Do eucalyptus trees increase wildfires?

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Abstract

Addressing an ongoing, highly controversial debate, this study estimates the degree to which eucalyptus trees causally increase the spread of wildfire in California. Exploiting exogenous variation in wind direction at the point of fire ignition, I estimate the effect of eucalyptus presence on the final extent of the wildfire (total area burned), relative to similar forest types. Counter to the widely held belief that eucalyptus is especially flammable, I find no evidence that eucalyptus causally increases burn area. These results could improve decision making on how best to utilize scarce fire management funds.

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1. Introduction

In the last 20 years, Californians have experienced 17 of the 20 largest wildfires and 18 of the 20 most destructive wildfires in the state's history (CAL FIRE 2021a; 2021b). Increasing development in the Wildland Urban Interface (WUI) has led to more human-started fires which are more destructive and more costly to fight (Balch et al. 2017; Calkin et al. 2014). As California becomes hotter and drier due to climate change, wildfires are expected to become larger and more destructive (Fried, Torn, and Mills 2004; Williams et al. 2019).

The role of eucalyptus trees in spreading wildfires is controversial. Many argue that eucalyptus increase fire risk because they are oily--which make them more ignitable and longer burning--and because they create piles of woody debris (Agee et al. 1973; Santos 1998). The potential fire risks from eucalyptus trees have led to calls for their removal, but critics contest the claim that eucalyptus trees increase wildfire spread more than other vegetation. For example, a $5.67 million federal grant to remove eucalyptus trees from the Oakland Hills was recently cancelled after a successful lawsuit pointed out the lack of evidence that eucalyptus trees causally increase wildfire spread (Hall 2016).

This dispute hinges on an unresolved question: do eucalyptus trees causally increase the spread of wildfire in California? I answer this question by conditioning the analysis on the point of fire ignition and exploiting exogenous variation in wind direction. Conditional on a fire starting, sometimes the wind is blowing toward eucalyptus trees and sometimes the wind is blowing toward a different land use type, such as non-eucalyptus forest, agricultural land, or other land use types. In the instances in which the wind is blowing toward eucalyptus trees, is the final extent of the wildfire (total area burned) greater than when the wind is blowing toward a different land use type?

My regressions control for a variety of natural and anthropogenic factors as well as time and location fixed effects. The coefficients of interest are the interactions between land use type and wind direction. I estimate these regressions using the following panel data: locations of eucalyptus and other vegetation and land use types in California from CAL FIRE's fveg data set (California Department of Forestry and Fire Protection 2015); point of ignition of wildfires as well as the total area they ultimately burn from USFS Fire Program Analysis (Short 2017); and wind direction from NOAA's North American Regional Reanalysis daily reanalysis data (National Oceanic and Atmospheric Association 2016).

Policymakers and experts are divided on the relative fire risk of eucalyptus trees and on whether to fund their removal. By assessing the wildfire threat posed by eucalyptus trees, this research will improve decision-makers' ability to prevent wildfire.

2. Background

To motivate this research, I provide a brief summary of the history of eucalyptus in California. During the Gold Rush, eucalyptus trees were brought to California from their native Australia (Santos 1998). Eucalyptus provided oil, fuel, and construction materials. In the late 1800s, eucalyptus trees were planted across California to provide fuel, windbreaks, shade, and building materials for railroad construction. In 1935, an Agricultural Extension Specialist from the University of California wrote that, "Eucalyptus is now one of the outstanding trees on almost any California landscape where trees have been planted" (Butterfield 1935). When the trees proved to be poor construction materials, the eucalyptus boom ended, but they continued to provide fuel and windbreaks (Santos 1998).

In 1990, a winter freeze killed many eucalyptus trees, resulting in highly flammable dead wood (Santos 1998). In 1991, the Berkeley-Oakland Hills fire destroyed 3,354 structures, killed 25 people, and injured 150 people (U.S. Fire Administration, n.d.). Many people blamed eucalyptus for this highly destructive fire, while others blamed the flammable grasslands, precariously built homes, and a poorly coordinated firefighting response (Pagni 1993; Santos 1998; McBride and Kent 2019). Eucalyptus are oily which make them more ignitable and longer burning (Santos 1998). Furthermore, eucalyptus trees' fallen bark, leaves, branches, and seed pods are called "litter," which build up on the forest floor. Without frequent fuel management, significant fuel buildup occurs (Agee et al. 1973). Of course, the presence of fire in the East Bay hills predates the arrival of eucalyptus (Santos 1998; McBride and Kent 2019).

