a lower cost per acre, which supports the idea that planning prior to the fire event can improve the efficient use of suppression resources. We then compare the average cost per acre of POD and non-POD fires to mechanical and prescribed treatments to see if cost savings are present.

2. Data and Methods

Our objective is to empirically analyze the impact of the POD process on suppression operations and to compare the cost of POD fires to alternative methods of fuel treatment. The POD process is relatively new and has only been administered on a few forests. In particular, the Tonto National Forest (Southwestern US) developed PODs in 2017. As of 2021, the Southwest Region has 40+ landscapes in national forests that have undergone the PODs process. We compare a set of fires that burned in the Southwest region in 2019 (POD fires) to statistically similar fires that were not in a forest with developed PODS (non-POD fires). We compare POD fires to non-POD fires across multiple outcome variables through regression analysis. We then compare the costs of wildfires managed under these strategies to fuel treatment costs in the same areas. Our methods are straightforward and contribute to the novel research around POD fires. Prior research on the benefits of PODs is qualitative in nature using mechanisms like interviews and surveys. Our econometric-driven approach is a useful lens to support other PODs research.

2.1. Data

We assemble a dataset from several disparate sources to investigate the impact of PODs on suppression operations. We begin with 20 fires from 2019 that occurred in US National Forests that underwent the POD planning process. We extract the ignition location point, start and end dates of suppression or management operations, and final fire size from USFS records. We cross-reference this list of fires with US Forest Service suppression billing records to estimate the cost of the fires. We also extract preparedness level from the National Interagency Fire Center to account for the level of strain on the wildfire response system during a fire.

In addition to location and dates, we use weather and topographical data to incorporate pre-fire conditions into our matching approach. Weather variables, including temperature, energy release component, precipitation, humidity, and wind speed were averaged for the 10 days leading up to the first reporting date from Gridmet data. Topographical features such as elevation, slope, aspect, and ruggedness are generated from a digital elevation model using the elevatr package in R.

2.2. Matching Methods

We employ several empirical strategies to analyze the impact of the POD process on suppression operations. Our primary empirical strategy is to match fires that ignite in forests that have undergone the PODs process, so called POD fires, with fires that ignite in forests that have not undergone the PODs process, non-POD fires. The intuition behind matching is that we are able to identify non-POD fires that are similar to POD fires along several observable dimensions to serve as the “control” group in our experimental design. Ideally, the occurrence of the fire in a POD forest is the only meaningful difference between the POD fire and its non-POD (control) counterparts.

To accurately investigate the cost savings and other benefits of POD fires, similar non-POD fires are needed for comparison. Using the data described above, we develop a propensity score matching model to find suitable non-POD matches for the set of POD fires. Specifically, fires are matched based on: region of the US (GACC), national preparedness level, fire cause, topographic and weather in the 10 days preceding ignition. Topographic data include elevation, slope, aspect, and ruggedness within 2km of the point of ignition. Weather data include energy release component, precipitation, minimum near-surface relative humidity, maximum near-surface air temperature, wind speed. We use the 10 days before fire ignition to avoid the effects of the fire progression and suppression operations that may confound our estimate of the effect of the POD process on wildfire outcomes.

POD fires were matched to non-POD fires at a ratio of 1 to 3. In total, we matched 17 POD fires to 51 non-POD fires. We requested management cost data for non-POD fires and received data for 24 fires where at least one of the 51 matched fires corresponded to a POD fire. Our end sample size included 16 POD fires and 24 non-POD fires. The locations of these fires are shown in Figure 1.

