Landowner Expectations of Wildfire Risk Have Accelerated Harvest, Reduced Volume, and Altered Fuel Loads in Western U.S. Forests

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AEC Working Group

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Wildfire Risk Is Rising, and It's Costly

- Large wildfires in the western US have become more frequent and severe (Abatzoglou and Williams, 2016)
- The mortality cost of climate-driven smoke is projected to exceed the climate damages from all other causes combined (Qiu et al., 2025)
  - Wildfires account for up to half of western $PM_{2.5}$ emissions in recent years (Burke et al., 2021)
  - CO_2 emissions from California's 2020 wildfires were about twice the state's total greenhouse gas reductions since 2003 (Jerrett et al., 2022)

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  - CO_2 emissions from California's 2020 wildfires were about twice the state's total greenhouse gas reductions since 2003 (Jerrett et al., 2022)
- Two drivers of rising fire activity
  - A warmer, drier climate (Abatzoglou and Williams, 2016)
  - Increase in fuels driven by a century of fire suppression (Hagmann et al., 2021)
- How much fuel is on the landscape is partly a management choice
  - How private landowners manage their forests can affect smoke, carbon, and generate other social costs and benefits

More Fuels Lead to More Smoke

Emissions per acre burned from two 2020 wildfires:



Western Oregon forest. Photo: Oregon State University

- Beachie Creek, Western Oregon (194,000 acres)
  - $PM_{2.5}$: 1.07 tons per acre
  - CO_2: 109 tons per acre

Source: Wildland Fire Emissions Information System (WFEIS). Metric tons.

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Conifer forest in the Sierra Nevada. Photo: Avery Hill

- North Complex, Sierra Nevada California (316,000 acres)
  - $PM_{2.5}$: 0.25 tons per acre
  - CO_2: 30 tons per acre

Source: Wildland Fire Emissions Information System (WFEIS). Metric tons.

More Fuels Lead to More Smoke

Implied damages from two 2020 wildfires:



Western Oregon forest. Photo: Oregon State University

- Beachie Creek, Western Oregon (194,000 acres)
  - $PM_{2.5}$: \$11.3 billion
  - CO_2: \$3.9 billion
  - Damages: \$15.2 billion



Conifer forest in the Sierra Nevada. Photo: Avery Hill

- North Complex, Sierra Nevada California (316,000 acres)
  - $PM_{2.5}$: \$4.3 billion
  - CO_2: \$1.7 billion
  - Damages: \$6.1 billion

Source: Wildland Fire Emissions Information System (WFEIS). Metric tons. $PM_{2.5}$ at \$54,114 per ton (Strabo et al., 2026); CO_2 at \$185 per ton (Rennert et al., 2022).

Private Forests Make Up a Large Share of the Landscape

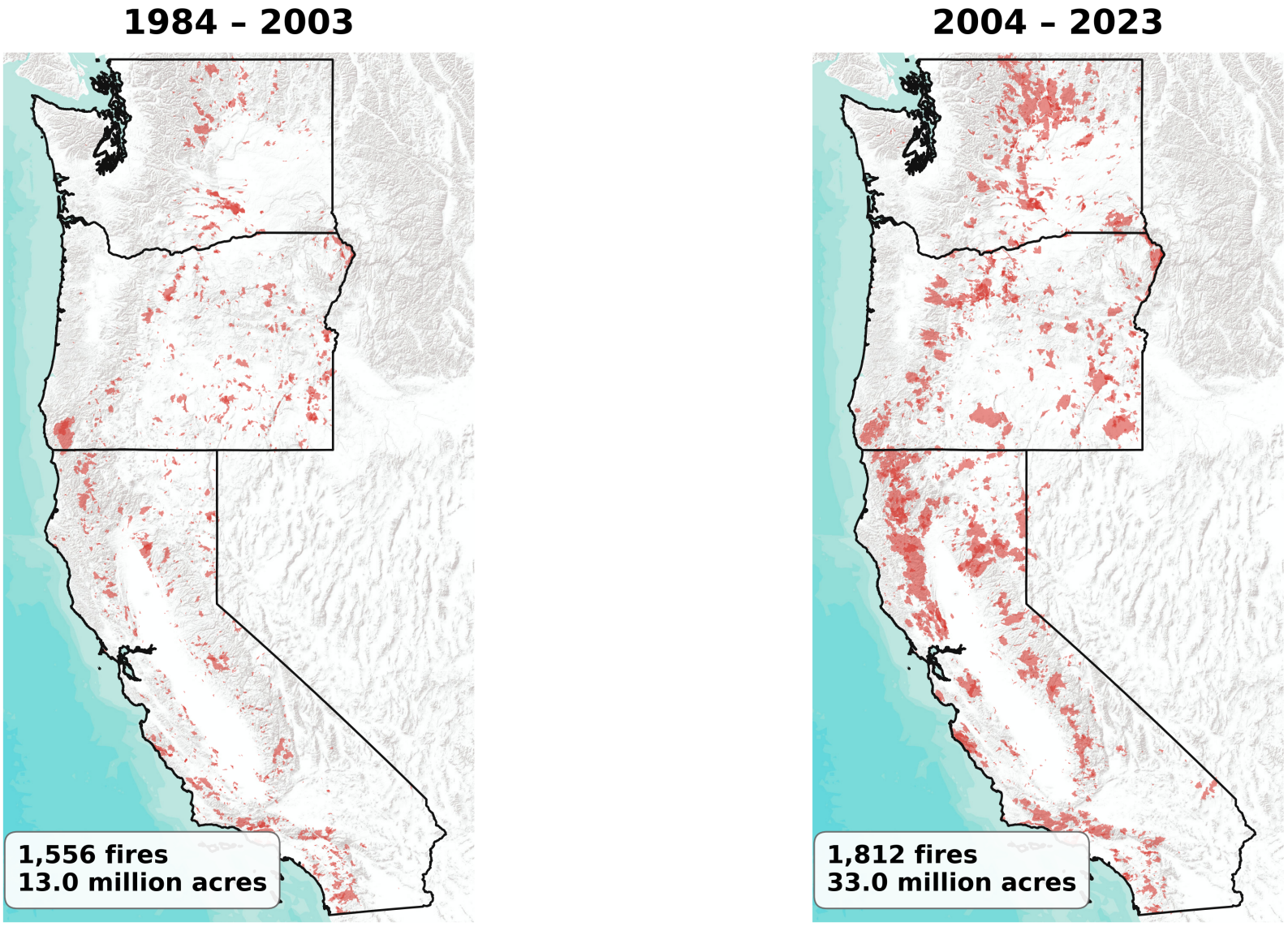
- 60% of US forest land is privately owned (USDA Forest Service, 2023)
  - In California, Oregon, and Washington, about 45% of forest land is non-federal (Harris et al., 2025)
- Private timberland is often managed for timber revenue
  - Private lands supply 89% of the US timber harvest (Oswalt et al., 2019)
- Private forest management can therefore have significant effects on fire outcomes

Theory Predicts How Management Should Respond to Risk

- Economic theory predicts how management should respond to increased risk (Reed, 1984; Amacher et al., 2005; Patto and Rosa, 2022)

- We have no large-scale empirical evidence on how landowners actually respond
  - Need evidence on how adaptation changes smoke, carbon, and other externalities
  - The Western U.S. provides us a natural setting to test some long-standing theoretical predictions

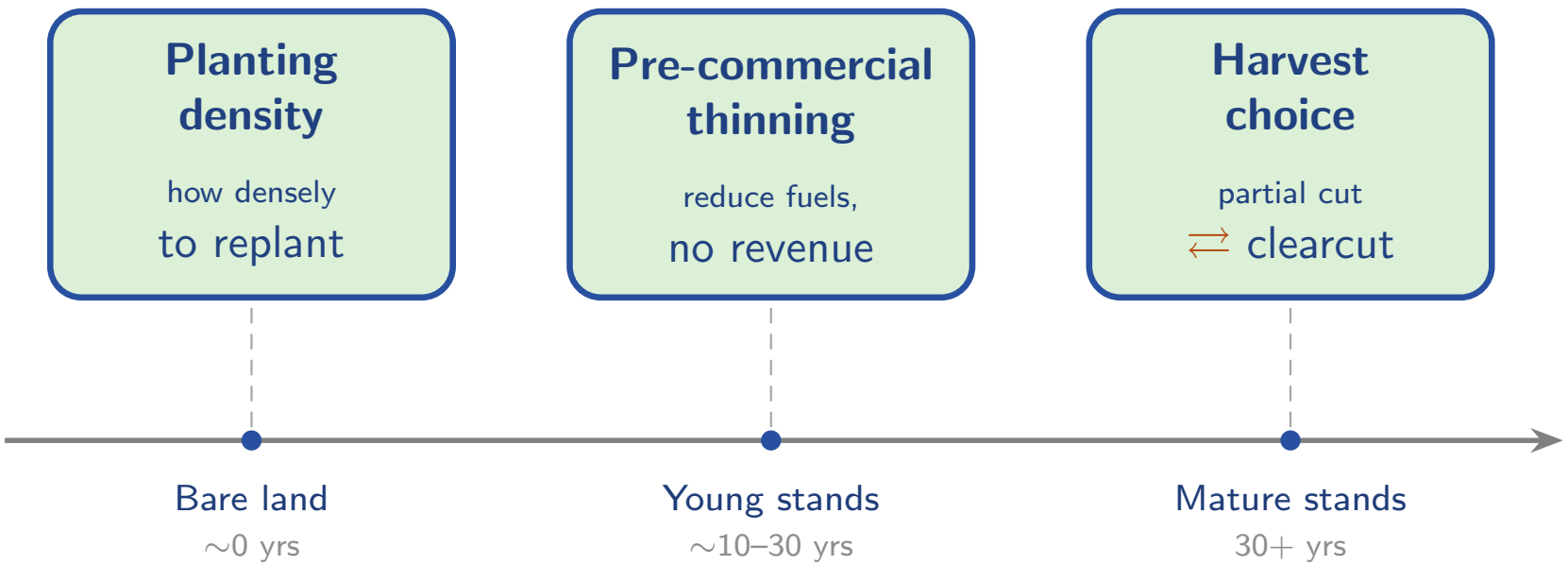
Burned Area in the Western US Has More Than Doubled Since 2004



Data: MTBS (fires ≥ 1,000 acres) | Basemap: Esri World Terrain

How has Rising Wildfire Risk Affected Forest Management?

Research question: How has rising wildfire risk affected private forest management decisions in the western United States?



Preview of Results

- Changing wildfire risk perceptions have significantly affected forest management decisions
  - Nearby fire and hot, dry weather conditions drive landowners to harvest earlier
  - Managers respond to nearby fire by planting less densely
  - Fire-related weather conditions increase the likelihood of pre-commercial thinning

- We then conduct a bio-economic simulation to understand how adaptation changes the landscape and to price some of the resulting externalities

Preview of Results: Bio-Economic Simulation

- Landowner adaptation since 2001 has lowered standing volume on non-federal western forests by 7 to 10 percent
- 2020 fires: more $PM_{2.5}$ ($63 to $72 million in smoke damages), less CO_2 ($28 to $58 million in climate benefits)
  - Present value if this occurs on an annual basis: $1.3 to $1.4 billion in smoke damages, $0.6 to $1.2 billion in climate benefits
- A policy of universal site preparation after clearcuts would have avoided about $37 million in smoke damages
  - Present value: about $740 million

Contribution: How Private Landowners Respond to Wildfire Risk

- Large literature on the costs and public responses to wildfire
  - Smoke and health: Burke et al. (2021); Qiu et al. (2025)
  - Welfare losses from smoke: Gellman et al. (2025)
  - Determinants of fire suppression: Plantinga et al. (2022); Baylis and Boomhower (2023)
  - Fuel treatments on public land: Strabo and Reimer (2026); Strabo et al. (2026)
  - Fire risk and land markets: Huang and Skidmore (2024), Wang and Lewis (2024)

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- No large-scale empirical evidence on how rising risk has changed private forest management decisions

Contribution: Climate Change Adaptation

- Strong evidence that people adapt to changing climate and disaster risk
  - Agriculture: Hornbeck (2012); Burke and Emerick (2016); Taraz (2017)
  - Forestry: Hashida and Lewis (2019); Johnson and Lewis (2024); Hashida et al. (2025)

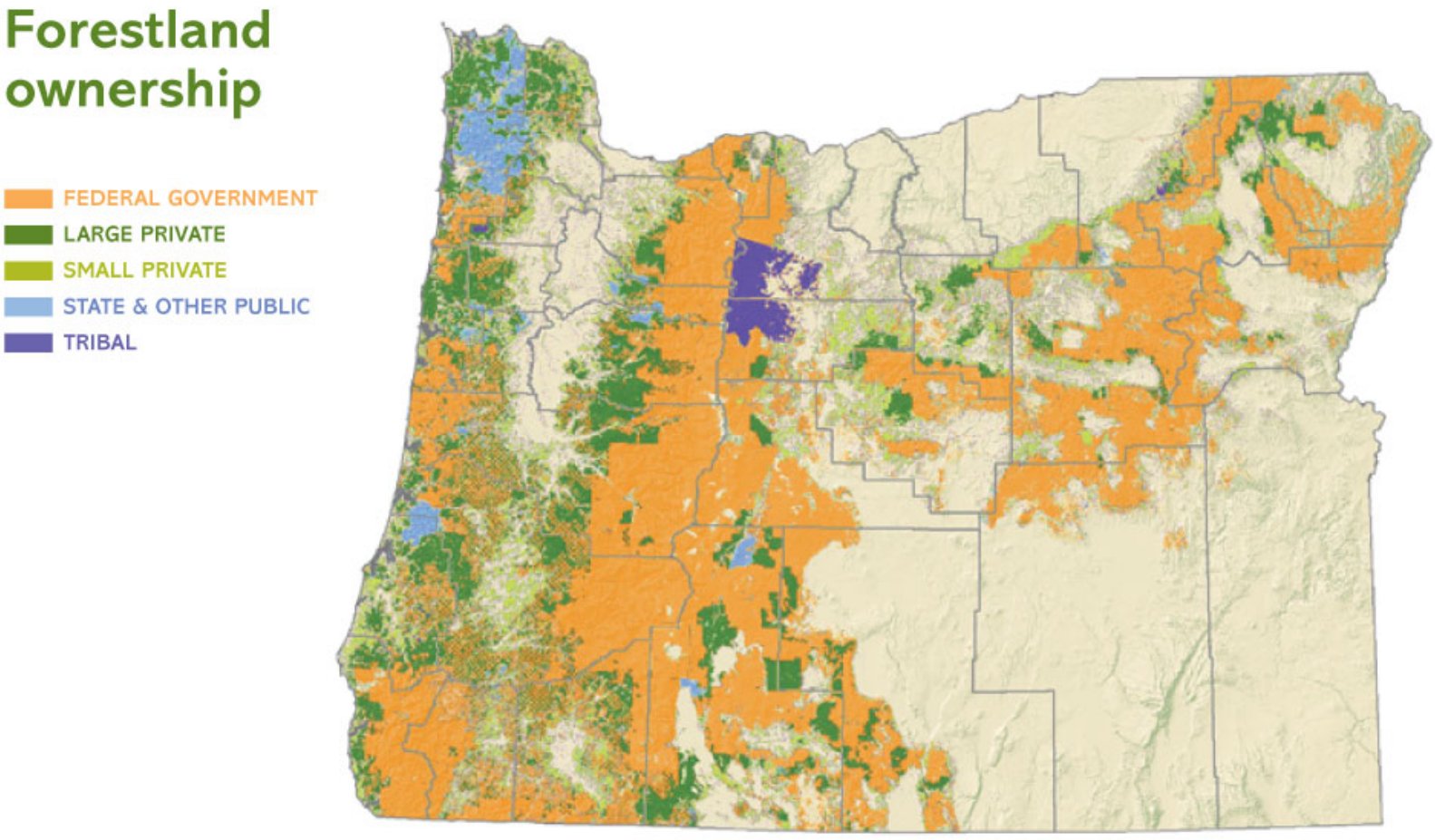
- We provide evidence of another channel of climate change adaptation: forest management responses to wildfire risk

- We document novel landowner adaptation to changing climate risks, which can generate notable social benefits and social costs

Contribution: Forest Management and Air Pollution

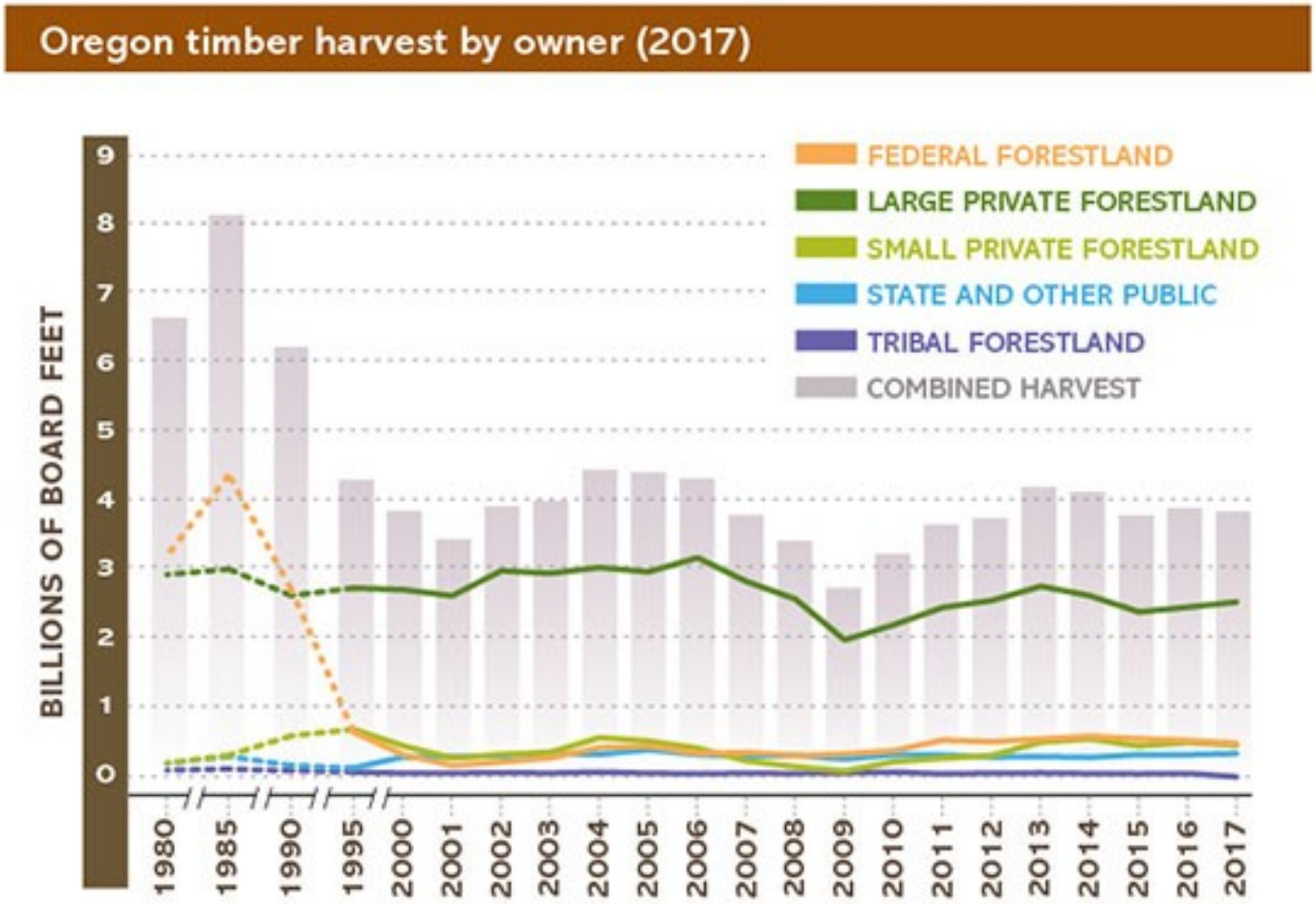
- Economics of air pollution has focused largely on industrial sources
  - Manufacturing and power plants: Greenstone (2002); Fowlie (2010); Shapiro and Walker (2018)
  - Transportation: Davis (2008); Currie and Walker (2011); Auffhammer and Kellogg (2011)
- Wildfire is now a major source of air pollution
- We bring a natural resource angle to this traditional air pollution literature
  - Forest management can change fuels, which in turn can affect air pollution
- Fuels treatments on private land could generate large benefits through cleaner air

Western Forests Are a Mix of Federal and Private Ownership



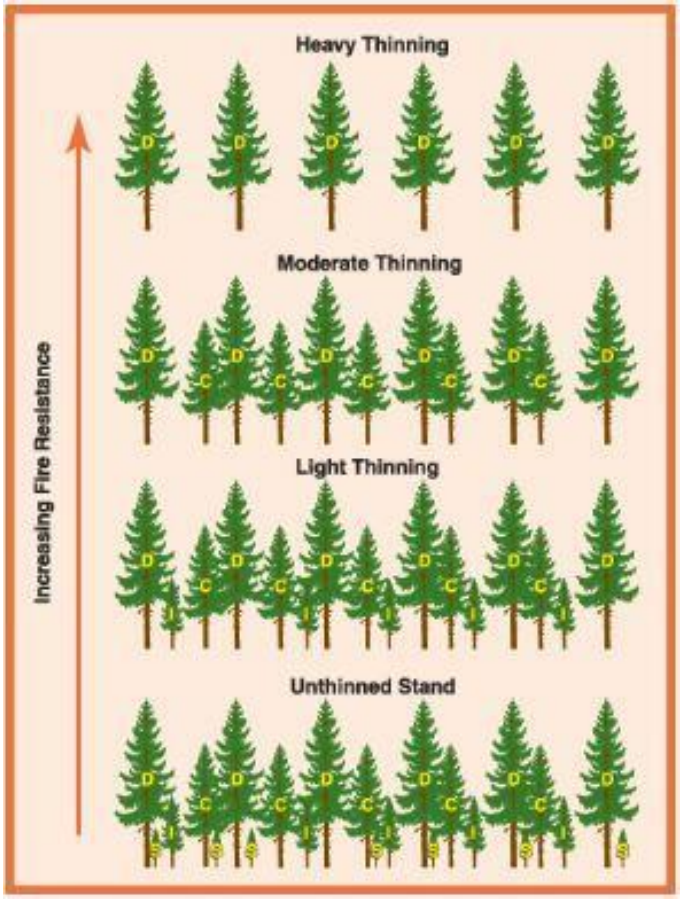
Source: Oregon Forest Resources Institute (OFRI).