Eucalyptus fuel loads can be managed with prescribed burning, mechanical thinning, or tree removal using herbicides (Mirra et al. 2017). In 2015, East Bay agencies received a $5.6 million grant from the Federal Emergency Management Agency (FEMA) primarily to remove eucalyptus trees using herbicides (Hall 2016). After the grant was announced, the Hills Conservation Networked (HCN) sued, arguing that there was not enough evidence of the flammability of eucalyptus to support such a policy. Subsequently, the portion of the grant designated for eucalyptus removal was rescinded. Between 1923 and 2018, more than 30 plans for region-wide fuel reduction have been proposed and have met a variety of obstacles to implementation (McBride and Kent 2019). The debate over whether eucalyptus trees causally increase fire spread remains contentious. This paper aims to answer this old question by combining newly available spatial data with econometric analysis.

3. Literature Review

In 2020, the area burned by wildfire in California was more than four times larger than the 2015–2019 average (Munich Re 2021). Development in the Wildland Urban Interface (WUI) has led to more human-started fires which are more destructive and more costly to fight (Balch et al. 2017; Calkin et al. 2014). Aggressive fire suppression in the 20th century created significant fuel build-up and the conditions for larger wildfires (Arno and Brown 1991). As climate change creates hotter and drier conditions, wildfires are expected to become larger and more destructive (Fried, Torn, and Mills 2004; Williams et al. 2019). Federal fire suppression expenditures reached $2.3 billion annual average from 2015 to 2020 (National Interagency Fire Center 2020). One of the main challenges facing policy makers is how to allocate limited resources for wildfire management and prevention. Removing highly flammable vegetation constitutes one potential management strategy. However, it remains unclear whether eucalyptus should be considered highly flammable and to what extent. In order for policymakers to decide whether to allocate resources to eucalyptus removal, it is necessary to estimate the causal effect of eucalyptus on wildfire spread.

Several experimental studies have modeled the relationship between eucalyptus and fire. In Portugal, researchers estimated the effect of fuel management techniques on reducing fire hazard in eucalyptus plantations (Mirra et al. 2017) . In Australia, researchers modeled the flame height and rate of fire spread in dry eucalyptus forests (Cheney et al. 2012). Experiments conducted at the University of California, Berkeley in the 1970s, documented the rapid fuel build up and flammability of eucalyptus (Agee et al. 1973). All three of the prior studies were conducted in relatively small scale, experimental settings. In contrast to these previous studies, my research design utilizes fire data across California over several decades. My research also differs in its focus by comparing eucalyptus to other forest types to see the relative impact of eucalyptus on fire spread.

A 2019 study by Baylis and Boomhower informs my identification strategy. The authors estimate the effect of the presence of private homes on firefighting expenditures in the western United States (Baylis and Boomhower 2019). Their analysis uses "plausibly exogenous" variation in ignition locations. My paper follows a similar identification strategy, relying on plausible exogeneity of wind direction at an ignition point with regard to vegetation types. Baylis and Boomhower (2019) is also relevant in that if eucalyptus increase fire spread and eucalyptus are disproportionately close to private homes, the impacts of removing eucalyptus could be quite large due to preventing the costliest wildfires.

Another recent paper found that fire suppression is more likely if the fire is close to homes, especially more expensive homes (Plantinga, Walsh, and Wibbenmeyer 2020). The authors used a U.S. Forest Service fire model to determine how fire would spread without intervention and then compared those results with the actual fire spread. This paper used census data housing value, income, and housing density to control for suppression. I also use these census variables to control for the effects of fire suppression in my analysis, as well as distance to the nearest road and location fixed effects.

4. Data

My research draws on several publicly available datasets. Wildfire ignition coordinates and total area burned from 1992 to 2015 are provided by the Fire Program Analysis fire-occurrence database (Short 2017). I use CAL FIRE's Fire Resource Assessment Program for vegetation spatial data covering all of California, spanning 1990 to 2014 (California Department of Forestry and Fire Protection 2015). In addition to providing the locations of specific types of vegetation, the vegetation data includes other land use types, such as agriculture, range land, and urban. Since this data is a spatial cross-section, some vegetation types may differ from the true vegetation present at point and time of ignition. Wind direction and wind speed at the point of ignition is determined from National Oceanic and Atmospheric Administration (NOAA) North American Regional Reanalysis daily reanalysis data (National Oceanic and Atmospheric Association 2016).