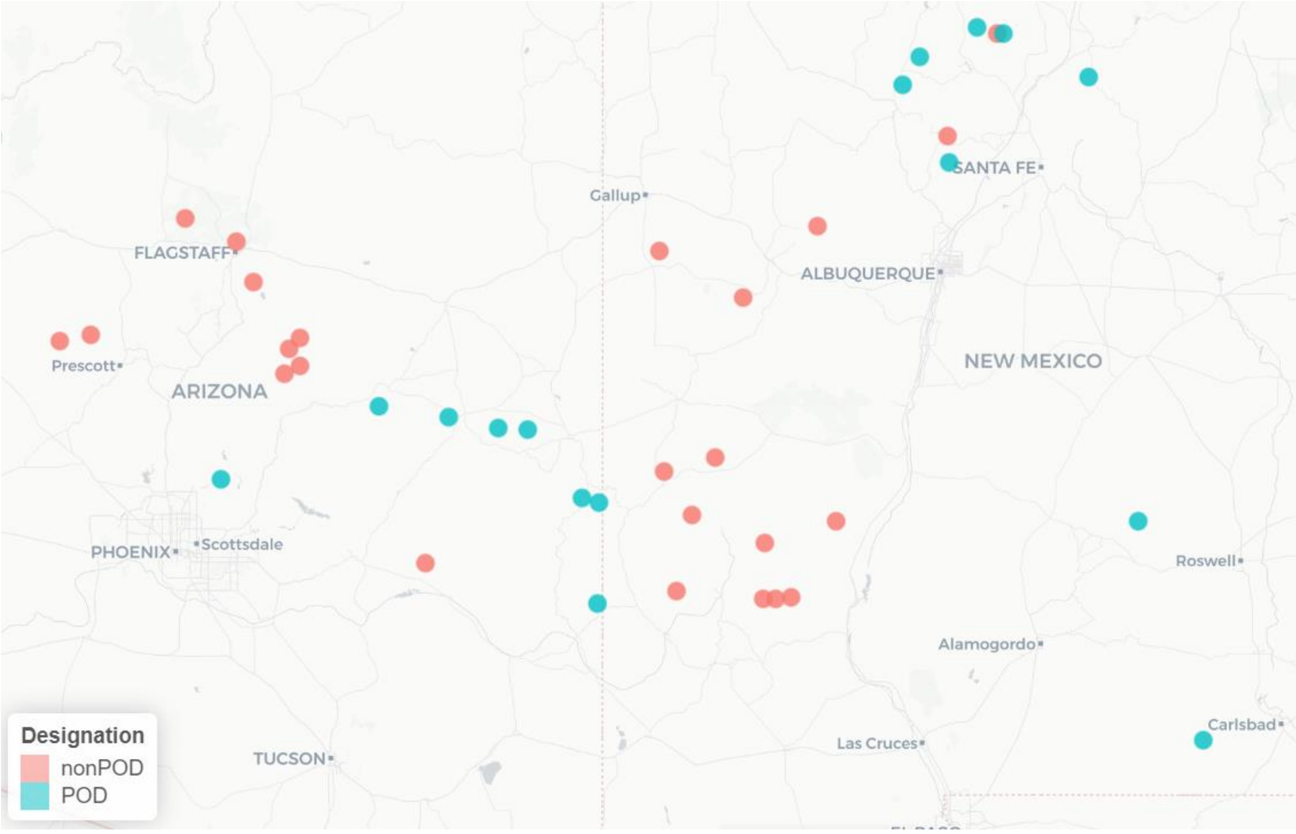

Figure 1: Map of Arizona and New Mexico (USA) showing location of POD and non-POD fires used in the sample.

Table 1 contains summary statistics for the set of POD and non-POD fires used in the matching analysis. Suppression costs are lower on POD fires than their non-POD counterparts both in total cost and cost per day. POD fires, on average, have a larger start size in acres than non-POD fire counterparts but also have a smaller ending size. This could indicate effective planning of POD fires before ignition. Interestingly, POD fires have shorter durations than non-POD fires, possibly suggesting a more efficient use of daily resources. POD fires are also shorter in duration and less expensive per acre when compared to fires managed under direct, modified, and limited suppression strategies from 2006-2008 (Gebert and Black, 2012).

Table 1. Summary statistics comparing POD and non-POD fires

Variable	N	Mean	SD
Fire Size first day (acres)			
POD	16	901	1,572
non-POD	24	265	243
Fire size last day (acres)			
POD	16	3,536	3,966
non-POD	24	4,041	5,466
Fire Cost			
POD	16	720,419	1,313,024
non-POD	24	1,011,137	1,783,758
Duration			
POD	16	13.69	8.52
non-POD	24	18.33	14.29
Fire Cost ($USD/Day)			
POD	16	57,287	84,080
non-POD	24	57,643	95,458
Fire Cost ($USD/Acre)			
POD	16	206	182
non-POD	24	591	971

3. Results and Discussion

Table 2 contains the results of the matching analysis. POD and non-POD fires are matched on characteristics and conditions that exist before ignition to mitigate the effect of matching on factors affected by management decisions over the course of the fire. We compare the POD and non-POD fires along four dimensions: Final Cost, Final Fire Size, Cost/Acre, Duration. We run regressions using only the POD indicator and then again with the variables the POD and non-POD fires are matched on.

Table 2. Regression results based on matched dataset

	Final Fire Cost	Final Fire Size	Cost/Acre	Duration
(Intercept)	30,577	308,778*	-33,864	419
	[-68,048, 129,202]	[-4,226, 621,782]	[-76,144, 8,414]	[-548, 1,388]
POD Fires	-222	603	-373*	-3.40
	[-1225, 779]	[-2,577, 3,784]	[-802, 56]	[-13.25, 6.44]
R2 Adj.	0.279	0.217	0.440	-0.158

Notes: N=40 in all regressions. All regressions include the following controls, but are omitted from the table for brevity: region of the US (GACC), national preparedness level, fire cause, topographic and weather

We find little statistical evidence that there are differences between POD and non-POD fires with the exception of Cost/Acre. Specifically, the cost per acre on POD fires is $373 less than comparable non-POD fires (statistically significant at 10% level. This result supports the hypothesis that less costly suppression effort is expended on POD fires. Suppression resources may be monitoring fire growth in areas with few values at risk or focusing containment effort on the operating delineations identified in the planning process rather than responding to fire growth as an emergency. The lack of statistical significance in the other regression models is likely the result of small sample sizes given the relatively recent implementation of the POD process.

3.1. Comparison to Mechanical and Prescribed Treatments

While we observe some evidence that POD fires are cost effective compared to non-POD fires, we also compare the average cost per acre to the costs of prescribed and mechanical treatments. We estimate per-acre prescribed burning and mechanical treatment costs in the Southwestern US (USFS Region 3) using data from the Hazardous Fuel Treatment Reduction dataset. We remove all prescribed and mechanical projects that fall outside of three standard deviations of the mean cost per acre. We find that POD fires average suppression expenditures of $206/ac and are less expensive per acre than mechanical treatments ($408) and non-POD fires ($591, Table 3). While not all POD fires are necessarily managed for resource benefits, our results suggest that the pre-fire planning during the POD process does curtail suppression expenditures making them comparable to prescribed burning treatments. This result suggests a potential role for managing POD fires for resource benefit.

Table 3: Cost per acre ($USD) of POD and non-POD fires and Southwestern US fuel treatments

Fire Treatment	N	Mean	SD
POD Fire	16	$206	$182
Non-POD Fire	24	$591	$971
Prescribed	982	$189	$1,268
Mechanical	3,356	$408	$612

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