Timber Harvests Have Shifted from Federal to Private Lands



Source: Oregon Forest Resources Institute (OFRI).

Partial Cutting as a Management Strategy



Credit: Gretchen Bracher, © Oregon State University.

- A partial cut removes some of the trees and leaves the rest to keep growing
- The landowner earns revenue from the trees removed
- Less dense stands are more resistant to fire

Before and After a Partial Cut

Before



After



Credit: © Oregon State University.

Clearcutting as a Management Strategy



A clearcut in a mixed conifer stand in California.

Photo: Philip McDonald, USDA Forest Service, Bugwood.org.

- A clearcut removes nearly all of the trees at once
- State forest practice rules require the land to be reforested after a clearcut
- Clearcutting is most common on productive west-side forests

Harvests Can Leave Behind Logging Slash



Photo: Francis Eatherington, clearcutoregon.com.

Slash is the branches, treetops, and other woody debris left on the ground after a harvest

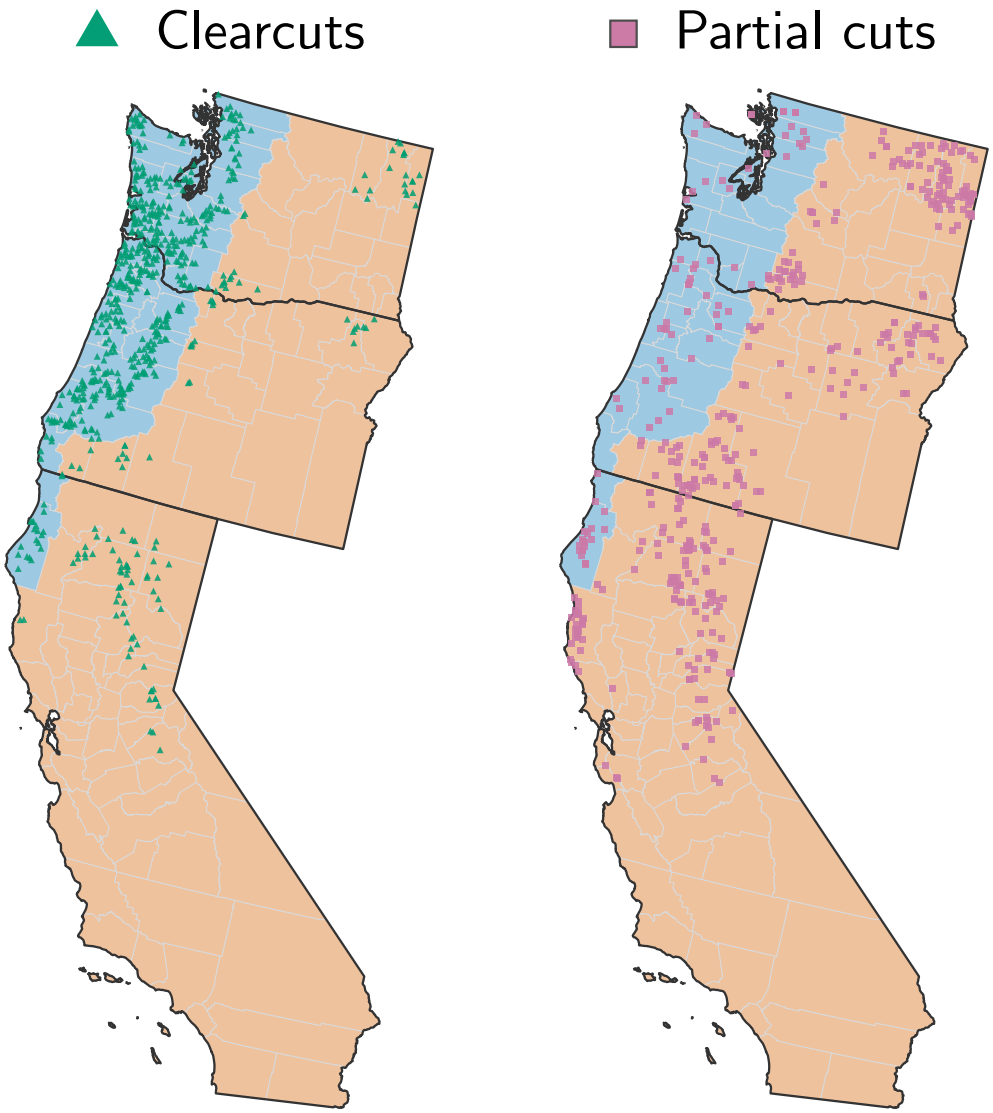
Site Preparation Can Reduce Fuels

- Site preparation gets a harvested site ready for a new stand (Fitzgerald, 1998)
    - Reduces logging slash, controls competing vegetation, and makes planting easier
- Landowners can do it in several ways
    - Cutting by hand
    - Piling slash with machines
    - Burning slash piles or the whole site
    - Spraying herbicides
- Site prep is a way to reduce fuels after a harvest



Slash pile burn. Photo: OSU Extension

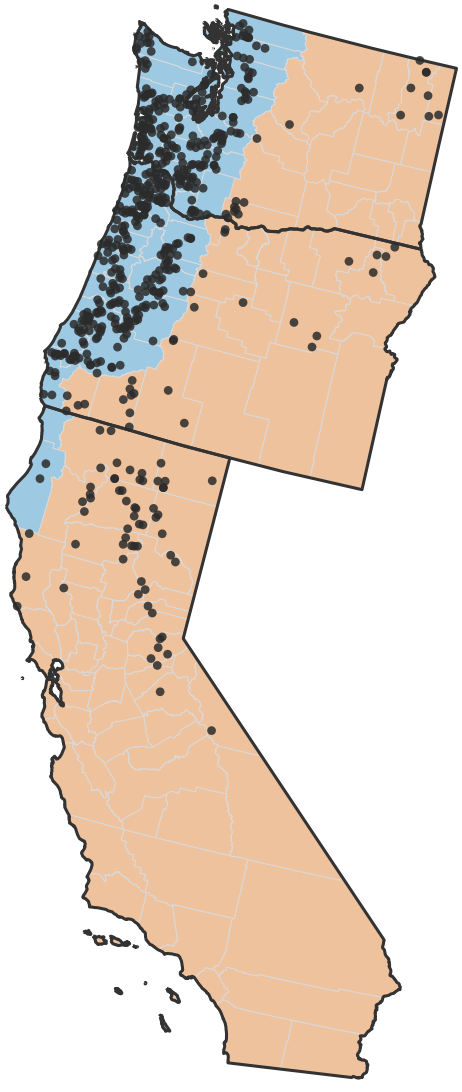
Different Management Regimes in West- and East-Side Forests



Harvests on non-federal timberland in the sample. Blue: west side; orange: interior.

Planting and Natural Regeneration

- Planted stands



Planted stands in the planting density sample.

- Planting is common on valuable west-side forests
  - Landowners replant after a clearcut and choose how densely to plant
- Natural regeneration is another way to start a new stand
  - Remaining trees seed future stands
  - More common in the interior

Planting vs. Natural Regeneration

Planting



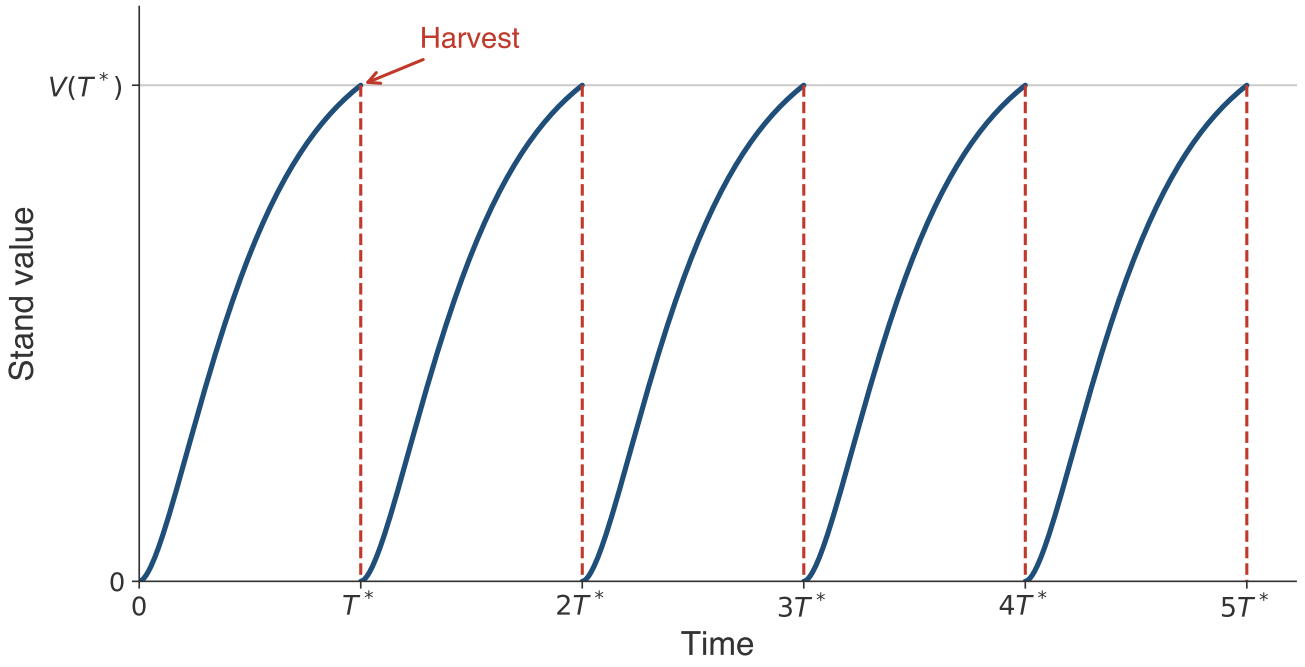
Credit: Oregon Forest Resources Institute

Natural regeneration



Ponderosa pine regeneration. Credit: John Punches

The Landowner's Problem Without Fire Risk

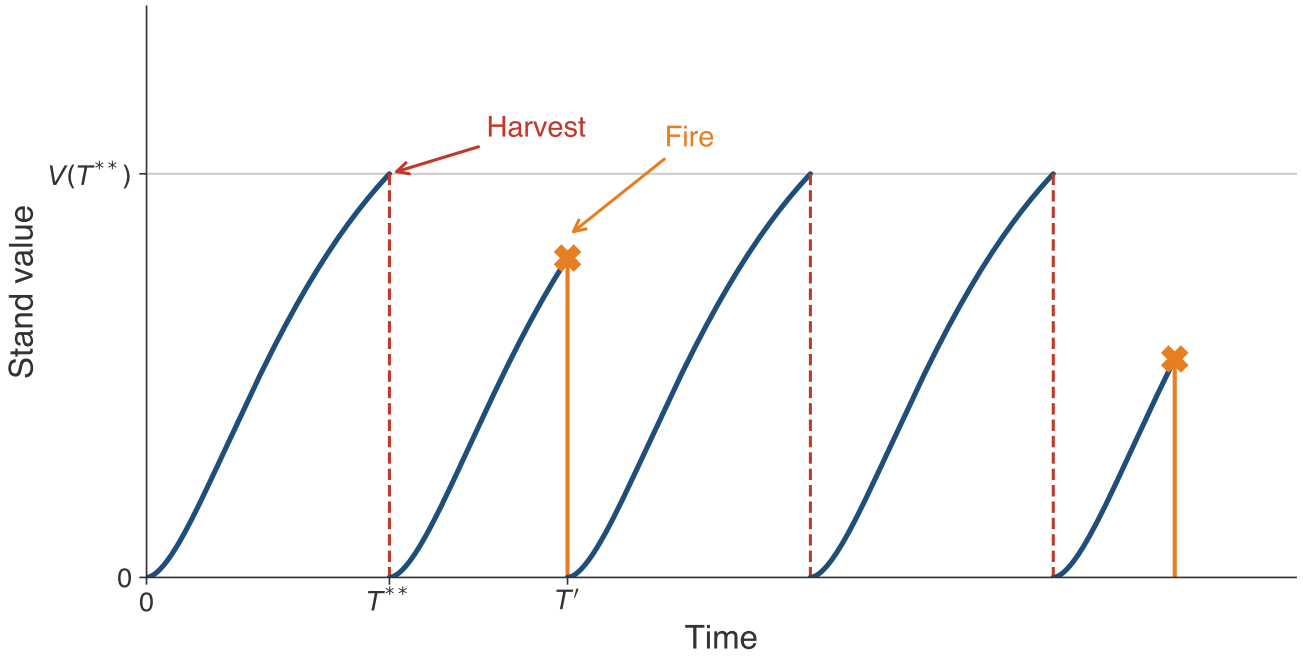


- The landowner maximizes the present value of timber revenue from an infinite series of rotations (Faustmann, 1849)

$$\max_{T} \frac{p\,V(T)\,e^{-rT} - c}{1 - e^{-rT}}$$

- Choice variable: the rotation age T, or when to clearcut and replant

Fire Risk Acts Like a Higher Discount Rate



- Reed (1984) adds wildfire that arrives as a Poisson process with rate λ and destroys the stand
- Higher λ acts like an increase in the discount rate, from r to $r + \lambda$
- Empirical Prediction: landowners harvest sooner ($T^{**} < T^{*}$), so higher λ raises the probability of a harvest in any year
  - The same logic applies where landowners only partial cut

Fire Risk and Other Management Choices

- When managers both partial cut and clearcut a stand, higher λ leads to more partial cuts earlier in the rotation (Patto and Rosa, 2022)
- Amacher et al. (2005) assume fewer fuels raise the salvage value of a stand that burns
  - Higher λ leads landowners to plant at lower densities and do more pre-commercial thinning
- Together, landowners can respond to fire risk through several choices
  - Whether to harvest, and whether to partial cut or clearcut
  - How densely to replant after a clearcut
  - Whether to pre-commercially thin a young stand

Each Year the Landowner Makes a Discrete Choice

Given a stand of age a, climate C, and wildfire arrival rate λ:

$$V_t(a, C, \lambda) = \max \begin{cases} \pi^C(a, C) - R(D) + \delta \, \mathbb{E} \, V_{t+1}(1, C, \lambda) & \text{clearcut} \\ \pi^P(a, C) + \delta \, \mathbb{E} \, V_{t+1}(a' + 1, C, \lambda) & \text{partial cut} \\ \delta \, \mathbb{E} \, V_{t+1}(a + 1, C, \lambda) & \text{grow} \end{cases}$$

- Each year, the landowner makes a discrete choice: let the stand grow, partial cut, or clearcut
  - Fire risk, λ, shifts the value of each action

Measuring Wildfire Risk Perceptions

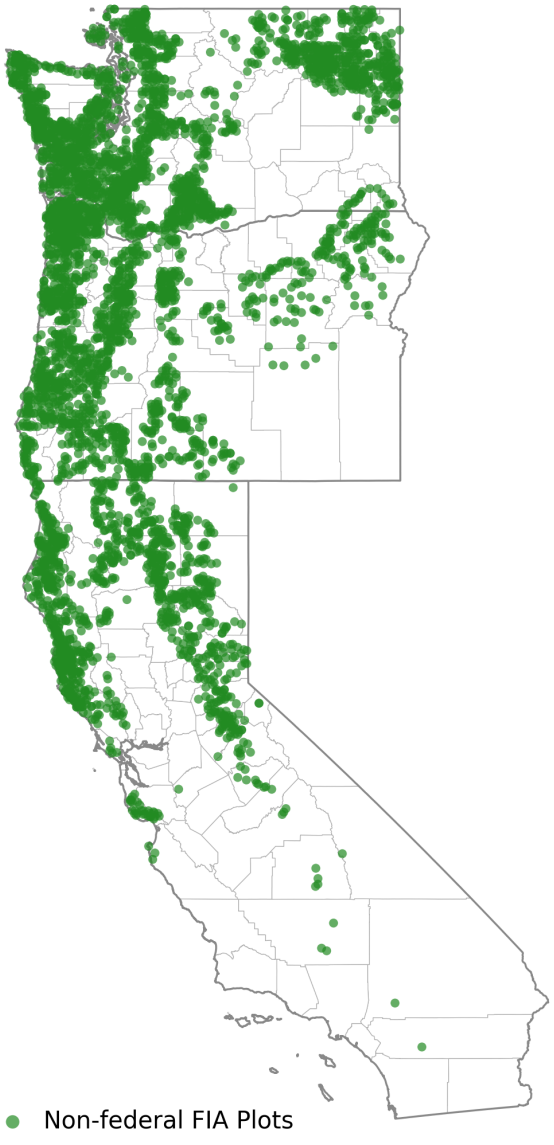
- Landowners respond to changes in their perceived wildfire arrival rate λ, which we do not observe
- We model perceived risk as a function of what landowners observe (Wang and Lewis, 2024):

$$\lambda_{it} = \lambda(\text{Fire}_{it},\ W_{it}), \qquad \lambda_{\text{Fire}} > 0, \quad \lambda_W > 0$$

- Fire_{it}: recent wildfire activity near the stand
- W_{it}: recent hot, dry fire-season weather, measured by vapor pressure deficit (VPD)
  - Rising VPD is the dominant driver of recent growth in western U.S. forest fire area (Abatzoglou and Williams, 2016)
  - The same conditions that drive Red Flag Warnings

Fire Count Distribution

Observing Forest Management Decisions Over Time



- Private and state forest land in CA, OR, and WA, 2001–2024
- USDA Forest Inventory and Analysis (FIA): a national inventory of permanent forest plots, revisited about every 10 years in the West
  - Crews record harvests, thinning, and planting, with timing
- We use confidential true plot locations

Harvest Choice Estimating Sample

- We build an annual panel of stands from the FIA
  - Crews record the year of each harvest
  - Stand age is measured at each visit, so we infer age in the years between visits
  - Fire and weather are observed annually
- Sample of stands aged 30 and older
  - salvage harvests are dropped
  - clearcut plots exit the sample
- 51,451 stand-years from 5,277 stands
  - 447 partial cuts and 640 clearcuts

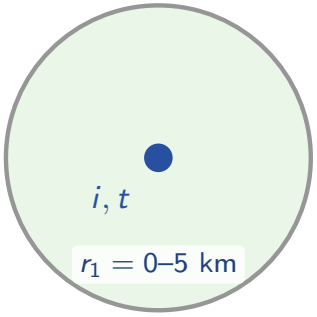
Planting Density Sample

- Pooled cross section of 556 recently planted stands, planted between 2004 and 2023
- Planting density: trees per acre (TPA) of the stand's dominant species
  - Observed at the first FIA visit after planting
- Mostly west-side Douglas-fir (401 of 556 stands), with a mean density of about 400 TPA