I use the R package "tidycensus" to access U.S. census data on population density, median income, and median home value to partially control for the effect of fire suppression. I use the R package "tigris" to calculate distance between point of ignition and nearest road. I use the R package "prism" to calculate temperature and precipitation. I use the R package "elevtr" to calculate the mean elevation and slope. Figure 1 provides summary statistics for the main variables in the analysis.

Figure 1: Summary Statistics

Statistic	N	Mean	St. Dev.	Median	Min	Max
Area burned (acres)	188,926	67.420	2,033.291	0.250	0.001	315,578.800
Eucalyptus	188,926	0.018	0.135	0	0	1
Windspeed (m/s)	188,926	3.148	1.817	2.866	0.009	22.609
Mean Elevation (m)	188,926	655.343	659.497	432.874	-81.507	3,904.486
Elevation Range (m)	188,926	116.238	115.117	84	0	1,080
Mean Temperature (°C)	188,926	20.038	5.911	20.611	-8.442	41.170
Population Density (person/sq m)	188,926	0.0002	0.001	0.00001	0.000	0.013
Distance to Road (km)	188,926	0.308	0.947	0.060	0.000	20.150

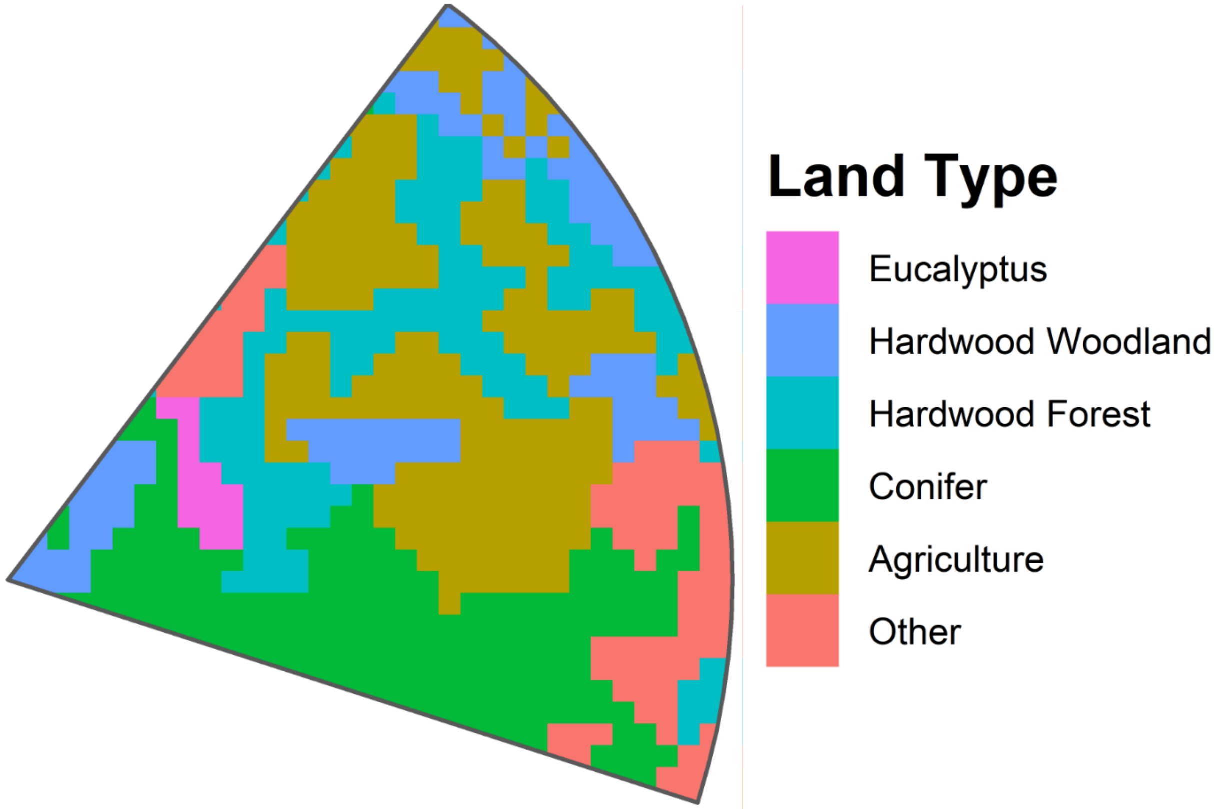
Note: Unit of observation is a fire.

5. Empirical Strategy

I estimate the impact of eucalyptus on fire spread by exploiting exogenous variation in wind direction at the point of fire ignition. Conditional on a fire starting, sometimes the wind is blowing toward eucalyptus trees and sometimes the wind is blowing toward a different land use type, such as other forest, cropland, or rangeland. To determine the land use types for each fire, I create 90° sectors of 1-kilometer radius, centered at the fire ignition coordinates and extending in the direction of the wind at the time of ignition.

Using these sectors, I construct dummy variables for each land use type. For example, if eucalyptus is present in a sector, then the eucalyptus dummy variable will equal 1 for that fire. Eucalyptus observations are within the hardwood woodland land use type. Therefore, I define hardwood woodlands without eucalyptus as my omitted category. In addition to eucalyptus, my regression includes three other forest type indicators: hardwood forest and conifer (I combine conifer forest and conifer woodland). I also include an indicator variable in my regression for agricultural land use. Finally, the "Other" land use type includes herbaceous, shrub, barren, wetland, urban, water, desert shrub, desert woodland. Since these land use types are not the focus of this research, I group them together. Figure 2 depicts an example fire sector, and the land use types within the sector. Since this sector includes every land use type, all of the indicator variables are equal to one for this fire.

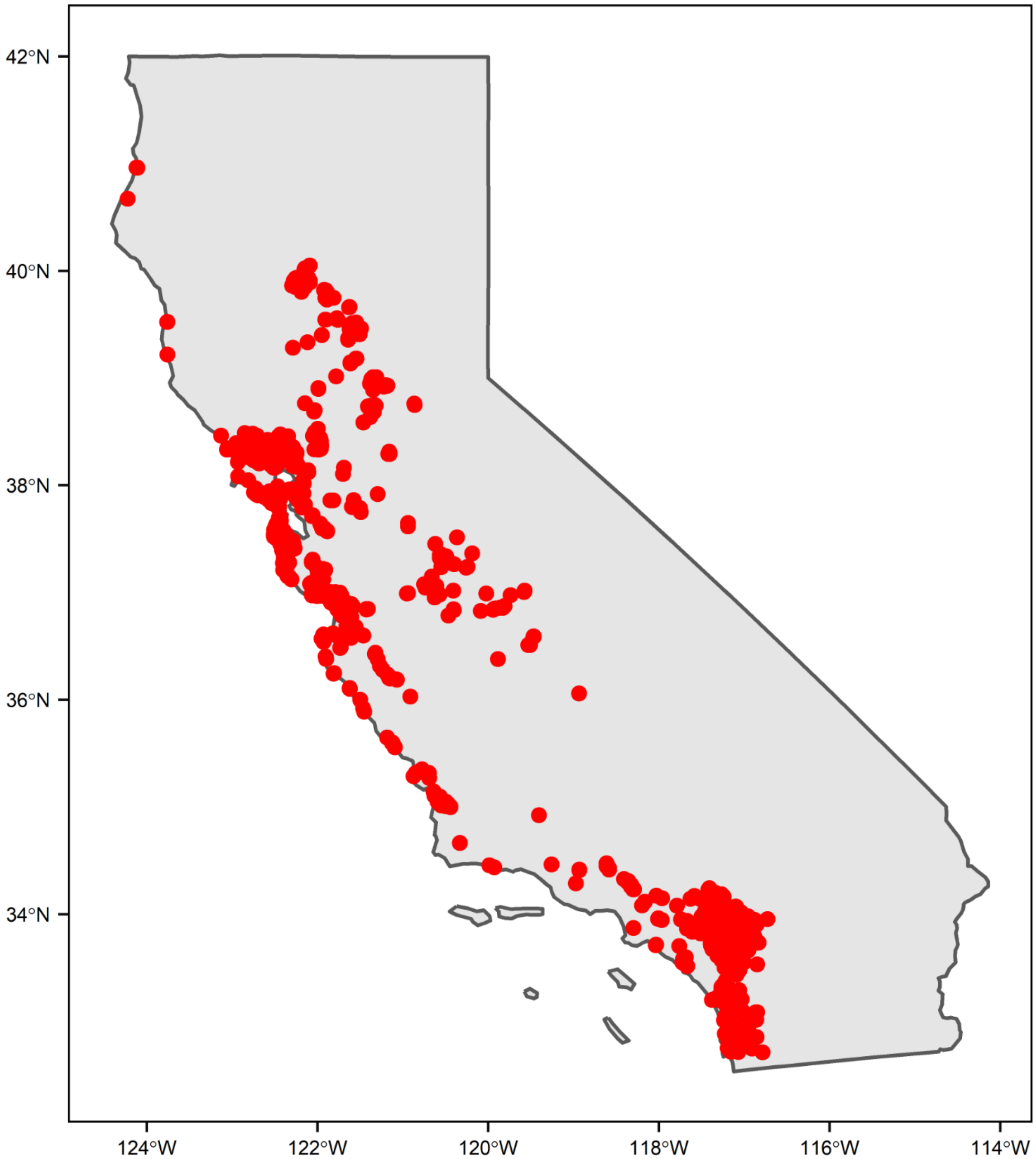
Figure 2: Example Fire Sector



Note: Unit of observation is a fire. Since this sector includes every land use type, all of the indicator variables are equal to one for this fire.

Figure 3 displays the spatial distribution of fire sectors with eucalyptus trees in California. Points on the map are larger than sectors for visual clarity. Actual sectors are too small to see on a state map.

Figure 3: Fires near eucalyptus tree



Due to the history of settlers planting eucalyptus trees in California, eucalyptus trees may be located more closely to developed areas than other forest types. I partially control for the effect of fire suppression by controlling for population density, median income, house value, and distance to nearest road. Since these census data are only available at census tract and census block level, I include location fixed effects to account for finer-scale variation in suppression and other spatial confounders. I create location fixed effects by diving the state of California into equally sized 2 kilometers length grid cells.