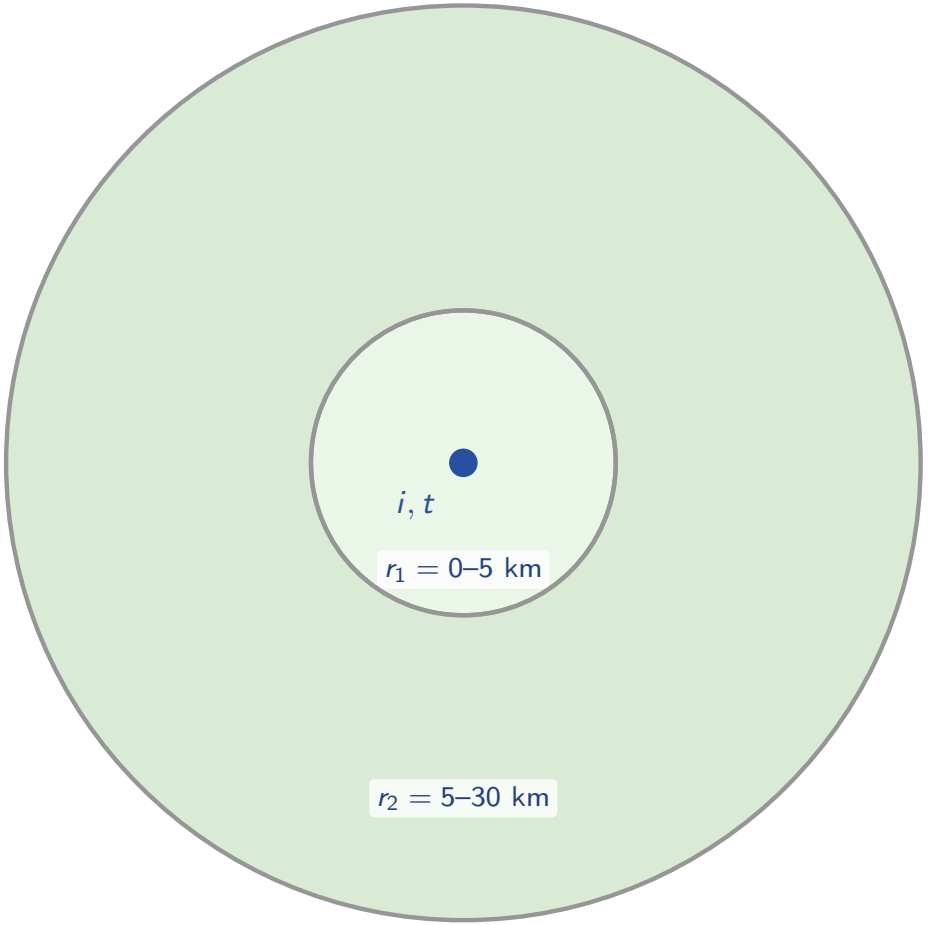
Measuring Local Fire Exposure Around Each Plot



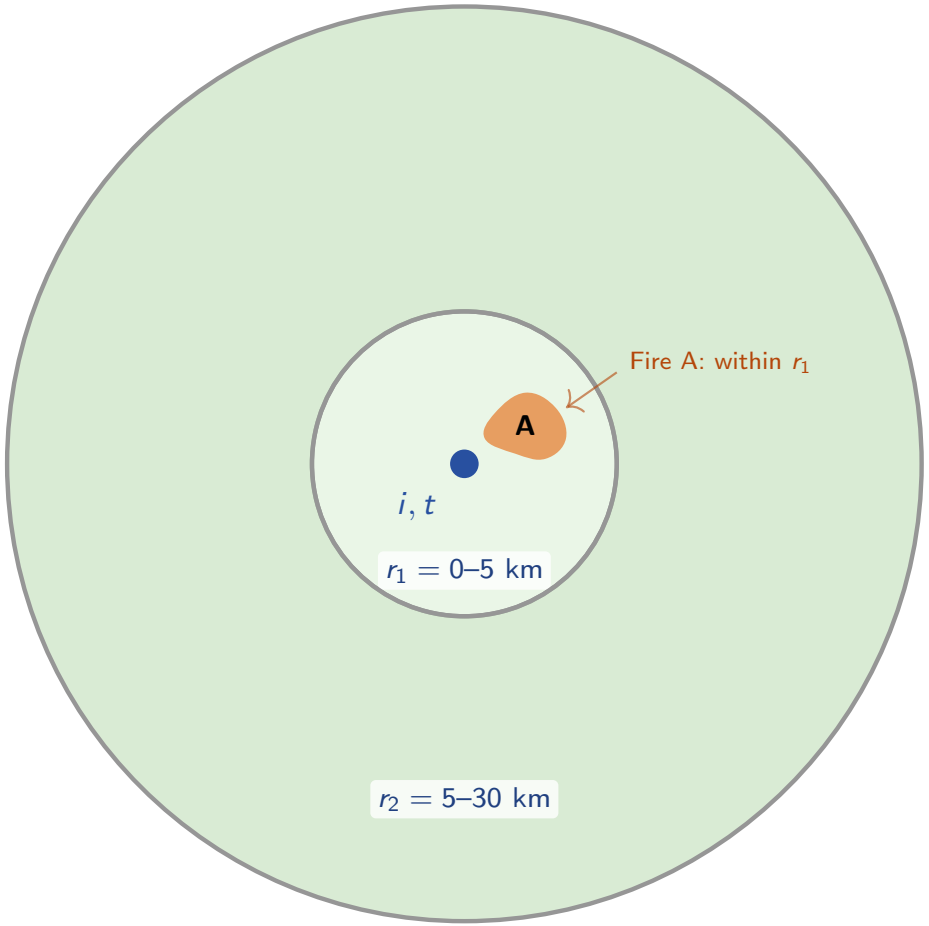
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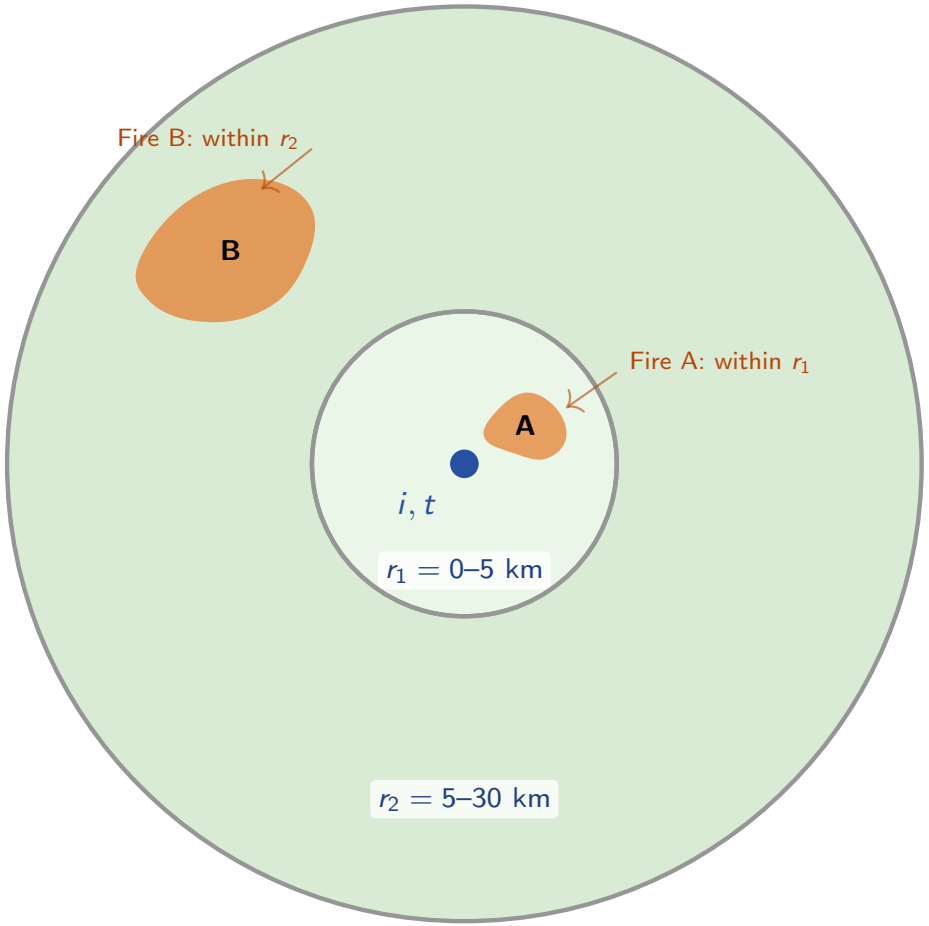


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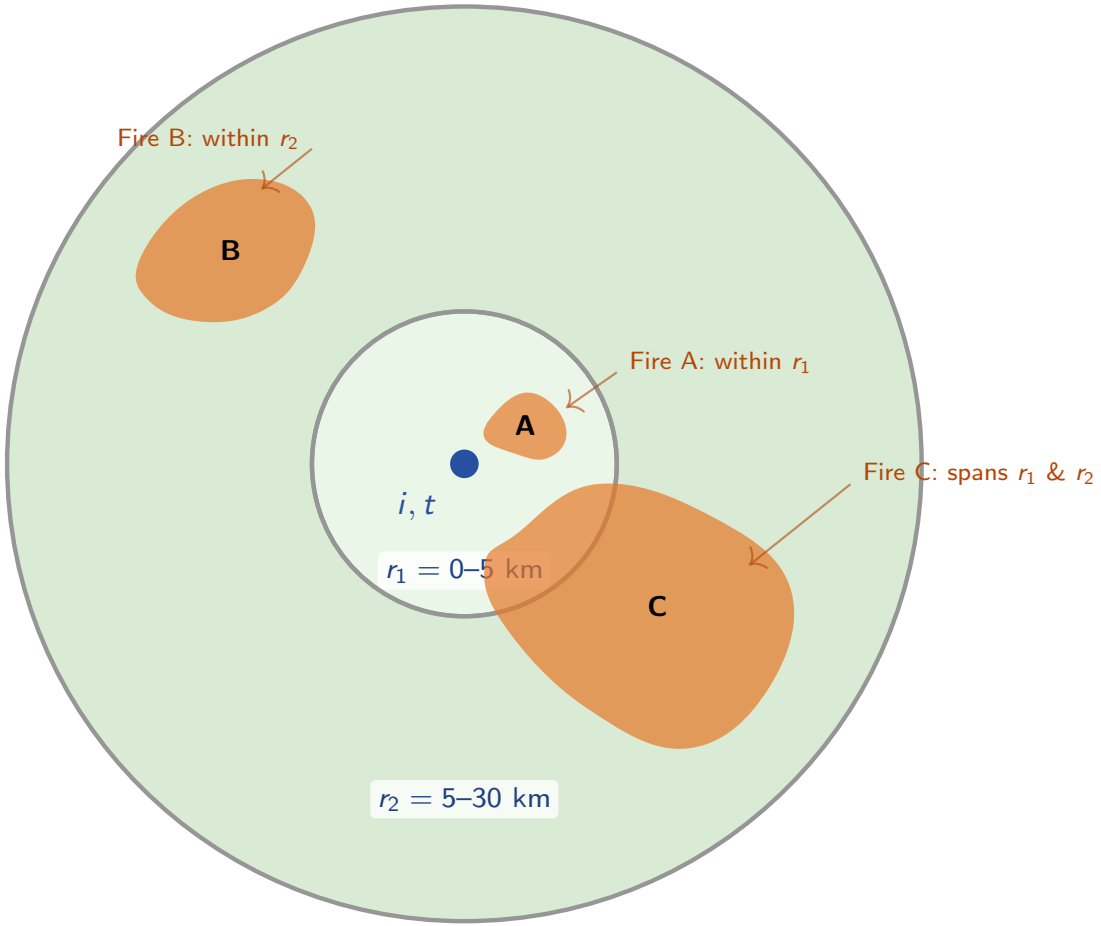
Fire perimeters: MTBS (fires $\geq$ 1,000 acres)

Measuring Local Fire Exposure Around Each Plot



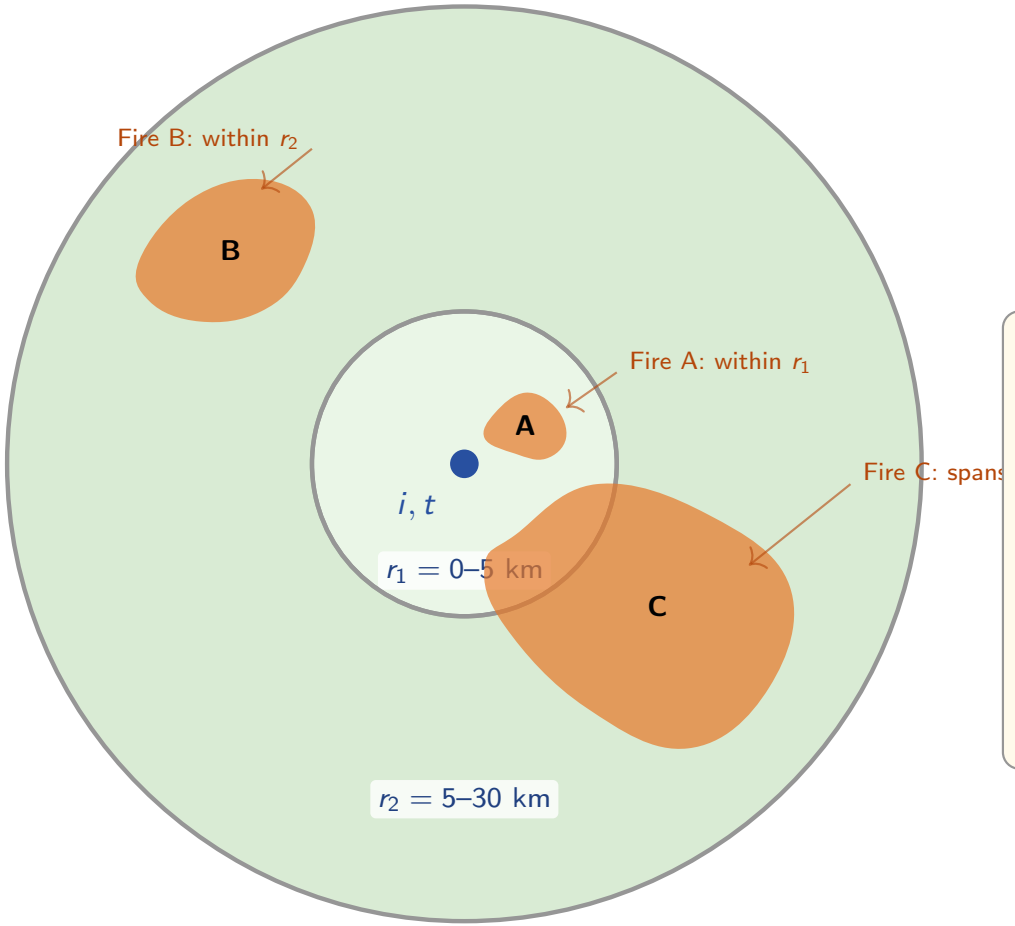
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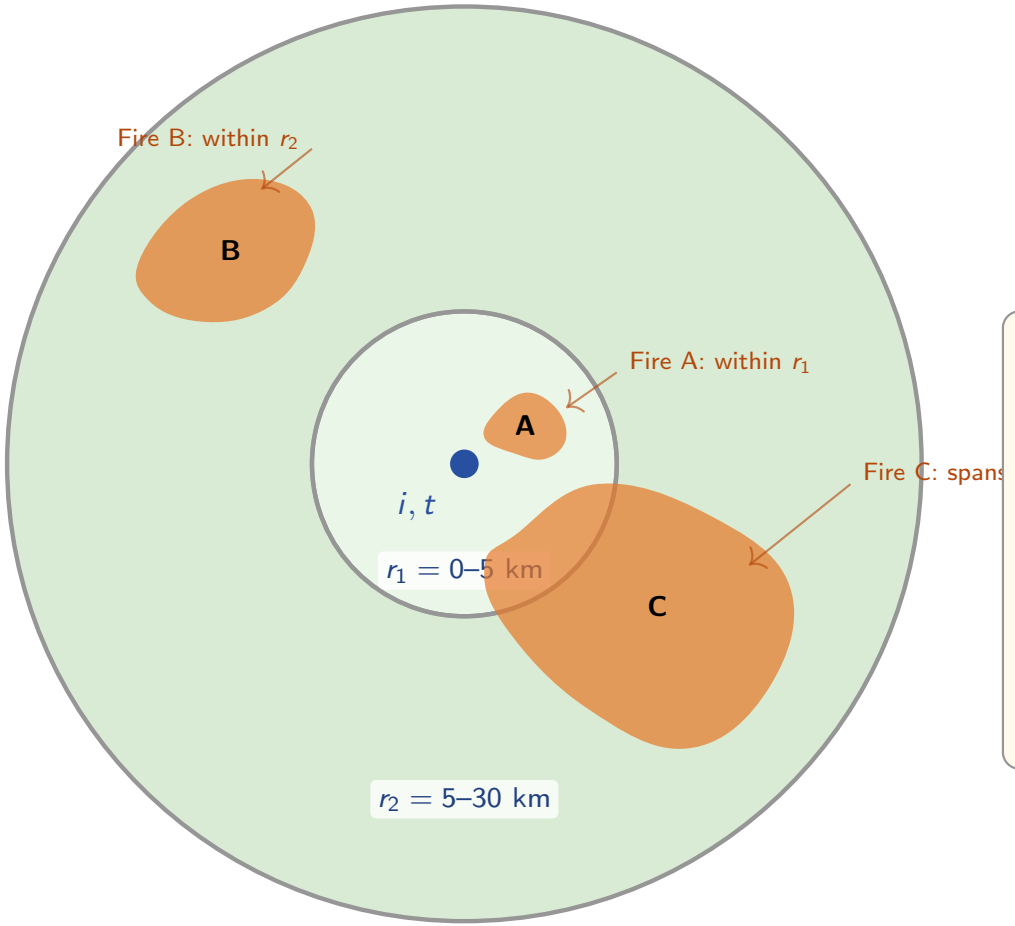


r_1 **(0–5 km):**

Count = **2** (A + C)

Fire perimeters: MTBS (fires $\geq$ 1,000 acres)

Measuring Local Fire Exposure Around Each Plot



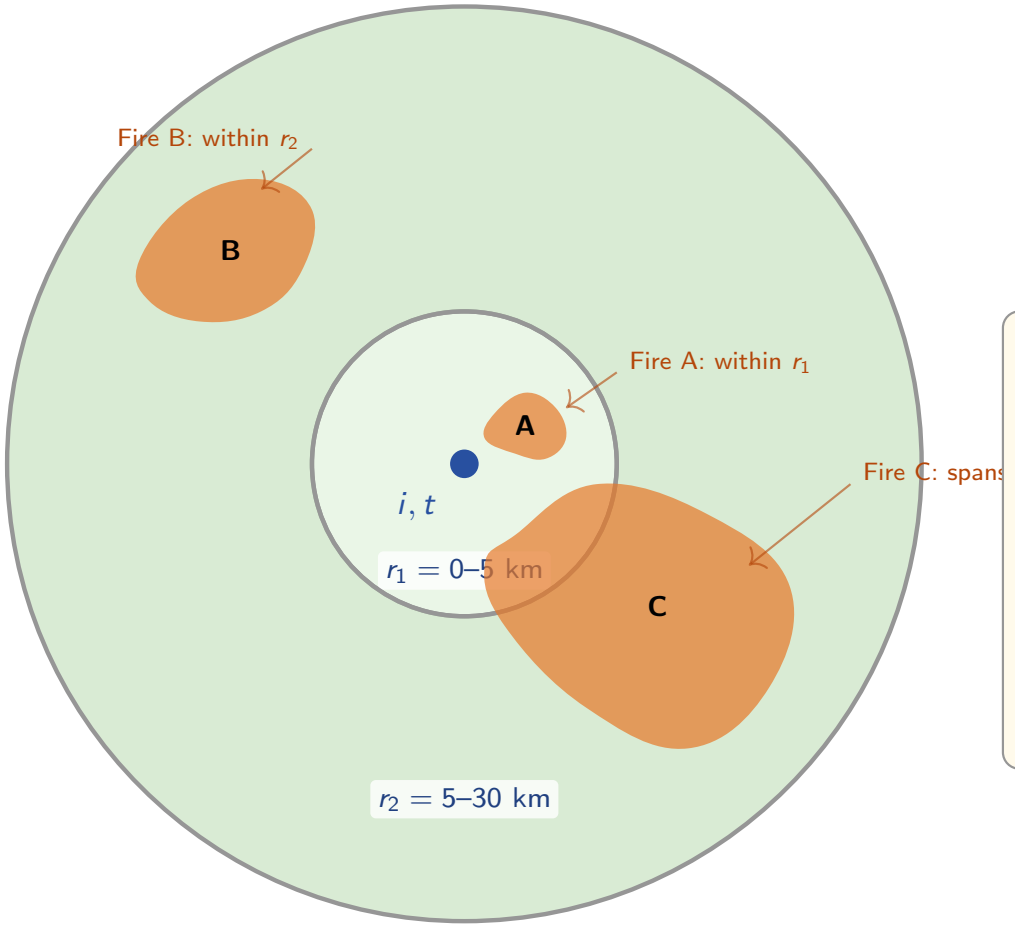
r_1 (0–5 km):