I also control for natural factors such as temperature and windspeed at the location and mean elevation and elevation range within the sector. I include month-of-sample fixed effects to account for seasonal variation, drought years, changes in fire suppression budget, and other time varying factors.

I estimate the effect of eucalyptus on total burn area with the following ordinary least squares regression:

$$BurnArea_{ibmg} = \boldsymbol{\alpha} + \beta_1 Eucalyptus_i + \beta_2 HardwoodForest_i + \beta_3 Conifer_i + \beta_4 Agriculture_i + \beta_5 Other_i + \sigma_b + \omega_i + \gamma_m + \delta_g + \boldsymbol{\epsilon}_{ibmg} ,$$

Where *i* is a fire incident on a given day at a given longitude and latitude, *b* is a census block, *m* is month of sample, and *g* is a grid cell; $BurnArea_{ibmg}$ is the natural logarithm of the final burn area; $\boldsymbol{\alpha}$ represents the average fire spread for non-eucalyptus hardwood woodlands (the omitted category); β_1 gives the effect of eucalyptus trees on fire spread relative to non-eucalyptus hardwood woodlands; σ_b is a vector of controls for fire suppression (comprised of population density, median incomes, median home value, and road distance); ω_i is a vector of natural factors affecting fire spread (comprised of temperature, elevation, elevation range, and wind speed); γ_m is month-of-sample fixed effects; and δ_g are 2 km grid cell fixed effects. I cluster standard errors at the month-of-sample level.

My identification assumption relies on the plausible exogeneity of wind direction at an ignition point with regard to vegetation types. To test the validity of my identification assumption, I employ a placebo test wherein each sector is defined by the opposite of the true wind direction at ignition. If the wind is blowing in the opposite direction (not toward eucalyptus), the coefficient on eucalyptus should not have statistical significance.

6. Results

First, I estimate the effect of eucalyptus using the main regression specification and 1-kilometer radius sectors. These results (Table 1) imply that eucalyptus decrease burn area by 8.8 percentage points. The coefficient is statistically significant at the 5% level. Is it possible that eucalyptus trees decrease acres burned relative to non-eucalyptus hardwood woodlands? One explanation for the negative coefficient could come from the fire data skewing heavily toward small fires. Only 7.5% of fires in the data are greater than or equal to 10 acres (.04 km^2). Since eucalyptus are large trees, they may be unlikely to catch fire from only a small ignition. Furthermore, if eucalyptus trees are close to homes, small ignitions may be observed and put out more quickly than in other areas.

Table 1: Effect of Eucalyptus on Area Burned

	Dependent variable:			
	log(BurnArea)			
	(1)	(2)	(3)	(4)
Eucalyptus	-0.220***	-0.172***	-0.095**	-0.092**
	(0.034)	(0.033)	(0.047)	(0.046)
Hardwood Forest	0.160***	-0.036***	-0.002	-0.010
	(0.011)	(0.012)	(0.024)	(0.024)
Conifer	-0.772***	-0.638***	-0.111***	-0.117***
	(0.011)	(0.013)	(0.041)	(0.041)
Agriculture	-0.011	-0.085***	0.040*	0.040*
	(0.011)	(0.012)	(0.022)	(0.022)
Other	-0.162***	-0.031*	-0.004	0.008
	(0.018)	(0.018)	(0.027)	(0.027)
Elevation		-0.0003***		-0.0002*
		(0.00001)		(0.0001)
Elevation Range		0.001***		0.0005***
		(0.0001)		(0.0001)
Wind speed		0.042***		0.047***
		(0.003)		(0.004)
Temperature		0.038***		0.026***
		(0.001)		(0.002)
Population Density		-401.535***		-85.736***
		(7.440)		(15.253)
Income		-0.00000***		-0.00000
		(0.00000)		(0.00000)
Home Value		0.00003***		0.00003
		(0.00001)		(0.00003)
Road Distance		0.0001***		0.0003***
		(0.00001)		(0.00003)
Constant	-0.455***	-1.275***		
	(0.019)	(0.032)		
Fixed Effects	No	No	Yes	Yes
Observations	188,926	188,914	188,926	188,914
R^2	0.030	0.069	0.476	0.479
Adjusted R^2	0.030	0.069	0.285	0.288
Residual Std. Error	1.973 (df = 188920)	1.932 (df = 188900)	1.694 (df = 138379)	1.689 (df = 138364)
Note:				*p<0.1; **p<0.05; ***p<0.01

CAL FIRE classifies fires seven size categories[1]. In Table 2, I test whether eucalyptus cause an increase in the probability of large fires. I define large fires as greater than or equal to 10 acres (Class C and above). By this definition, 7.5% of the fires in the data are large fires. Eucalyptus is no longer statistically significant once fixed effects are included (Columns 3 and 4). The results indicate that eucalyptus do not increase the probability of large fires. In column 4, elevation range, wind speed, temperature, population density, and road distance are all statistically significant at the 1% level, and the signs of their coefficients are consistent with my expectations. Since greater elevation range implies steeper slopes, this should be correlated with larger fires and we indeed find a positive coefficient. Higher wind speeds and hotter temperatures are also associated with larger fires. Higher population density at the census block level is associated with smaller fires, which is consistent with more fire suppression in more populated areas. Median income and home value are at the census tract level, so their effects are largely absorbed by the location fixed effects in Column 4. Greater distances from ignition point to the nearest road is associated with larger fires, which approximates the effect of less fire suppression in more remote areas. These results are robust to defining large fires as greater than or equal to .25 acres (Class B and above). The results are also robust to 5 kilometer sectors.

[1] Class A is 0-.25 acres, Class B is .26-9.99, Class C is 10-99 acres, Class D is 100-299 acres, Class E is 300-999, Class F is 1,000-4,999, Class G is 5,000 acres or more (California Department of Forestry and Fire Protection 2017).