Count = **2** (A + C)

Acres = $a_A + a_{C \cap r_1}$

Fire perimeters: MTBS (fires $\geq$ 1,000 acres)

Measuring Local Fire Exposure Around Each Plot



r_1 **(0–5 km):**

Count = **2** (A + C)

Acres = $a_A + a_{C \cap r_1}$

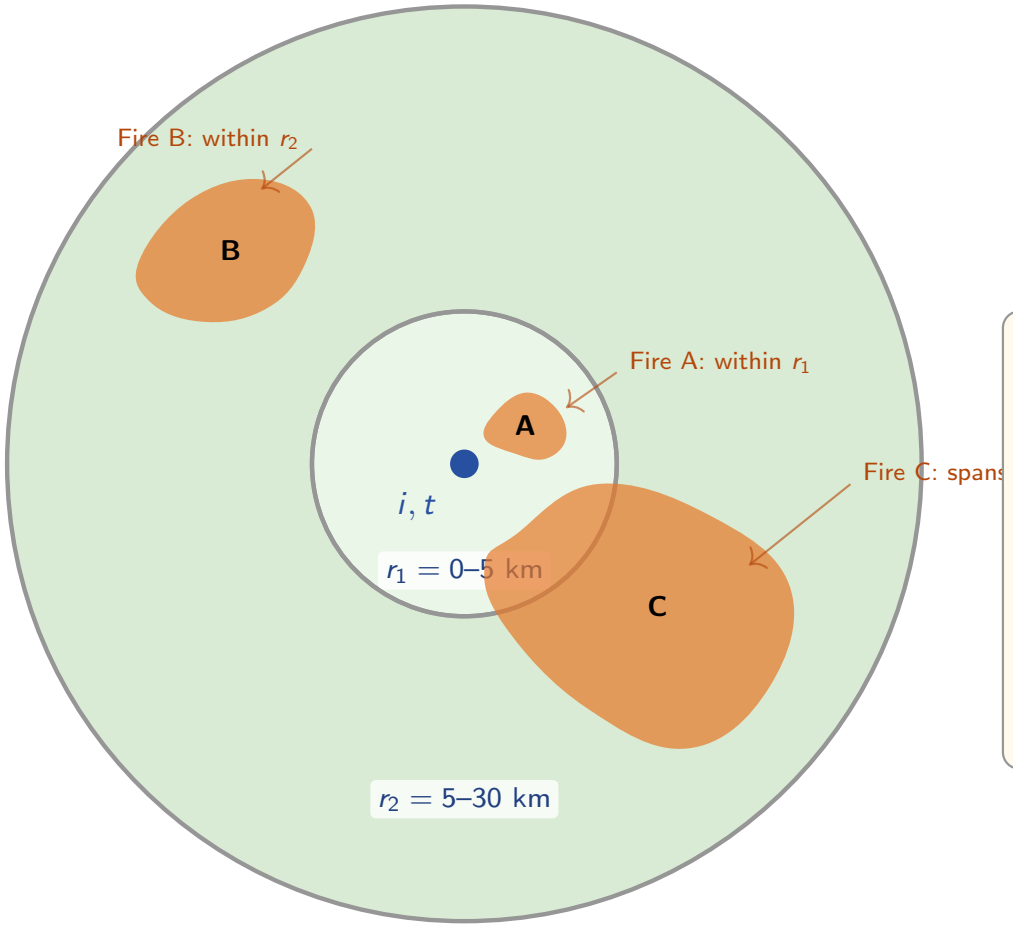
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r_2 **(5–30 km):**

Count = **1** (B only)

Fire perimeters: MTBS (fires $\geq$ 1,000 acres)

Measuring Local Fire Exposure Around Each Plot



r_1 (0–5 km):

Count = **2** (A + C)

Acres = $a_A + a_{C \cap r_1}$

r_2 (5–30 km):

Count = **1** (B only)

Acres = $a_B + a_{C \cap r_2}$

C counted in r_1 only; acres split

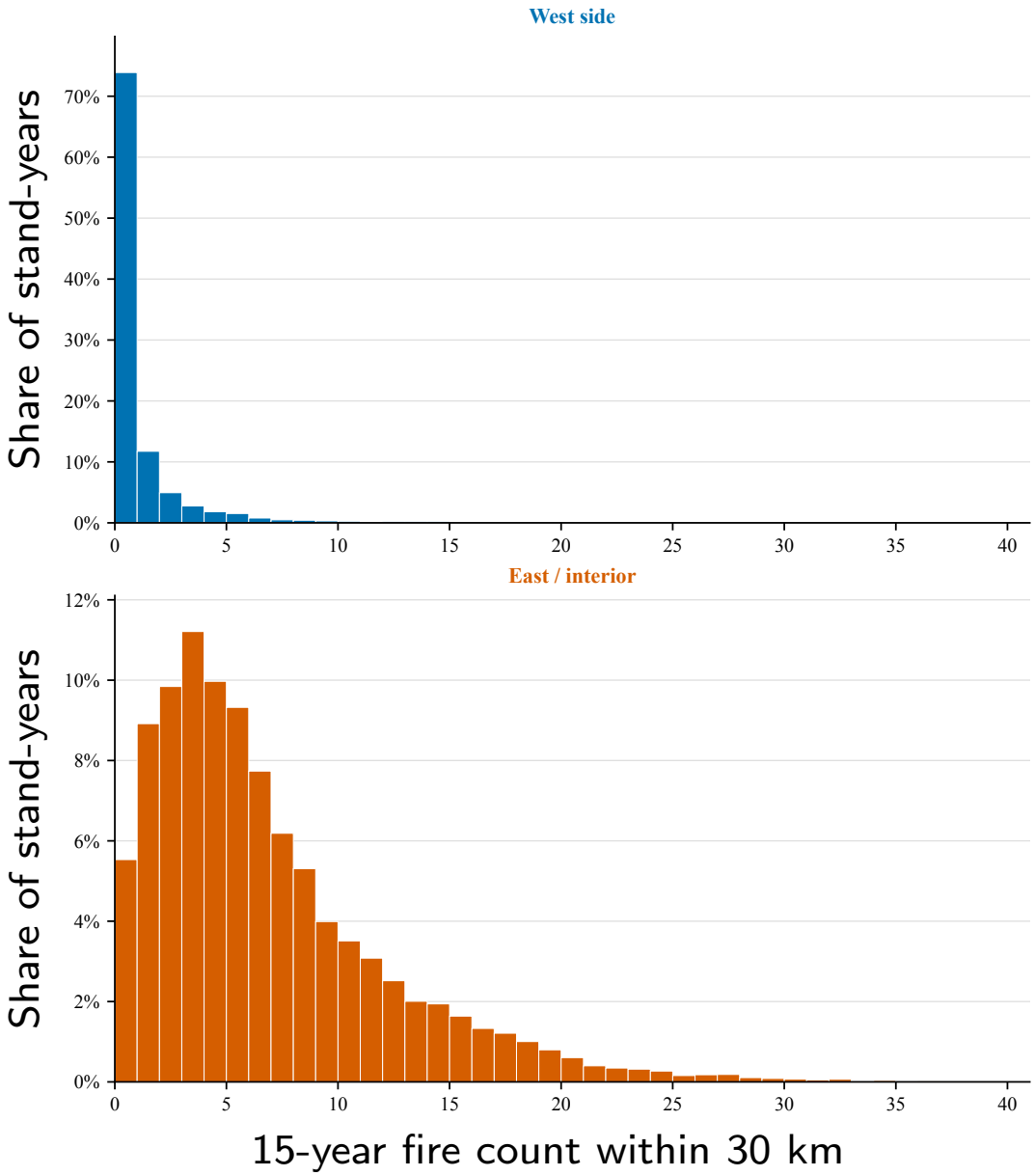
Fire perimeters: MTBS (fires $\geq$ 1,000 acres)

Harvest Summary Statistics | Planting Summary Statistics

Which Measure of Fire Is Salient to Landowners?

- No clear guidance on what measure of fire is salient for landowners
  - Number of fires? Acres burned?
  - Within what distance? Over what time horizon? 5 years? 10? 15?
- Economic theory does not prescribe a specific measure of fire exposure
- We choose the measure that best fits the data in each model, and report results across several different measures

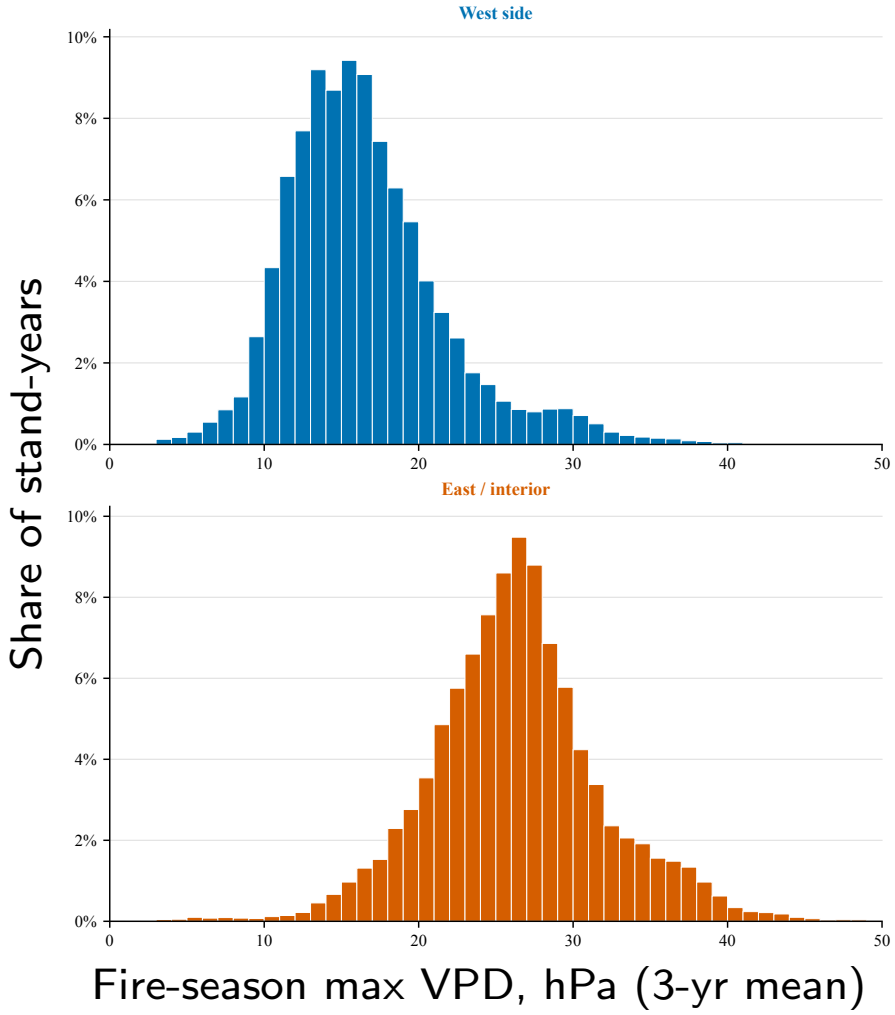
Distribution of Nearby Fires



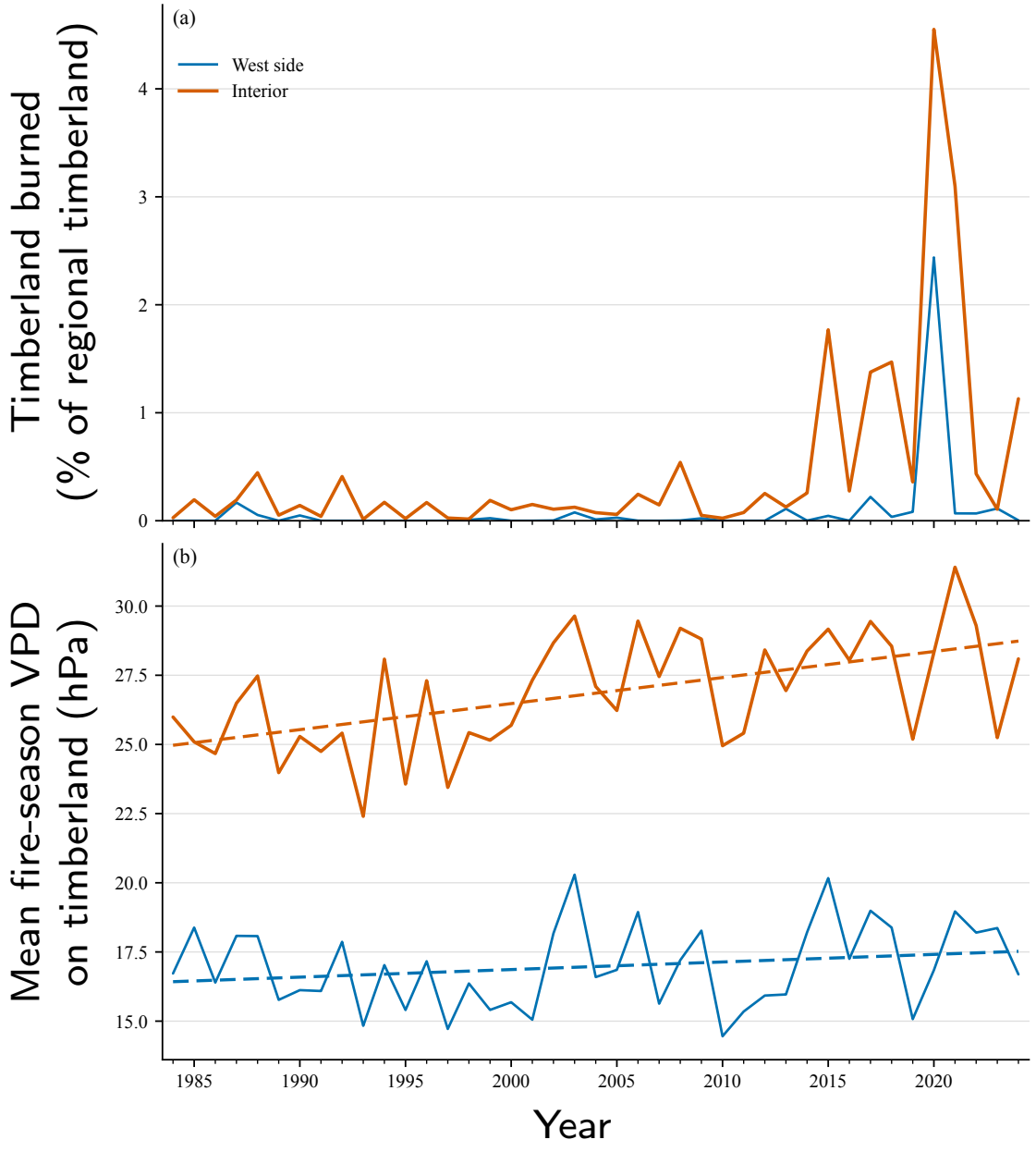
15-year fire count within 30 km, stand-years in the harvest sample.

Measuring Hot, Dry Weather with VPD

- Fires are noisy signals of risk
  - Ignitions are random, so risk can rise in an area before any fire burns nearby
- We measure VPD with PRISM (4 km) over several time windows
  - Preferred: average fire-season (June–September) maximum VPD over the three years before a management decision



Fire and VPD Have Changed Over Time



Harvest Choice Estimating Equation

- Each year, the landowner of stand i chooses no harvest ($j = 0$), a partial cut ($j = P$), or a clearcut ($j = C$)
- Following Hashida and Lewis (2019), the landowner picks the action with the highest value

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt}$$

- V_{ijt}: the part of the value of action j that we observe
- ε_{ijt}: the part we do not observe, such as expectations, management skill, and objectives
- If ε_{ijt} is i.i.d. Type I extreme value, the model is a multinomial logit (Train, 2009)

Estimating Harvest Responses to Wildfire Risk

Normalizing the value of no harvest, $V_{i0t} = 0$, for $j \in \{P, C\}$:

$$V_{ijt} = \alpha_j + \beta_j \, Fire_{it} + \delta_j \, VPD_{it} + \gamma_j' \, Age_{it} + \theta_j \, West_i + \tau_{jt} + u_{ij}$$

- $Fire_{it}$: nearby fire before management year t
- VPD_{it}: recent fire-season VPD
- Age_{it}: flexible stand age controls
- $West_i$: stands west of the Cascades
- τ_{jt}: period fixed effects for shocks common to all stands, such as timber prices, demand, and interest rates
- u_{ij}: time-invariant stand effect, such as baseline fire risk and site productivity

If fire and VPD signal elevated risk, theory predicts $\beta_P, \beta_C, \delta_P, \delta_C > 0$

Correlated Random Effects

- The stand effect u_{ij} may be correlated with fire and VPD
  - Stands in fire-prone areas may differ in ways that also affect harvest
- Fixed effects in a nonlinear model may suffer from the incidental parameters problem (Neyman and Scott, 1948; Lancaster, 2000)
- Instead, we model the stand effect with group means (Mundlak, 1978; Wooldridge, 2019)

$$u_{ij} = \xi_j \overline{Fire}_i + \psi_j \overline{VPD}_i + \eta_{ij}$$

- Group means capture each stand's baseline risk, which should already be capitalized into management
- β_j and δ_j are identified from changes in fire and VPD within a stand over time
  - Similar to the climate econometrics literature, using weather shocks around long-run averages to identify responses (Dell et al., 2014; Hsiang, 2016)

Estimation and Identification

- Estimated by maximum likelihood
  - Standard errors clustered by FIA plot
  - Multi-year period fixed effects, since harvests are rare and not observed in every year
- Identifying assumption: conditional on group means, period effects, and age, within-stand changes in fire and VPD are unrelated to other time-varying drivers of harvest
  - Fire and weather are measured before the management year
  - Nearby fire is largely outside a landowner's control: 94% of large fires near private timberland in the Pacific states burned on non-private timberland (Wang and Lewis, 2024)

Estimating Planting Density Responses to Wildfire Risk

$$\ln TPA_{it} = \beta_0 + \beta_1 Fire_{it} + \beta_2 VPD_{it} + \beta_3 Burn_i + \beta_4 TSP_i + \beta_5 DF_i + \phi' Site_i + \omega' X_i + \mu_{c(i)} + \tau_t + \varepsilon_{it}$$

- $Burn_i$: stand burned before planting; DF_i: Douglas-fir; $Site_i$, X_i: site class and topographic controls
- TSP_i: number of years between planting and FIA visit
- $\mu_{c(i)}$, τ_t: county and planting-period fixed effects
- Fire effect is identified from differences in pre-planting fire among stands planted in the same county and time period
- Weighted least squares, standard errors clustered by county
- Theory predicts $\beta_1 < 0$ and $\beta_2 < 0$

Nearby Fire and Hot, Dry Seasons Increase Harvest

Average marginal effects on the annual probability of each harvest (percentage points)