Table 2: Effect of Eucalyptus on the Probability of a Fire ≥ 10 acres

	Dependent variable:			
	Probability of Large Fire			
	(1)	(2)	(3)	(4)
Eucalyptus	-0.035^{***}	-0.025^{***}	-0.008	-0.007
	(0.005)	(0.005)	(0.006)	(0.006)
Hardwood Forest	-0.001	-0.014^{***}	-0.004	-0.004
	(0.001)	(0.002)	(0.003)	(0.003)
Conifer	-0.058^{***}	-0.062^{***}	-0.016^{***}	-0.016^{***}
	(0.001)	(0.002)	(0.005)	(0.005)
Agriculture	-0.027^{***}	-0.024^{***}	0.002	0.003
	(0.001)	(0.002)	(0.003)	(0.003)
Other	-0.003	0.007^{***}	0.003	0.004
	(0.002)	(0.002)	(0.003)	(0.003)
Elevation		-0.00001^{***}		-0.00002
		(0.00000)		(0.00002)
Elevation Range		0.0001^{***}		0.0001^{***}
		(0.00001)		(0.00001)
Wind speed		0.004^{***}		0.004^{***}
		(0.0003)		(0.001)
Temperature		0.004^{***}		0.003^{***}
		(0.0001)		(0.0002)
Population Density		-31.713^{***}		-5.238^{***}
		(1.003)		(1.584)
Income		-0.00000		0.00000
		(0.00000)		(0.00000)
Home Value		-0.00000^{***}		-0.00000
		(0.00000)		(0.00000)
Road Distance		0.00001^{***}		0.00003^{***}
		(0.00000)		(0.00000)
Constant	0.109^{***}	0.018^{***}		
	(0.003)	(0.004)		
Fixed Effects	No	No	Yes	Yes
Observations	188,926	188,914	188,926	188,914
R^2	0.010	0.028	0.423	0.425
Adjusted R^2	0.010	0.028	0.213	0.215
Residual Std. Error	0.263 (df = 188920)	0.260 (df = 188900)	0.234 (df = 138379)	0.234 (df = 138364)
Note:				*p<0.1; **p<0.05; ***p<0.01

As an indirect test of the validity of my identification assumption, I employ a placebo test wherein each sector is defined by the opposite of the true wind direction at ignition. The controls are the same as in the previous regression and retain the expected signs. If the wind is blowing in the opposite direction (not toward eucalyptus), the coefficient on eucalyptus should not have statistical significance. Table 3 provides the results of the placebo test for the regression specification in Table 2 (the probability of a fire greater than or equal to 10 acres). In the placebo test results, the eucalyptus coefficient is close to zero and statistically insignificant after including fixed effects. These results validate the identification assumption.

Table 3: Placebo Test for Effect of Eucalyptus on the Probability of a Fire ≥ 10 acres

	Dependent variable:			
	Probability of Large Fire			
	(1)	(2)	(3)	(4)
Eucalyptus	-0.026^{***}	-0.015^{***}	0.004	0.004
	(0.005)	(0.005)	(0.007)	(0.007)
Hardwood Forest	-0.001	-0.013^{***}	0.002	0.003
	(0.001)	(0.002)	(0.002)	(0.002)
Conifer	-0.056^{***}	-0.059^{***}	-0.001	-0.002
	(0.001)	(0.002)	(0.004)	(0.004)
Agriculture	-0.029^{***}	-0.027^{***}	-0.003	-0.003
	(0.001)	(0.002)	(0.003)	(0.003)
Other	-0.004	0.005^{*}	-0.002	-0.001
	(0.002)	(0.002)	(0.003)	(0.003)
Elevation		-0.00001^{***}		-0.00002
		(0.00000)		(0.00002)
Elevation Range		0.0001^{***}		0.00005^{***}
		(0.00001)		(0.00001)
Wind speed		0.004^{***}		0.004^{***}
		(0.0003)		(0.001)
Temperature		0.004^{***}		0.003^{***}
		(0.0001)		(0.0002)
Population Density		-31.155^{***}		-5.294^{***}
		(1.000)		(1.588)
Income		-0.00000		0.000
		(0.00000)		(0.00000)
Home Value		-0.00001^{***}		-0.00000
		(0.00000)		(0.00000)
Road Distance		0.00001^{***}		0.00003^{***}
		(0.00000)		(0.00000)
Constant	0.109^{***}	0.021^{***}		
	(0.003)	(0.004)		
Fixed Effects	No	No	Yes	Yes
Observations	188,926	188,914	188,926	188,914
R^2	0.009	0.027	0.423	0.425
Adjusted R^2	0.009	0.027	0.212	0.215
Residual Std. Error	0.263 (df = 188920)	0.261 (df = 188900)	0.234 (df = 138379)	0.234 (df = 138364)
Note:				*p<0.1; **p<0.05; ***p<0.01

7. Conclusion

Californians have long disagreed as to whether eucalyptus trees causally increase the spread of wildfire in California. I find no evidence that eucalyptus trees cause increased area burned. This is not to say that eucalyptus never increase fire spread. Rather, on average, the effect of eucalyptus on fire size is not detectably larger than comparable vegetation (other hardwood woodland). Given this result, costly efforts to remove eucalyptus trees may not constitute an efficient allocation of resources in a fire prevention plan. Future studies could improve upon this work by incorporating more complex fire models. Furthermore, my analysis does not account for the effect of repeat fires decreasing subsequent fire risk. Nonetheless, my results suggest that removing eucalyptus may not significantly reduce wildfire spread.

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Appendix

Effect of Eucalyptus on Area Burned for Fires ≥ .25 acres

	Dependent variable:			
	logacres			
	(1)	(2)	(3)	(4)
euc	-0.294***	-0.171***	-0.096	-0.094
	(0.042)	(0.042)	(0.059)	(0.058)
hardwood_forest	-0.047***	-0.151***	-0.019	-0.030
	(0.015)	(0.016)	(0.038)	(0.038)
conifer	-0.403***	-0.593***	-0.094*	-0.103*
	(0.015)	(0.018)	(0.055)	(0.056)
ag	-0.353***	-0.223***	0.034	0.041
	(0.013)	(0.014)	(0.029)	(0.029)
other	-0.005	0.088***	0.038	0.056
	(0.023)	(0.023)	(0.041)	(0.041)
mean_elev		0.0001***		-0.0004
		(0.00001)		(0.0002)
elev_range		0.002***		0.001***
		(0.0001)		(0.0002)
windspeed		0.042***		0.051***
		(0.003)		(0.006)
mean_temp		0.033***		0.024***
		(0.001)		(0.002)
popden		-286.605***		-51.860***
		(10.533)		(17.953)
median_income		0.00000		-0.00000
		(0.00000)		(0.00000)
median_home_value		-0.0001***		-0.00002
		(0.00001)		(0.00004)
road_distance		0.0001***		0.0003***
		(0.00001)		(0.0001)
Constant	0.872***	-0.077*		
	(0.024)	(0.042)		
Fixed Effects	No	No	Yes	Yes
Observations	95,096	95,092	95,096	95,092
R^2	0.014	0.051	0.562	0.565
Adjusted R^2	0.014	0.051	0.312	0.316
Residual Std. Error	1.800 (df = 95090)	1.766 (df = 95078)	1.503 (df = 60550)	1.499 (df = 60541)
Note:				*p<0.1; **p<0.05; ***p<0.01

5 km radius sectors: Effect of Eucalyptus on the Probability of a Fire ≥ 10 acres

	Dependent variable:			
	Probability of Large Fire			
	(1)	(2)	(3)	(4)
Eucalyptus	-0.024***	-0.014***	-0.008***	-0.009***
	(0.002)	(0.002)	(0.003)	(0.003)
Hardwood Forest	-0.004***	-0.012***	-0.005*	-0.004
	(0.001)	(0.002)	(0.002)	(0.003)
Conifer	-0.049***	-0.044***	-0.007**	-0.005*
	(0.002)	(0.002)	(0.003)	(0.003)
Agriculture	-0.022***	-0.021***	-0.002	-0.004*
	(0.001)	(0.002)	(0.002)	(0.002)
Other	-0.003	0.001	0.005	0.005
	(0.022)	(0.022)	(0.023)	(0.023)
Elevation		-0.00001***		-0.00004***
		(0.00000)		(0.00001)
Elevation Range		0.00002***		0.00002***
		(0.00000)		(0.00000)
Wind speed		0.004***		0.004***
		(0.0003)		(0.001)
Temperature		0.004***		0.004***
		(0.0001)		(0.0003)
Population Density		-35.303***		-12.880***
		(1.480)		(1.920)
Income		0.00000***		-0.00000
		(0.00000)		(0.00000)
Home Value		-0.00000**		-0.00000
		(0.00000)		(0.00000)
Road Distance		0.00001***		0.00002***
		(0.00000)		(0.00000)
Constant	0.118***	0.017		
	(0.022)	(0.022)		
Fixed Effects	No	No	Yes	Yes
Observations	188,929	188,917	188,929	188,917
R^2	0.008	0.021	0.107	0.111
Adjusted R^2	0.008	0.021	0.085	0.089
Residual Std. Error	0.263 (df = 188923)	0.261 (df = 188903)	0.253 (df = 184340)	0.252 (df = 184320)
Note:				*p<0.1; **p<0.05; ***p<0.01