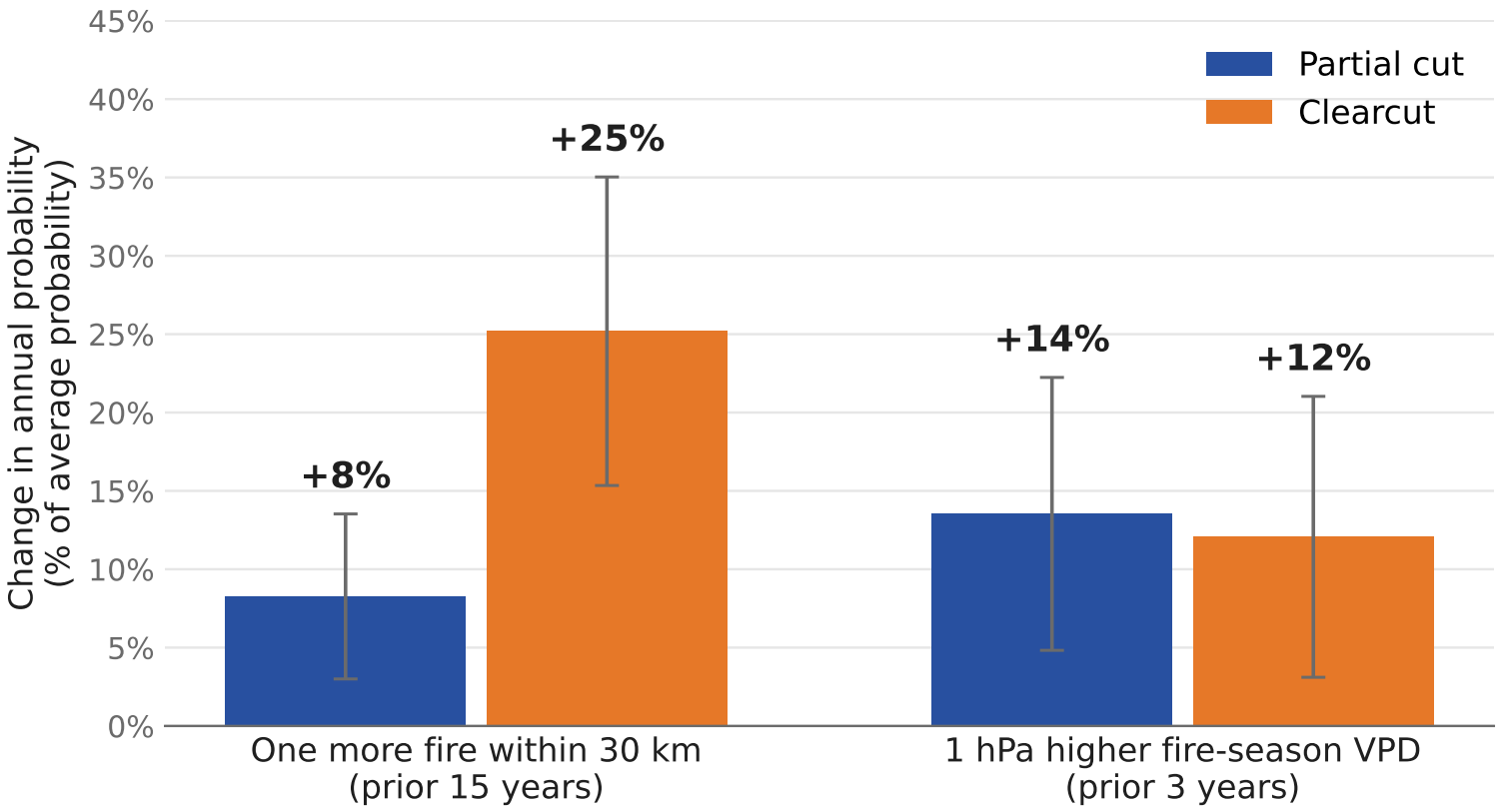
	Partial cut	Clearcut
One more fire within 30 km (prior 15 years)	0.080^{***}	0.336^{***}
	(0.026)	(0.067)
1 hPa higher fire-season VPD (prior 3 years)	0.131^{***}	0.161^{***}
	(0.043)	(0.061)
Average annual probability	0.97	1.33

- The likelihood of harvest rises with nearby fire and with hot, dry fire seasons
- Results are consistent when fire is measured as acres burned

Multinomial logit with correlated random effects, 51,451 stand-years. Standard errors clustered by plot in parentheses. *** $p < 0.01$.

Full Table

Fire Raises the Chance of a Clearcut by About 25%



Average marginal effect divided by the average annual probability of harvest. Bars show 95% confidence intervals, holding the average probability fixed.

- Consistent with Reed (1984): higher perceived risk leads landowners to remove volume sooner

Planting Density: No Effect of Fire Levels or VPD

Δ Fire Measure Full Table

Dependent variable: log trees per acre

	Fire count (15-yr)	Acreage burned (15-yr)
Wildfire exposure, 0–30 km	−0.030	0.006
	(0.035)	(0.016)
Fire-season max VPD (hPa)	0.027	0.025
	(0.019)	(0.020)
Planted stands	614	614

- No effect of the level of nearby fire, acres burned, or VPD

County and planting-period FE and stand controls in all columns. SEs clustered by county. *** $p < 0.01$.

Rising Nearby Fire Lowers Planting Density

Δ Fire Measure | Full Table

Dependent variable: log trees per acre

	Fire count (15-yr)	Acreage burned (15-yr)	Δ Fire count (10-yr)
Wildfire exposure, 0–30 km	−0.030	0.006	−0.081***
	(0.035)	(0.016)	(0.024)
Fire-season max VPD (hPa)	0.027	0.025	0.024
	(0.019)	(0.020)	(0.021)
Planted stands	614	614	556

- No effect of the level of nearby fire, acres burned, or VPD
- Statistically significant effects when measuring plot level changes in fire over time
  - Fires in the last 10 years minus fires in the 10 years before

County and planting-period FE and stand controls in all columns. SEs clustered by county. *** $p < 0.01$.

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Planted stands	614	614	556

- No effect of the level of nearby fire, acres burned, or VPD
- Statistically significant effects when measuring plot level changes in fire over time
  - Fires in the last 10 years minus fires in the 10 years before
- One additional fire in the recent decade: ∼7.8% fewer trees per acre, ∼41 fewer trees on average

County and planting-period FE and stand controls in all columns. SEs clustered by county. *** $p < 0.01$.

Rising Nearby Fire Lowers Planting Density

Δ Fire Measure | Full Table

Dependent variable: log trees per acre

	Fire count (15-yr)	Acreage burned (15-yr)	Δ Fire count (10-yr)
Wildfire exposure, 0–30 km	−0.030	0.006	−0.081***
	(0.035)	(0.016)	(0.024)
Fire-season max VPD (hPa)	0.027	0.025	0.024
	(0.019)	(0.020)	(0.021)
Planted stands	614	614	556

- Consistent with Amacher et al. (2005), where landowners plant fewer trees to reduce future losses from fire and lower their own risk

County and planting-period FE and stand controls in all columns. SEs clustered by county. *** $p < 0.01$.

Hot, Dry Seasons Increase Pre-Commercial Thinning

Full Table

Average marginal effects on the annual probability of thinning (pp)

	Fire count (15-yr)	Acreage burned (15-yr)
Wildfire exposure, 0–30 km	0.019	0.011
	(0.024)	(0.010)
1 hPa higher fire-season VPD	0.054**	0.053**
	(0.023)	(0.023)
Average annual probability	0.29	0.29

- Hot, dry fire seasons raise thinning by about 18% of the average annual probability
- No effect of nearby fire
- Thinning is rare (205 thins in 71,088 stand-years) mostly on the west side where there is little fire

Logit with correlated random effects, no stand age restriction. SEs clustered by plot. ** $p < 0.05$.

Estimating Equation

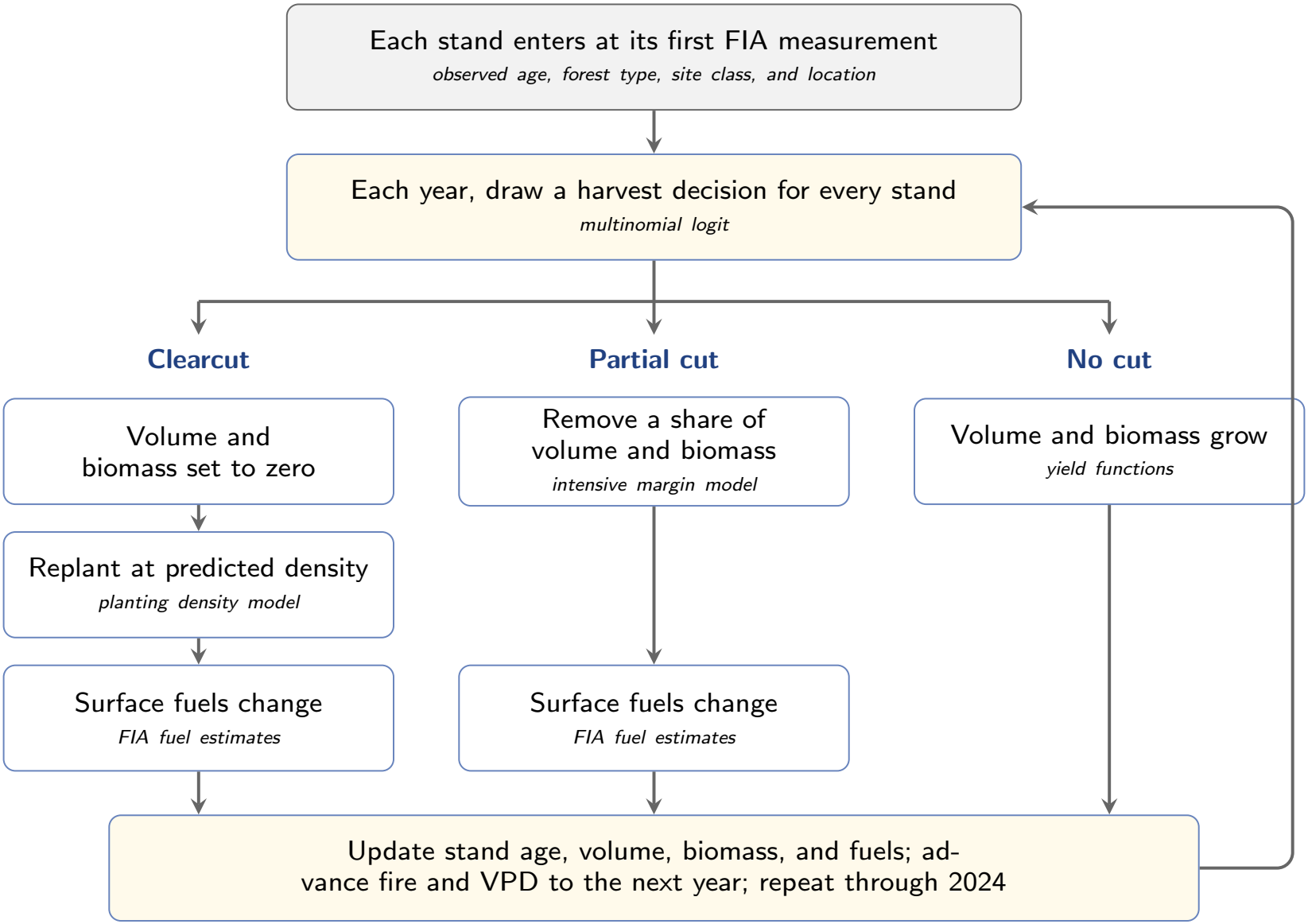
Robustness Checks

- Different spatial buffer sizes and time windows for fire exposure Windows Distance
- Relax the independence of irrelevant alternatives assumption with a nested logit Nested Logit
- Alternative measures of weather shocks VPD Measures
- Alternative planting density specifications Planting Density
- Conditional on a harvest, whether fire risk changes the stand age at harvest Harvest Timing
- Different specifications of the group means Group Means

How Does Adaptation Play Out Across the Landscape?

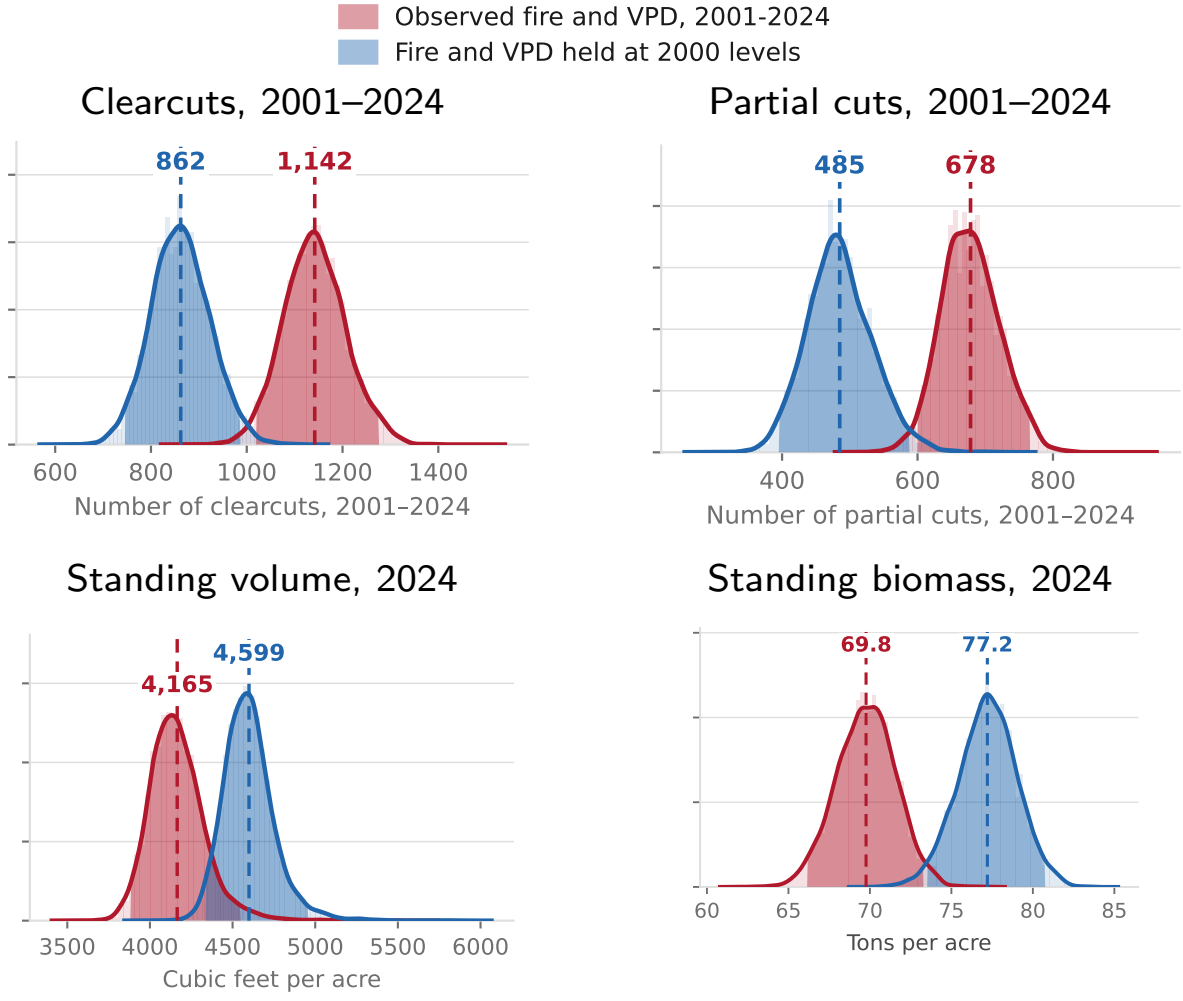
- Our estimates are changes in annual probabilities for a single stand. How do these responses compound over time across the landscape?
- Bio-economic Monte Carlo simulation of every stand in the harvest choice sample, 2001–2024
- Compare responses to observed fire and VPD to a counterfactual where each plot's fire and VPD stay at turn-of-century levels
  - 2000 level, 2000–04 average, 2000–09 average
- Track management decisions, standing volume, biomass, and surface fuels, then translate fuels into wildfire emissions

How the Simulation Works



5,000 iterations, each drawing model parameters from their estimated distribution (Krinsky and Robb, 1986). Observed and counterfactual iterations share the same random draws.

More Harvests and Less Standing Volume



Standing volume is 9.4% lower in 2024

Adaptation Means Less Carbon Stored on the Landscape

- In 2024, standing biomass is 7.4 tons per acre lower (69.8 vs. 77.2)
- About 12.4 fewer tons of CO_2 per acre
- At \$185 per ton of CO_2 (Rennert et al., 2022), about \$2,290 per acre
  - The average timberland price in the region is \$4,357.17 per acre (Wang and Lewis, 2024)
- This overstates the net climate cost (some harvested carbon is stored in wood products)
- However, more cutting has carbon / climate effects!

Fewer Crown Fuels, More Surface Fuels



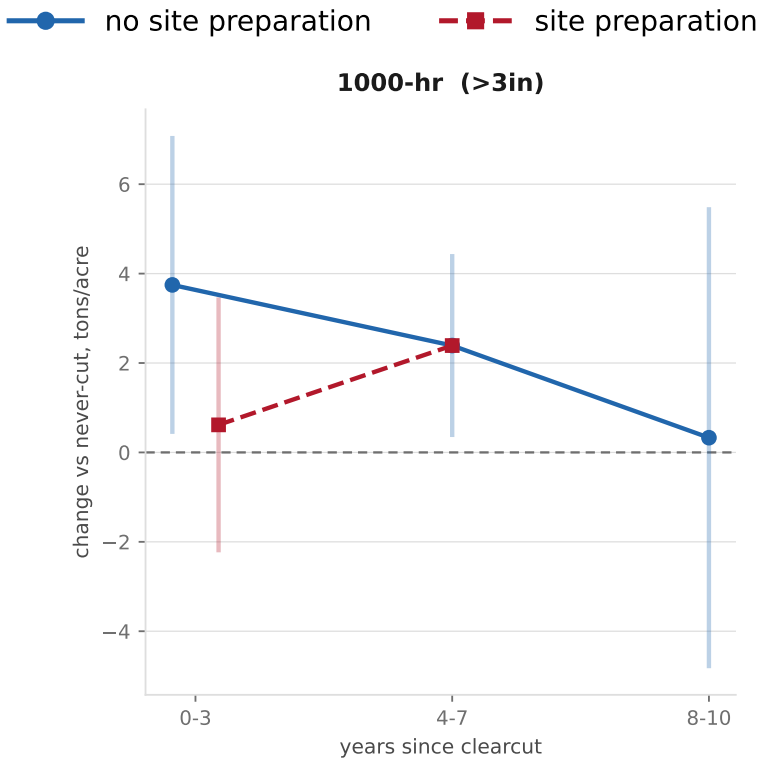
Photo: Francis Eatherington, clearcutoregon.com.

- Crown fuels: the standing trees
  - Harvest removes them
- Surface fuels: downed wood, duff, and litter on the forest floor
  - Harvest leaves slash behind
  - Site preparation can remove some of it
- Crown and surface fuels burn differently, so they produce different emissions

Measuring How Cutting Changes Surface Fuels

All Fuel Classes | Partial Cuts | DiD Equation

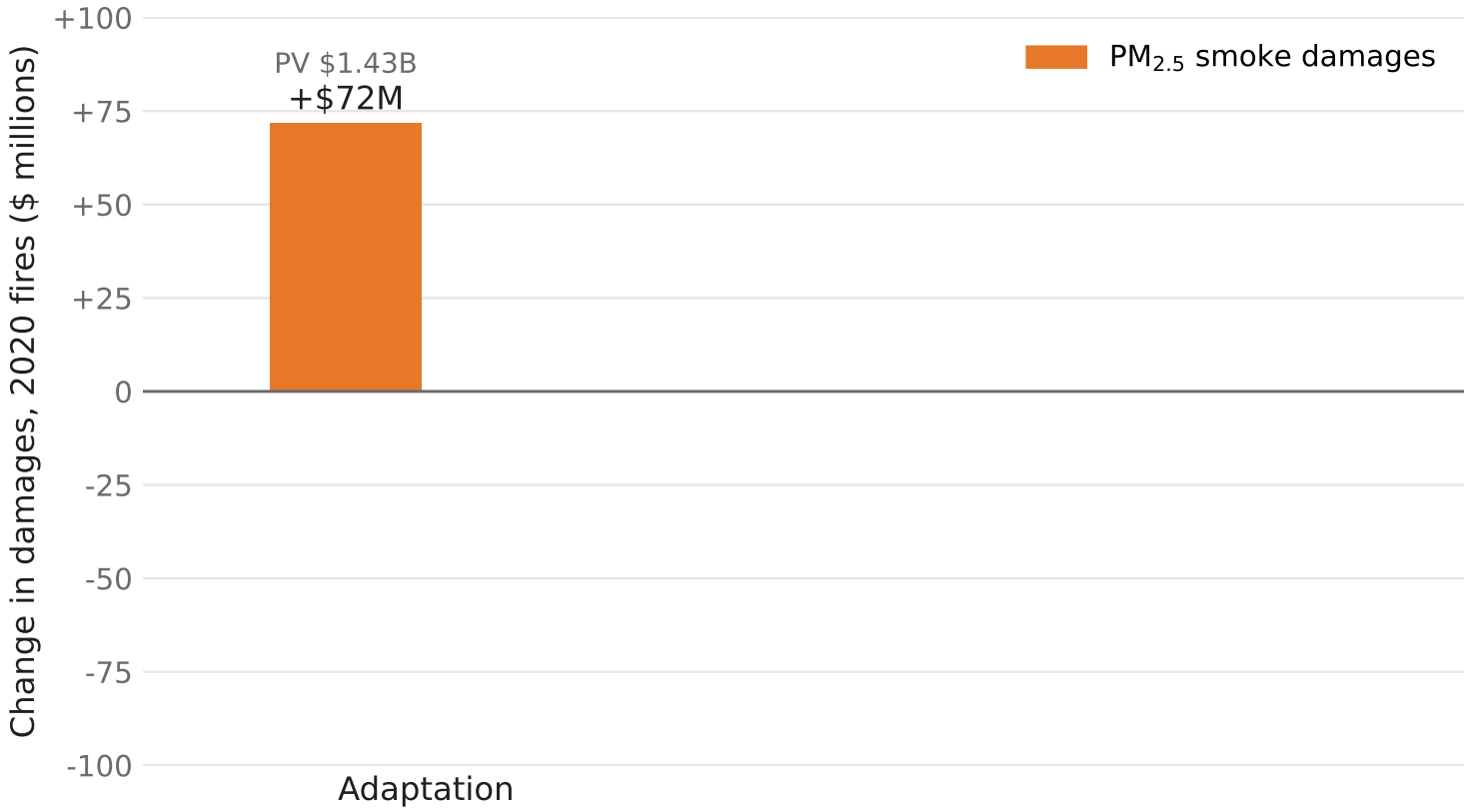
- FIA crews measure surface fuels at each visit
  - Downed wood by size: 1-, 10-, 100-, and 1000-hour fuels
  - Duff and litter depth
- Difference-in-differences: change in fuels between visits, cut vs. never-cut stands, by years since the cut
- Example: a clearcut adds about 4 tons per acre of 1000-hour fuels
  - with site preparation, the increase is much smaller



Translating Landowner Adaptation to Smoke Emissions

- First Order Fire Effects Model (FOFEM), a Forest Service model widely used by fire managers (Reinhardt et al., 1997; Lutes, 2020)
  - Input fuel loads, outputs how much was burned and emissions
- Baseline fuels on burned private and state timberland come from LANDFIRE (remote sensing)
- We shift those fuel loads by the simulated change in landscape fuels
- Hold the extent and severity of the 2020 fires fixed: 811,714 acres of private and state forest burned in 85 fires in 2020
- Damages: \$54,114 per ton of $PM_{2.5}$ (Strabo et al., 2026); \$185 per ton of CO_2 (Rennert et al., 2022)

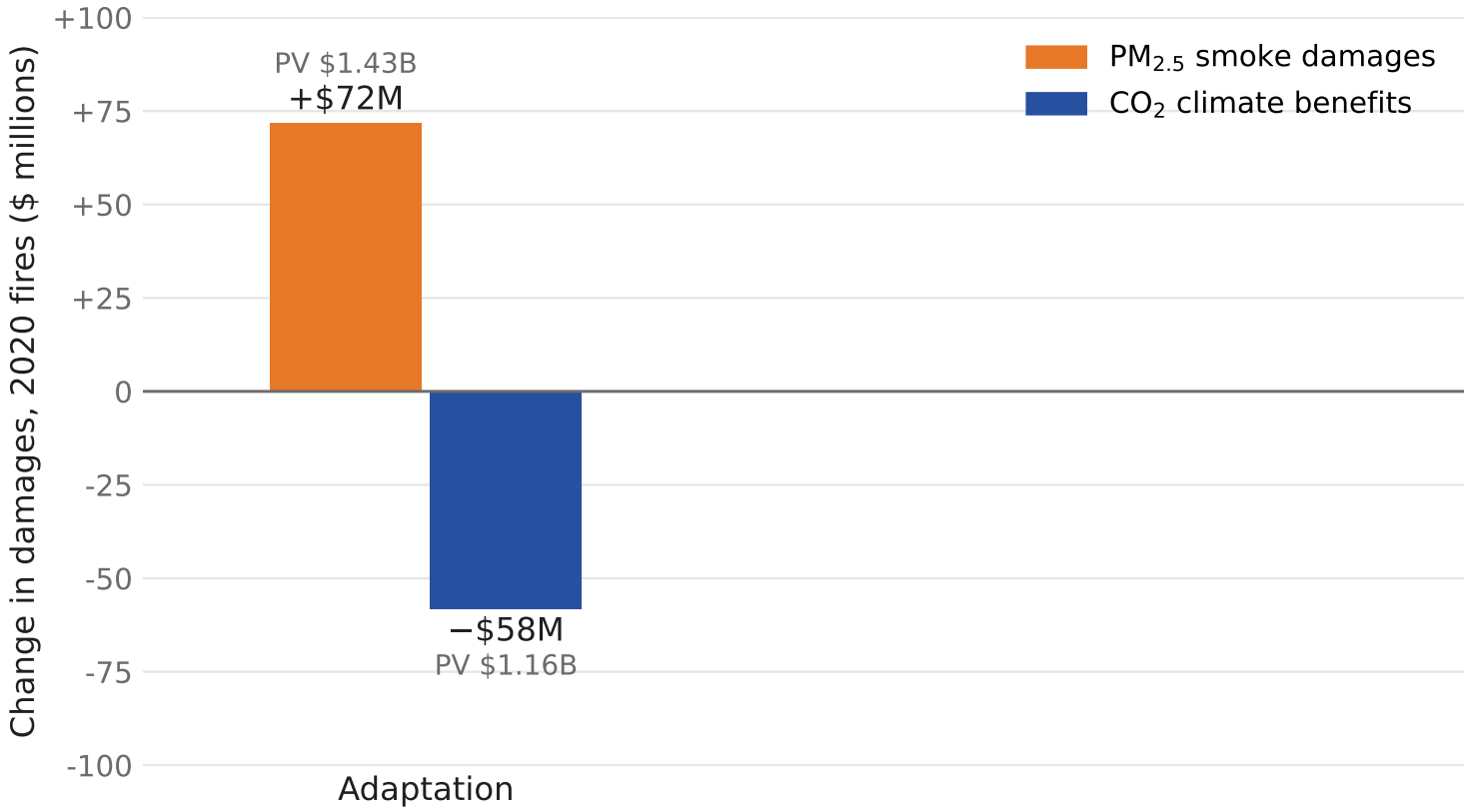
More Smoke Damages, Lower CO_2 Emissions



2020 fires on private and state timberland. Observed regime vs. fire and VPD held at 2000 levels; site preparation at its observed 31% of clearcuts vs. all clearcuts. $PM_{2.5}$ at $54,114 per ton; CO_2 at $185 per ton. PV: present value at 5% if a 2020-scale fire season recurred every year.

Emissions Table Fuel Changes

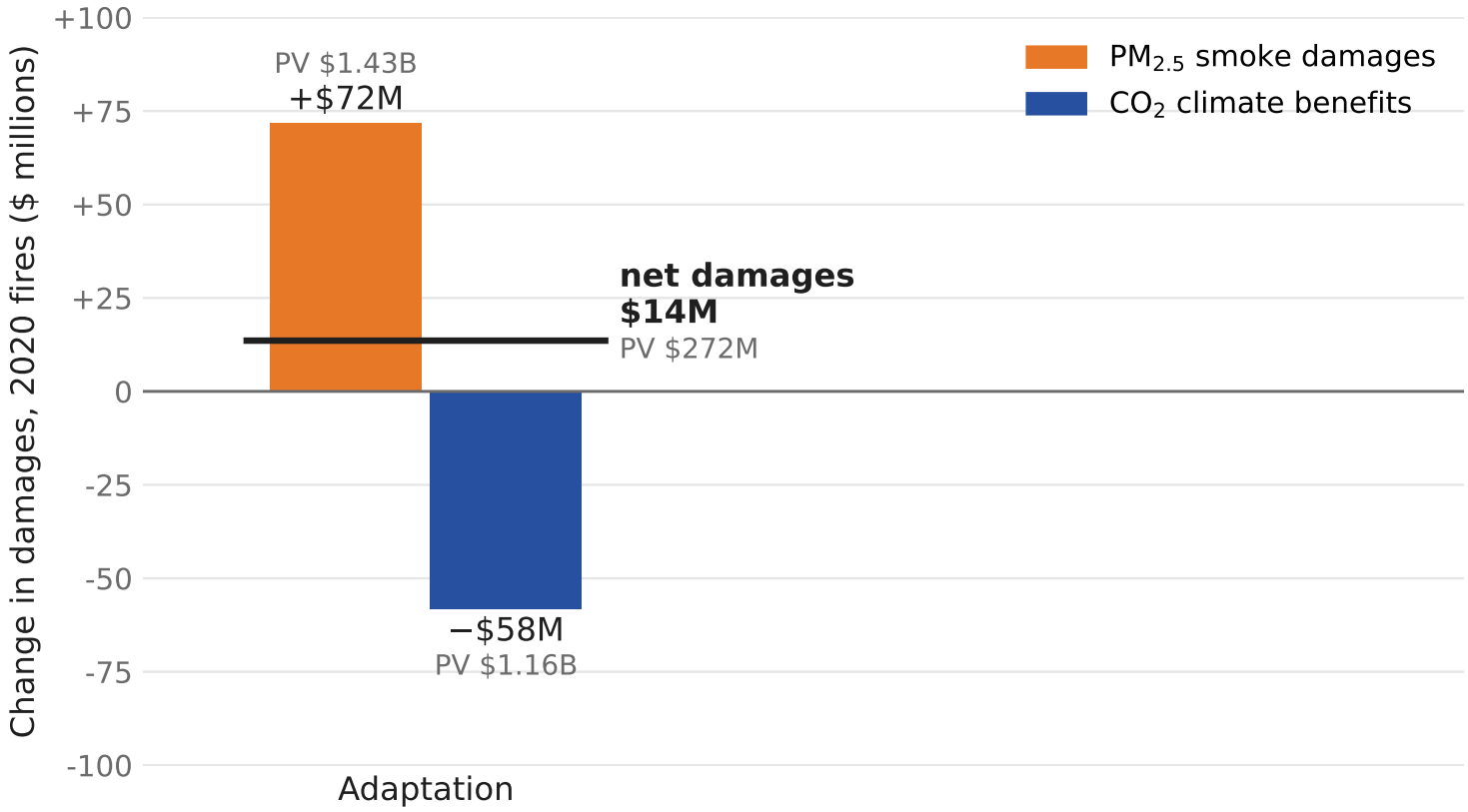
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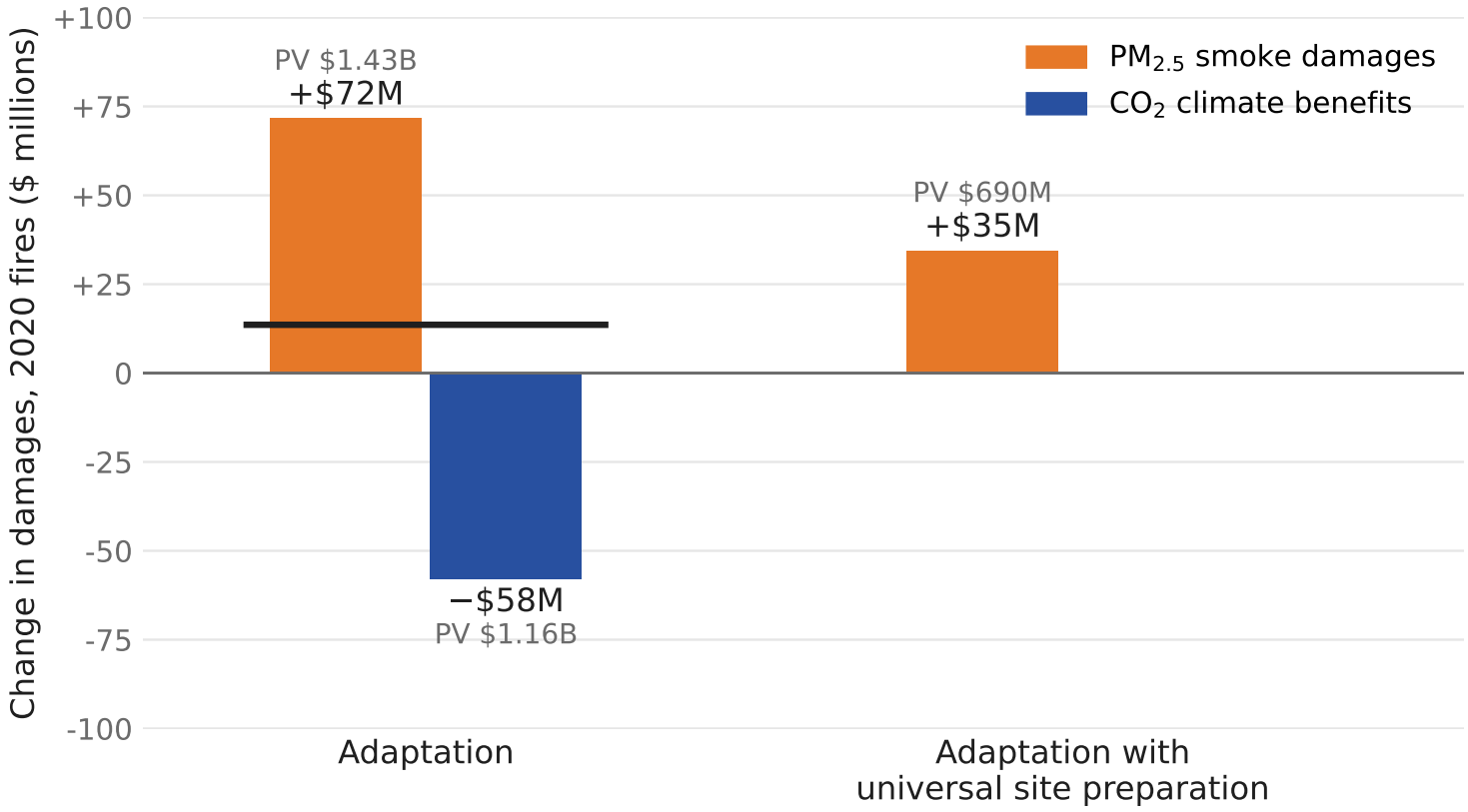
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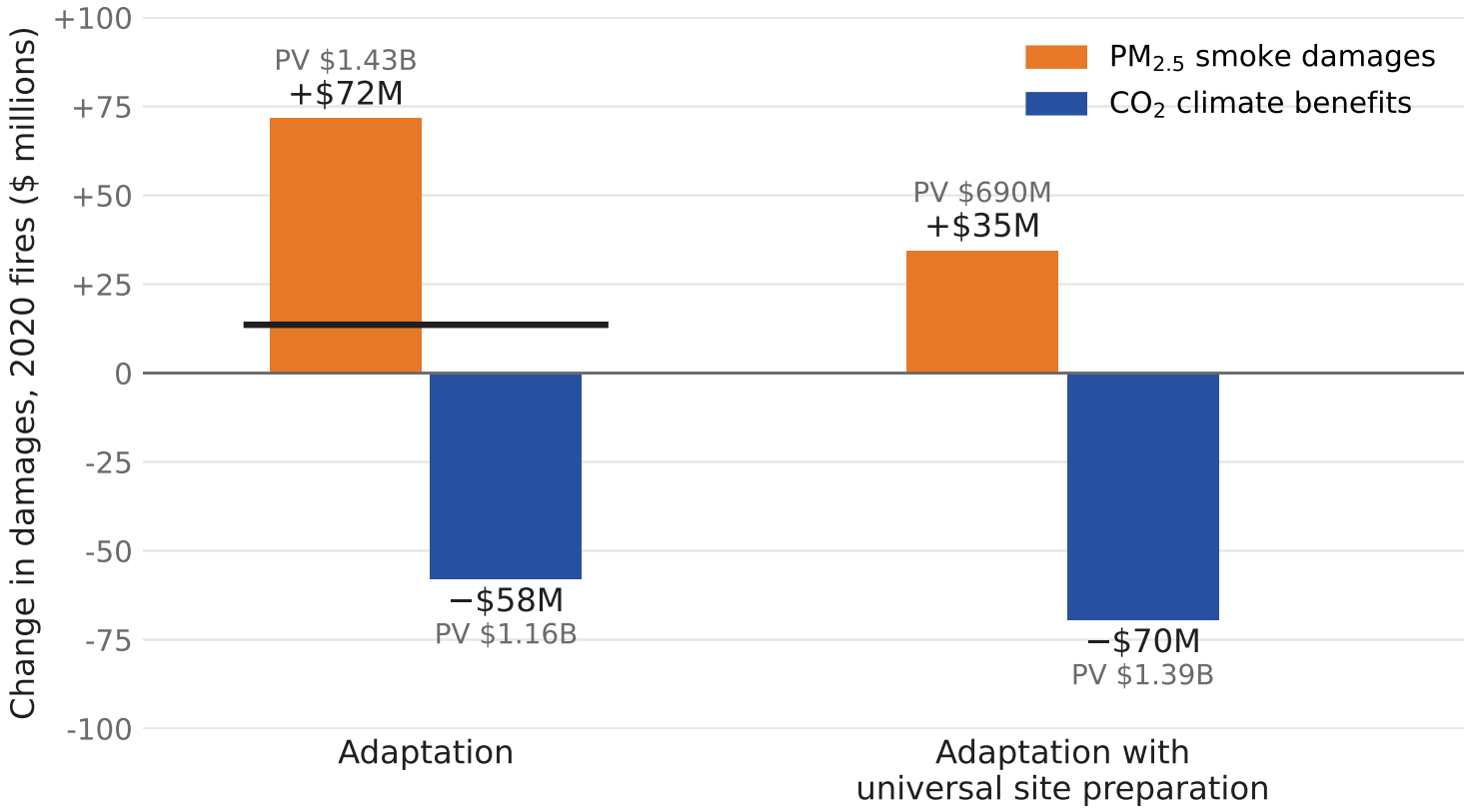
Site Preparation Turns Net Damages into a Net Benefit



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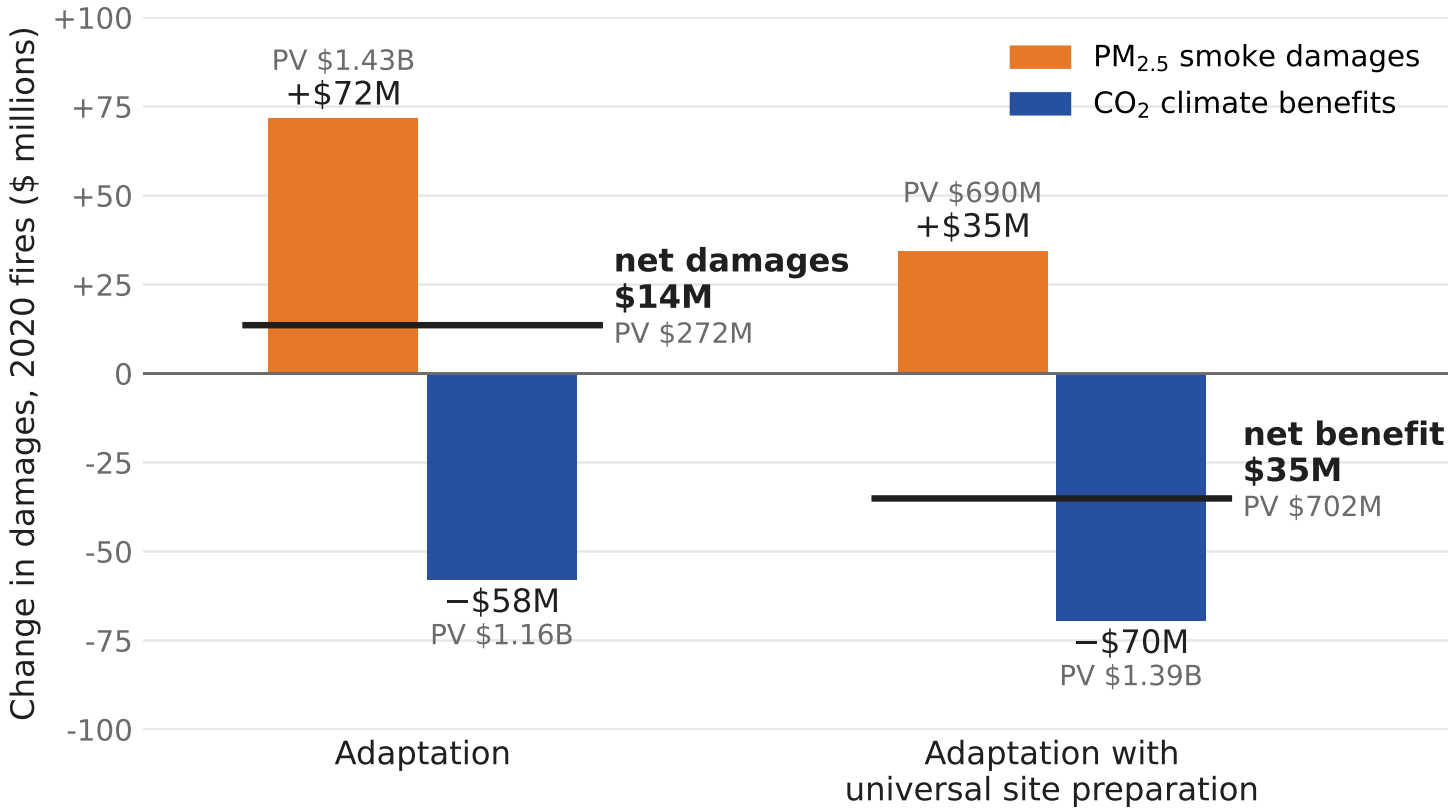
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Emissions Table Fuel Changes

What We Find

- Landowners are adapting to rising wildfire risk through forest management
- Consistent with long-standing theory: landowners act as if fire risk raises their discount rate (Reed, 1984; Amacher et al., 2005; Patto and Rosa, 2022)
  - A Reed model parameterized for the west coast implies 4–12% less standing volume, similar to our simulation results
- Forest landowners are asset managers reducing their own exposure to climate risk

Private Adaptation Has Social Benefits and Costs

- Private forests are 60% of US forest land and supply 89% of the timber harvest
  - Unsubsidized private decisions are reshaping a large share of the landscape
- Landowner adaptation has increased smoke, lowered wildfire CO_2 emissions, and lowered the standing stock of carbon
- Other potential externalities
  - Wildlife habitat
  - Water quality
  - Future fire risk

Policy Implications and Open Questions

- Designing thoughtful policy requires understanding what landowners are already doing
  - Subsidizing harvest raises additionality concerns
  - Better targets: costly activities whose benefits landowners do not capture, such as site preparation
- Tradeoffs between carbon payments and fuel treatment programs

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  - Clearcutting is rare on public land, need evidence on private management fire effects

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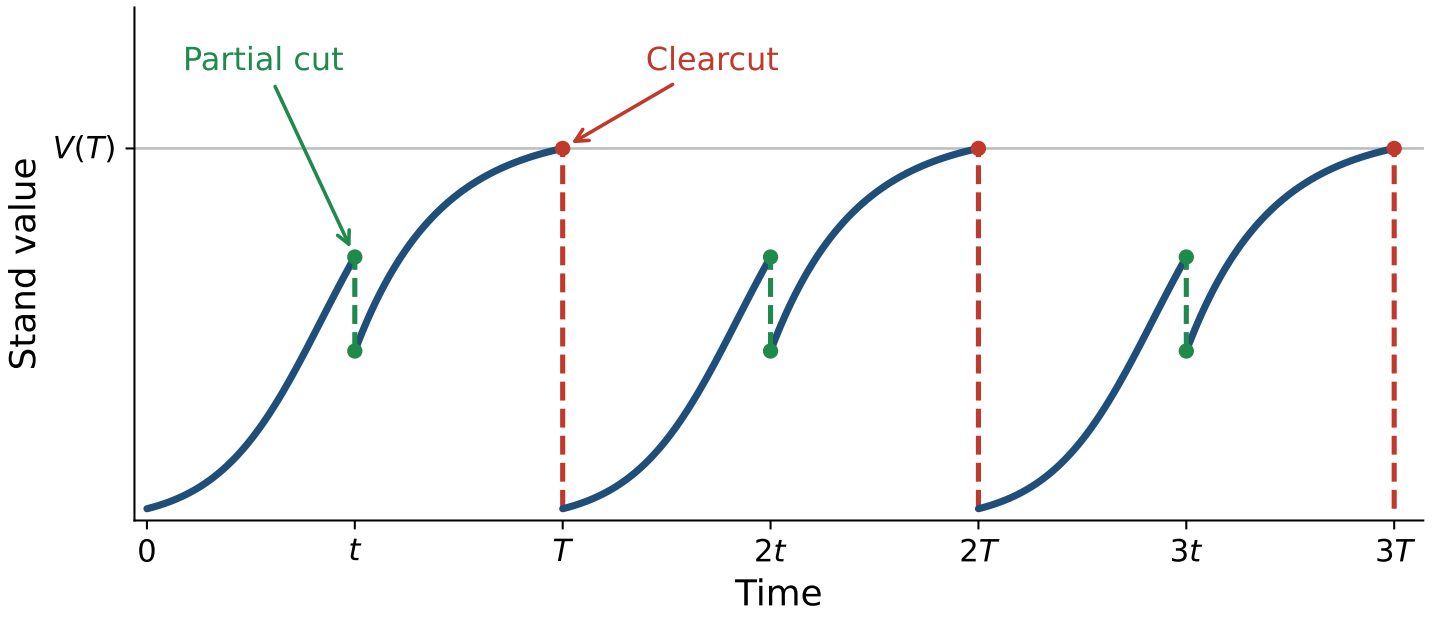
How does private forest management change how fires spread and how severely they burn?


Questions?

Appendix

Theoretical Predictions on Mixed Management Regimes

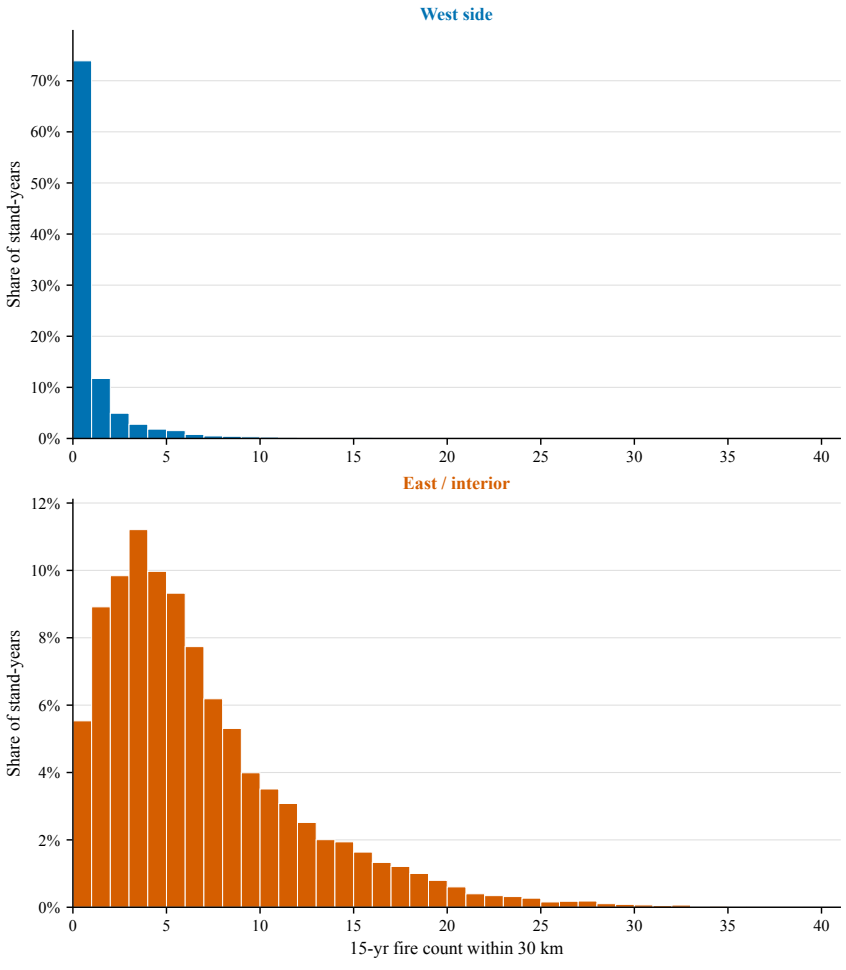
Back



- Under commercial thinning $\rightarrow$ clearcutting regimes, Patto and Rosa (2022) predict an increase in the arrival rate (λ) leads to **more partial cutting, earlier in the rotation**
- Applies to some west-side and Sierra Nevada forests in California

Repeat Fires Near a Stand Are Common

Back



15-year fire count within 30 km, stand-years in the harvest sample.

- On average, stands saw 3.97 nearby fires over the prior 15 years
- Interior: mean of 6.24 fires; only 6.0% of stand-years had no nearby fire
- West side: mean of 0.38 fires; 80.8% had no nearby fire

Summary Statistics: Harvest Choice Sample (Table 1)

Back

	Full sample	West side	East / interior
Sample size			
Stand-years	51,451	22,138	29,313
Stands	5,277	2,506	2,771
Plots	4,367	2,078	2,289
Stand-years in Washington	19,731	10,043	9,688
Stand-years in Oregon	18,360	9,859	8,501
Stand-years in California	13,360	2,236	11,124
Management actions (stand-years)			
No action	50,364	21,542	28,822
Partial cut	447	80	367
Clearcut	640	516	124
Wildfire exposure, mean (SD)			
Fire count, 0–30 km, 15-yr	3.97	0.76	6.39
	(5.10)	(2.00)	(5.39)
Acreage burned, 0–30 km, 15-yr (10,000 ac)	2.99	0.85	4.60
	(5.44)	(2.85)	(6.31)
Δ Fire count, 0–30 km, 10-yr	0.89	0.19	1.43
	(2.96)	(1.27)	(3.68)
Controls, mean (SD)			
Stand age (yrs)	74.7	60.5	85.4
	(39.2)	(34.0)	(39.6)
Fire-season max VPD, 3-yr (hPa)	22.12	16.56	26.32
	(7.27)	(5.20)	(5.61)

Notes: Estimating sample of Table 3: stand-years on private and state timberland in CA, OR, WA, 2001–2024, stands aged 30+, salvage excluded. Fire measures within 30 km; acreage in 10,000 acres. Fire-season max VPD: mean June–September maximum VPD over the three prior years. The 10-year change in fire count is undefined for 2001–2003 (1,974 stand-years).

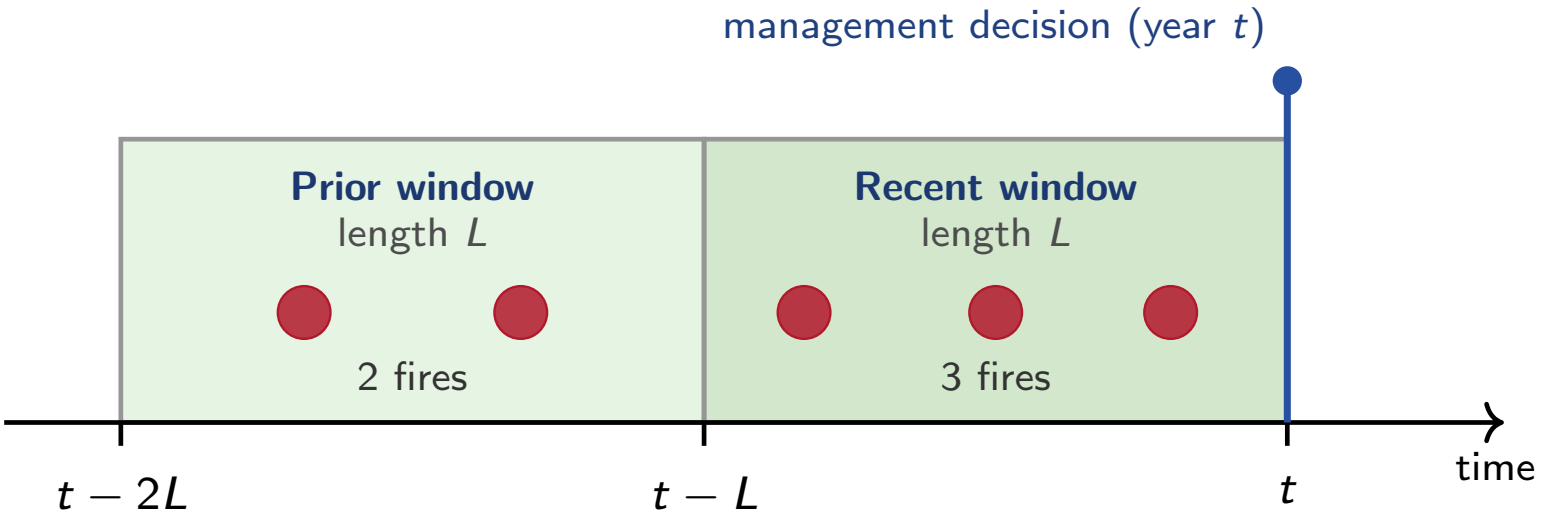
Summary Statistics: Planting Density Sample (Table 2)

Back

	Mean	Std. Dev.
Unit of observation: recently planted stands		
Sample size		
Stands	556	
Plots	530	
Counties	67	
States (OR / WA / CA)	280 / 214 / 62	
Planting years	2004–2023	
Measurement years	2004–2024	
Outcome: planting TPA, dominant species		
All stands	524.6	865.0
Douglas-fir (n=401)	401.7	346.6
Other (n=155)	842.5	1497.8
Wildfire exposure		
Δ Fire count, 0–30 km, 10-yr	0.50	1.79
Fire count, 0–30 km, 15-yr	1.61	3.40
Acreage burned, 0–30 km, 15-yr (10,000 ac)	1.54	4.24
Post-burn planting (share)	7.2%	—
Controls		
Time since planting (yrs)	3.9	2.5
Elevation (km)	1.81	1.41
Slope (%)	32.0	23.2
Fire-season max VPD, 3-yr (hPa)	18.77	6.17
Site class (stands)		
Classes 1–2	234	
Classes 3–4	273	
Classes 5–7	49	

Notes: Estimating sample of Table 4, column 1. Planting TPA is trees per acre of the dominant species as measured by FIA crews. Wildfire measures as in Table 1, with the planting year in place of the management year. Site class from 1 (most productive) to 7.

Measuring the Change in Nearby Fire Activity



$$\Delta\text{Count}_L = 3 - 2 = +1$$

- Compare fires in the recent window to the window before it, within 30 km of the plot
- Positive values mean local fire activity is rising; planting model uses $L = 10$ years

Back

Multinomial Logit of Forest Management Action (Table 3)

	(1) Fire count (15-yr)	(2) Acreage burned (15-yr)	(3) Δ fire count (10-yr)
Panel A: Partial Cut vs. Do Nothing			
Wildfire exposure, 0–30 km	0.0862***	0.0638***	-0.0116
	(0.0272)	(0.0191)	(0.0193)
Fire-season Max VPD (hPa)	0.1379***	0.1364***	0.1342***
	(0.0446)	(0.0445)	(0.0475)
West side	-1.4284***	-1.3916***	-1.3072***
	(0.1664)	(0.1645)	(0.1642)
Stand age 50–69	0.2151	0.2194	0.2369
	(0.1580)	(0.1576)	(0.1602)
Stand age 70–89	0.4116***	0.4060***	0.3860**
	(0.1563)	(0.1560)	(0.1591)
Stand age 90+	0.1514	0.1651	0.1357
	(0.1625)	(0.1618)	(0.1618)
Panel B: Clearcut vs. Do Nothing			
Wildfire exposure, 0–30 km	0.2588***	0.0979***	0.0771***
	(0.0503)	(0.0155)	(0.0269)
Fire-season Max VPD (hPa)	0.1250***	0.1381***	0.0959**
	(0.0470)	(0.0464)	(0.0480)
West side	1.3398***	1.4338***	1.5282***
	(0.1345)	(0.1249)	(0.1222)
Stand age 50–69	0.2523***	0.2459**	0.2506**
	(0.0971)	(0.0971)	(0.0980)
Stand age 70–89	0.1358	0.1222	0.1181
	(0.1179)	(0.1179)	(0.1184)
Stand age 90+	-0.5409***	-0.5312***	-0.5568***
	(0.1587)	(0.1587)	(0.1595)
Baseline Pr(Partial Cut), pp	0.968	0.968	0.982
Baseline Pr(Clearcut), pp	1.334	1.334	1.372
Average marginal effects (pp per unit, SE in parens.)			
on Pr(Partial Cut):			
Wildfire exposure	0.080*** (0.026)	0.060*** (0.018)	-0.012 (0.019)
Fire-season Max VPD	0.131*** (0.043)	0.129*** (0.043)	0.129*** (0.046)
on Pr(Clearcut):			
Wildfire exposure	0.336*** (0.067)	0.127*** (0.021)	0.103*** (0.036)
Fire-season Max VPD	0.161*** (0.061)	0.178*** (0.061)	0.127** (0.064)
Observations	51,451	51,451	49,477
Plots (clusters)	4,367	4,367	4,362
Log pseudolikelihood	-4761.0	-4759.1	-4679.9
Pseudo R^2	0.060	0.060	0.054

Notes: Stand-years on private and state timberland in OR, CA, WA, 2001–2024; stand age $\geq$ 30; salvage excluded; wait is the base outcome. Cols (1)–(2): fire count and acres burned (10,000 ac) within 30 km over 15 years; col (3): 10-year change in fire count. All columns include period FE and CRE group means for fire and VPD. AMEs in pp per unit. Weighted by stand size; SEs clustered by plot. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Full Coefficients Back

Full Coefficients: Partial Cut Equation

Clearcut Equation Back

	(1) Fire count (15-yr)	(2) Acreage burned (15-yr)	(3) Δ fire count (10-yr)
Wildfire exposure, 0–30 km	0.0862***	0.0638***	-0.0116
	(0.0272)	(0.0191)	(0.0193)
Wildfire, CRE bar	-0.1295***	-0.1257***	-0.0069
	(0.0302)	(0.0258)	(0.0258)
Fire-season Max VPD (hPa)	0.1379***	0.1364***	0.1342***
	(0.0446)	(0.0445)	(0.0475)
Max VPD, CRE bar	-0.1413***	-0.1396***	-0.1453***
	(0.0461)	(0.0460)	(0.0489)
Stand age 50–69	0.2151	0.2194	0.2369
	(0.1580)	(0.1576)	(0.1602)
Stand age 70–89	0.4116***	0.4060***	0.3860**
	(0.1563)	(0.1560)	(0.1591)
Stand age 90+	0.1514	0.1651	0.1357
	(0.1625)	(0.1618)	(0.1618)
West side	-1.4284***	-1.3916***	-1.3072***
	(0.1664)	(0.1645)	(0.1642)
Period 2005–08	0.3179	0.3298	0.2353
	(0.2392)	(0.2394)	(0.3158)
Period 2009–12	0.1451	0.2205	0.1271
	(0.2273)	(0.2281)	(0.3135)
Period 2013–16	0.3286	0.3924*	0.3028
	(0.2274)	(0.2277)	(0.3176)
Period 2017–24	0.1360	0.1773	0.1156
	(0.2457)	(0.2473)	(0.3178)
Constant	-4.3922***	-4.4693***	-4.3692***
	(0.3217)	(0.3248)	(0.3884)
Observations	51,451	51,451	49,477
Plots (clusters)	4,367	4,367	4,362
Log pseudolikelihood	-4761.0	-4759.1	-4679.9
Pseudo R^2	0.060	0.060	0.054

Notes: Same three specifications as Table 3. Wildfire exposure and VPD each enter with their within-stand group mean (CRE bar), so the level coefficient is the effect of a deviation from the stand's own average. Stand age bins with 30–49 omitted; omitted period 2001–04. Weighted by stand size; SEs clustered by plot. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Full Coefficients: Clearcut Equation

Partial Cut Equation Back

	(1) Fire count (15-yr)	(2) Acreage burned (15-yr)	(3) Δ fire count (10-yr)
Wildfire exposure, 0–30 km	0.2588***	0.0979***	0.0771***
	(0.0503)	(0.0155)	(0.0269)
Wildfire, CRE bar	-0.3331***	-0.1691***	-0.1278**
	(0.0671)	(0.0307)	(0.0517)
Fire-season Max VPD (hPa)	0.1250***	0.1381***	0.0959**
	(0.0470)	(0.0464)	(0.0480)
Max VPD, CRE bar	-0.1291***	-0.1416***	-0.1058**
	(0.0483)	(0.0475)	(0.0488)
Stand age 50–69	0.2523***	0.2459**	0.2506**
	(0.0971)	(0.0971)	(0.0980)
Stand age 70–89	0.1358	0.1222	0.1181
	(0.1179)	(0.1179)	(0.1184)
Stand age 90+	-0.5409***	-0.5312***	-0.5568***
	(0.1587)	(0.1587)	(0.1595)
West side	1.3398***	1.4338***	1.5282***
	(0.1345)	(0.1249)	(0.1222)
Period 2005–08	-0.0459	-0.0771	-0.4516
	(0.2546)	(0.2502)	(0.2753)
Period 2009–12	0.4476**	0.4796**	0.0338
	(0.2239)	(0.2215)	(0.2591)
Period 2013–16	0.7690***	0.8059***	0.3685
	(0.2177)	(0.2169)	(0.2655)
Period 2017–24	0.3292	0.3543	0.0029
	(0.2453)	(0.2441)	(0.2683)
Constant	-5.3346***	-5.4535***	-5.0603***
	(0.3120)	(0.3111)	(0.3272)
Observations	51,451	51,451	49,477
Plots (clusters)	4,367	4,367	4,362
Log pseudolikelihood	-4761.0	-4759.1	-4679.9
Pseudo R^2	0.060	0.060	0.054

Notes: Same three specifications as Table 3. Wildfire exposure and VPD each enter with their within-stand group mean (CRE bar), so the level coefficient is the effect of a deviation from the stand's own average. Stand age bins with 30–49 omitted; omitted period 2001–04. Weighted by stand size; SEs clustered by plot. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Planting Density and Wildfire Exposure (Table 4)

	(1) Δ Fire count (10-yr)	(2) Fire count (15-yr)	(3) Acreage burned (15-yr)
Wildfire exposure, 0–30 km	-0.0808***	-0.0299	0.0056
	(0.0238)	(0.0345)	(0.0158)
Fire-season Max VPD (hPa)	0.0243	0.0272	0.0253
	(0.0206)	(0.0194)	(0.0202)
Post-burn planting	-0.1194	-0.2618	-0.3695
	(0.2123)	(0.2309)	(0.2345)
Time since planting (yrs)	0.0397*	0.0458**	0.0456**
	(0.0217)	(0.0204)	(0.0206)
Douglas-fir	-0.4761**	-0.4233**	-0.4098**
	(0.1888)	(0.1712)	(0.1719)
Site class (base: classes 1–2)			
Classes 3–4	-0.2735**	-0.2725**	-0.2744**
	(0.1252)	(0.1218)	(0.1241)
Classes 5–7	-0.5193**	-0.4663**	-0.4645**
	(0.2298)	(0.2261)	(0.2355)
Topographic controls			
Elevation (km)	0.0772	0.1047	0.0889
	(0.0783)	(0.0766)	(0.0747)
Slope (%)	-0.0008	-0.0004	-0.0004
	(0.0021)	(0.0021)	(0.0022)
Aspect (degrees)	0.0001	-0.0002	-0.0002
	(0.0004)	(0.0004)	(0.0004)
County FE	Yes	Yes	Yes
Planting period FE	Yes	Yes	Yes
Observations	556	614	614
Counties (clusters)	67	68	68
R^2	0.366	0.313	0.311

Notes: WLS of log planting TPA (dominant species), recently planted stands in OR, CA, WA. Col (1): 10-year change in fire count within 30 km; cols (2)–(3): 15-year fire count and acres burned (10,000 ac). Weighted by stand size; SEs clustered by county. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Back

Logit of Pre-Commercial Thinning (Table 14)

	(1) Fire count (15-yr)	(2) Acreage burned (15-yr)
Wildfire exposure, 0–30 km	0.0669	0.0390
	(0.0833)	(0.0347)
Fire-season Max VPD (hPa)	0.1858**	0.1854**
	(0.0783)	(0.0786)
West side	-0.3761	-0.3718
	(0.2404)	(0.2321)
Stand age (base: 0–9)		
10–19	1.5108***	1.5022***
	(0.2955)	(0.2964)
20–29	0.6591**	0.6506**
	(0.3147)	(0.3148)
30+	-1.7132***	-1.7195***
	(0.3398)	(0.3396)
Baseline Pr(Thin), pp	0.292	0.292
Average marginal effects (pp per unit)		
Wildfire exposure	0.019	0.011
	(0.024)	(0.010)
Fire-season Max VPD	0.054**	0.053**
	(0.023)	(0.023)
Observations	71,088	71,088
Pre-commercial thins	205	205
Plots (clusters)	5,040	5,040
Log pseudolikelihood	-932.0	-931.7
Pseudo R^2	0.140	0.140

Notes: Annual pre-commercial thinning on stand-years with no stand age restriction. Fire and VPD measures, CRE group means, west-side dummy, period FE, weights, and clustering follow Table 3, cols (1)–(2). AMEs in pp per unit. SEs clustered by plot.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Back

Estimating Thinning Responses to Wildfire Risk

Back

$$\Pr(Thin_{it} = 1) = \Lambda\left(\alpha + \beta\, Fire_{it} + \delta\, VPD_{it} + \xi\, \overline{Fire}_i + \psi\, \overline{VPD}_i + \gamma' Age_{it} + \theta\, West_i + \tau_t\right)$$

- Correlated random effects logit of whether a stand is pre-commercially thinned in year t
  - Estimated by maximum likelihood, standard errors clustered by FIA plot
- No stand age sample restrictions
  - 205 pre-commercial thins across 71,088 stand-years
- Amacher et al. (2005) treat thinning as protective effort
  - Theory predicts $\beta > 0$ and $\delta > 0$

Alternative Fire Exposure Windows

Distance Bands Back

	(1)	(2)	(3)	(4)	(5)	(6)
		Fire count			Acreage burned	
	5-yr	10-yr	15-yr	5-yr	10-yr	15-yr
Panel A: Partial Cut vs. Do Nothing						
Wildfire exposure, 0–30 km	0.1173***	0.0581*	0.0862***	0.0569***	0.0518**	0.0638***
	(0.0345)	(0.0320)	(0.0272)	(0.0214)	(0.0210)	(0.0191)
Fire-season Max VPD (hPa)	0.1361***	0.1382***	0.1379***	0.1337***	0.1358***	0.1364***
	(0.0448)	(0.0451)	(0.0446)	(0.0447)	(0.0447)	(0.0445)
Panel B: Clearcut vs. Do Nothing						
Wildfire exposure, 0–30 km	0.0608	0.2481***	0.2588***	0.0823***	0.1017***	0.0979***
	(0.0622)	(0.0478)	(0.0503)	(0.0265)	(0.0181)	(0.0155)
Fire-season Max VPD (hPa)	0.1397***	0.1202**	0.1250***	0.1337***	0.1351***	0.1381***
	(0.0468)	(0.0470)	(0.0470)	(0.0465)	(0.0463)	(0.0464)
Average marginal effects (pp per unit)						
on Pr(Partial Cut):						
Wildfire exposure	0.112***	0.053*	0.080***	0.054***	0.049**	0.060***
	(0.033)	(0.031)	(0.026)	(0.021)	(0.020)	(0.018)
Fire-season Max VPD	0.129***	0.131***	0.131***	0.127***	0.129***	0.129***
	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)
on Pr(Clearcut):						
Wildfire exposure	0.078	0.322***	0.336***	0.107***	0.132***	0.127***
	(0.081)	(0.063)	(0.067)	(0.035)	(0.024)	(0.021)
Fire-season Max VPD	0.181***	0.155**	0.161***	0.173***	0.175***	0.178***
	(0.061)	(0.061)	(0.061)	(0.061)	(0.060)	(0.061)
Observations	51,451	51,451	51,451	51,451	51,451	51,451
Log pseudolikelihood	-4775.6	-4766.5	-4761.0	-4766.8	-4761.0	-4759.1

Fire Exposure by Distance Band

Time Windows Back

	(1)	(2)	(3)	(4)	(5)	(6)
		Fire count			Acreage burned	
	0–30 km	0–15 km	0–15, 16–30 km	0–30 km	0–15 km	0–15, 16–30 km
Panel A: Partial Cut vs. Do Nothing						
Wildfire exposure, 0–30 km	0.0862***			0.0638***		
	(0.0272)			(0.0191)		
Wildfire exposure, 0–15 km		0.0631	0.0007		0.1648***	0.0946
		(0.0587)	(0.0643)		(0.0534)	(0.0701)
Wildfire exposure, 16–30 km			0.1227***			0.0511
			(0.0413)			(0.0329)
Fire-season Max VPD (hPa)	0.1379***	0.1452***	0.1386***	0.1364***	0.1405***	0.1365***
	(0.0446)	(0.0445)	(0.0446)	(0.0445)	(0.0446)	(0.0446)
Panel B: Clearcut vs. Do Nothing						
Wildfire exposure, 0–30 km	0.2588***			0.0979***		
	(0.0503)			(0.0155)		
Wildfire exposure, 0–15 km		0.4504***	0.3450***		0.1933***	0.0055
		(0.1035)	(0.1138)		(0.0607)	(0.1076)
Wildfire exposure, 16–30 km			0.2211***			0.1308***
			(0.0743)			(0.0403)
Fire-season Max VPD (hPa)	0.1250***	0.1351***	0.1253***	0.1381***	0.1416***	0.1381***
	(0.0470)	(0.0468)	(0.0470)	(0.0464)	(0.0467)	(0.0463)
Average marginal effects (pp per unit)						
on Pr(Partial Cut):						
Wildfire, 0–30 km	0.080***			0.060***		
	(0.026)			(0.018)		
Wildfire, 0–15 km		0.057	-0.002		0.156***	0.090
		(0.056)	(0.061)		(0.051)	(0.067)
Wildfire, 16–30 km			0.115***			0.048
			(0.040)			(0.031)
Fire-season Max VPD	0.131***	0.138***	0.131***	0.129***	0.133***	0.129***
	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)
on Pr(Clearcut):						
Wildfire, 0–30 km	0.336***			0.127***		
	(0.067)			(0.021)		
Wildfire, 0–15 km		0.585***	0.449***		0.250***	0.006
		(0.136)	(0.149)		(0.080)	(0.140)
Wildfire, 16–30 km			0.286***			0.170***
			(0.097)			(0.053)
Fire-season Max VPD	0.161***	0.174***	0.162***	0.178***	0.183***	0.178***
	(0.061)	(0.061)	(0.061)	(0.061)	(0.061)	(0.061)
Test: 0–15 km = 16–30 km (*p*-value)						
Partial cut equation			0.17			0.65
Clearcut equation			0.43			0.38
Observations	51,451	51,451	51,451	51,451	51,451	51,451
Log pseudolikelihood	-4761.0	-4772.4	-4759.5	-4759.1	-4773.8	-4756.5

Nested Logit

Without West-Side Dummy Back

	(1) Multinomial logit	(2) Nested logit
Panel A: Partial Cut vs. Do Nothing		
Wildfire count	0.0862***	0.0489
	(0.0272)	(0.0394)
Max VPD (hPa)	0.1379***	0.2033***
	(0.0446)	(0.0645)
Panel B: Clearcut vs. Do Nothing		
Wildfire count	0.2588***	0.3907***
	(0.0503)	(0.0778)
Max VPD (hPa)	0.1250***	0.0757
	(0.0470)	(0.0632)
Panel C: Dissimilarity parameter		
λ_{cut}	—	12.162
		(13.627)
95% confidence interval	—	[−14.547, 38.871]
Wald test H_0: $\lambda_{\text{cut}} = 1$, $\chi^2(1)$	—	0.67
p-value	—	0.413
Observations	51,451	51,451
Plots (clusters)	4,367	4,367
Log pseudolikelihood	−4761.0	−4747.8

Nested Logit without the West-Side Dummy

With West-Side Dummy Back

	(1) Multinomial logit	(2) Nested logit
Panel A: Partial Cut vs. Do Nothing		
Wildfire count	0.0860***	0.0767***
	(0.0268)	(0.0286)
Max VPD (hPa)	0.1325***	0.1336***
	(0.0424)	(0.0483)
Panel B: Clearcut vs. Do Nothing		
Wildfire count	0.2601***	0.2922***
	(0.0504)	(0.0565)
Max VPD (hPa)	0.1206**	0.1204**
	(0.0492)	(0.0552)
Panel C: Dissimilarity parameter		
λ_{cut}	—	1.349
		(0.380)
95% confidence interval	—	[0.604, 2.093]
Wald test H_0: $\lambda_{\text{cut}} = 1$, $\chi^2(1)$	—	0.84
p-value	—	0.358
Observations	51,451	51,451
Plots (clusters)	4,367	4,367
Log pseudolikelihood	−4837.1	−4836.4

Alternative Measures of Weather Shocks (VPD)

Back

	(1) Baseline	(2)	(3)	(4)	(5)	(6)
		Alternative months			Alternative averaging	
Months	Jun–Sep	Apr–Jul	Jul–Sep	Jan–Dec	Jun–Sep	Jun–Sep
Years averaged	3	3	3	3	1	5
Panel A: Partial Cut vs. Do Nothing						
Wildfire count, 0–30 km	0.0862***	0.0835***	0.0890***	0.0844***	0.0878***	0.0858***
	(0.0272)	(0.0273)	(0.0272)	(0.0272)	(0.0270)	(0.0271)
Max VPD (hPa)	0.1379***	0.1009***	0.1352***	0.2253***	0.0578**	0.1909***
	(0.0446)	(0.0348)	(0.0483)	(0.0743)	(0.0243)	(0.0695)
Panel B: Clearcut vs. Do Nothing						
Wildfire count, 0–30 km	0.2588***	0.2597***	0.2635***	0.2589***	0.2590***	0.2574***
	(0.0503)	(0.0509)	(0.0499)	(0.0507)	(0.0499)	(0.0506)
Max VPD (hPa)	0.1250***	0.0703*	0.1417***	0.1987**	0.0849***	0.2339***
	(0.0470)	(0.0363)	(0.0547)	(0.0782)	(0.0211)	(0.0763)
Average marginal effects (pp per unit)						
on Pr(Partial Cut):						
Wildfire count	0.080***	0.078***	0.083***	0.078***	0.082***	0.080***
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
Max VPD	0.131***	0.096***	0.128***	0.214***	0.055**	0.180***
	(0.043)	(0.033)	(0.046)	(0.071)	(0.023)	(0.067)
on Pr(Clearcut):						
Wildfire count	0.336***	0.337***	0.342***	0.336***	0.336***	0.334***
	(0.067)	(0.067)	(0.066)	(0.067)	(0.066)	(0.067)
Max VPD	0.161***	0.091*	0.183**	0.256**	0.110***	0.303***
	(0.061)	(0.047)	(0.071)	(0.102)	(0.028)	(0.100)
Mean of Max VPD (hPa)	22.31	16.40	24.00	12.25	22.34	22.28
SD of Max VPD (hPa)	7.21	5.03	7.72	3.75	7.39	7.15
Observations	51,451	51,451	51,451	51,451	51,451	51,451
Log pseudolikelihood	-4761.0	-4762.8	-4761.6	-4761.0	-4760.4	-4759.7

Planting Density Robustness Checks

Back

	(1) Baseline	(2) State FE	(3) Planting year FE	(4) Forest-type FE	(5) 15-yr Δ count	(6) Annual 15-yr VPD	(7) Measured $\leq$ 3 yrs
Wildfire exposure, 0–30 km	-0.0808***	-0.0479*	-0.0824***	-0.0824***	-0.1082***	-0.0821***	-0.0840***
	(0.0238)	(0.0268)	(0.0250)	(0.0231)	(0.0355)	(0.0237)	(0.0314)
County FE	Yes	No	Yes	Yes	Yes	Yes	Yes
State FE	No	Yes	No	No	No	No	No
Planting-period FE	Yes	Yes	No	Yes	Yes	Yes	Yes
Planting-year FE	No	No	Yes	No	No	No	No
Douglas-fir dummy	Yes	Yes	Yes	No	Yes	Yes	Yes
Forest-type FE	No	No	No	Yes	No	No	No
Observations	556	556	556	556	232	556	274
Counties (clusters)	67	67	67	67	51	67	59
R^2	0.366	0.134	0.384	0.374	0.525	0.365	0.529

Stand Age at Partial Cut

Clearcuts Back

	0–15 km		0–30 km	
	(1) Fire count	(2) Acres burned	(3) Fire count	(4) Acres burned
Wildfire exposure (15-yr)	-2.140***	-1.600*	-0.779	-0.487
	(0.822)	(0.818)	(0.484)	(0.374)
Fire-season Max VPD (hPa)	0.377	0.300	0.380	0.306
	(0.461)	(0.461)	(0.470)	(0.462)
County FE	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes
Topographic controls	Yes	Yes	Yes	Yes
Mean stand age at partial cut (years)	71.0	71.0	71.0	71.0
Observations	537	537	537	537
Plots (clusters)	491	491	491	491
Counties	77	77	77	77
R^2	0.404	0.402	0.401	0.400

Stand Age at Clearcut

Partial Cuts Back

	0–15 km		0–30 km	
	(1) Fire count	(2) Acres burned	(3) Fire count	(4) Acres burned
Wildfire exposure (15-yr)	-0.177	0.457	-0.686	-0.432
	(1.419)	(2.085)	(0.581)	(0.437)
Fire-season Max VPD (hPa)	0.203	0.184	0.258	0.257
	(0.347)	(0.357)	(0.356)	(0.362)
County FE	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes
Topographic controls	Yes	Yes	Yes	Yes
Mean stand age at clearcut (years)	57.1	57.1	57.1	57.1
Observations	730	730	730	730
Plots (clusters)	630	630	630	630
Counties	65	65	65	65
R^2	0.396	0.396	0.398	0.397

Alternative Group Means

Back

	(1) Baseline	(2) Period-bin group means	(3) 2001–2024 group means
Panel A: Partial Cut vs. Do Nothing			
Wildfire count	0.0862***	0.0868***	0.0908***
	(0.0272)	(0.0283)	(0.0259)
Max VPD (hPa)	0.1379***	0.1371***	0.1266***
	(0.0446)	(0.0451)	(0.0414)
Panel B: Clearcut vs. Do Nothing			
Wildfire count	0.2588***	0.0432	0.0464
	(0.0503)	(0.0505)	(0.0380)
Max VPD (hPa)	0.1250***	0.1182**	0.0609
	(0.0470)	(0.0512)	(0.0397)
Average marginal effects (pp per unit, SE in parens.)			
on Pr(Partial Cut):			
Wildfire count	0.080***	0.083***	0.086***
	(0.026)	(0.027)	(0.025)
Max VPD	0.131***	0.130***	0.120***
	(0.043)	(0.043)	(0.040)
on Pr(Clearcut):			
Wildfire count	0.336***	0.053	0.060
	(0.067)	(0.063)	(0.050)
Max VPD	0.161***	0.147**	0.078
	(0.061)	(0.064)	(0.052)
Wildfire and VPD group-mean window	Sample years	Sample years	2001–2024
Period-bin group means	No	Yes	No
Observations	51,451	51,451	51,451
Plots (clusters)	4,367	4,367	4,367
Log pseudolikelihood	-4761.0	-4432.3	-4776.8
Pseudo R^2	0.060	0.125	0.057

Yield Functions

- Standing volume follows tree-level yield functions from Mihiar and Lewis (2021)
  - Estimated by county and forest type across the US
  - Because they are tree level, changes in planting density carry through to future volume

- Von Bertalanffy functional form, for a stand of age a:

$$v(a) = \alpha \left(1 - e^{-\beta a}\right)^3$$

- α: maximum size the stand approaches; β: how fast it gets there

- We estimate plot-level aboveground biomass functions with the same functional form, using FIA data
  - By forest type, region, and site class, fit by nonlinear least squares

Biomass Estimates Back

Biomass Growth Curve Estimates

Back

Region	Site class	n	Curve	α (tons/acre)	β	R^2
Douglas-fir						
East	I–II	19	pooled sc	74.8 (3.4)	0.0510 (0.0053)	0.074
East	III–IV	528	own	108.0 (8.5)	0.0423 (0.0051)	0.164
East	V–VII	833	own	76.8 (6.7)	0.0272 (0.0029)	0.111
West	I–II	1,565	own	240.4 (13.4)	0.0401 (0.0019)	0.631
West	III–IV	2,169	own	189.7 (8.2)	0.0398 (0.0016)	0.549
West	V–VII	193	own	127.7 (12.0)	0.0414 (0.0050)	0.423
Fir/Spruce						
East	I–II	16	pooled sc	93.7 (8.1)	0.0268 (0.0027)	0.199
East	III–IV	300	own	103.1 (11.1)	0.0275 (0.0033)	0.250
East	V–VII	205	own	90.0 (14.2)	0.0204 (0.0031)	0.230
West	I–II	48	pooled sc	251.0 (30.0)	0.0267 (0.0024)	0.628
West	III–IV	74	own	283.3 (41.7)	0.0244 (0.0027)	0.686
West	V–VII	16	pooled sc	251.0 (30.0)	0.0267 (0.0024)	0.628
Hemlock/Sitka spruce						
East	I–II	3	pooled sc	132.3 (17.9)	0.0198 (0.0030)	0.346
East	III–IV	33	pooled sc	132.3 (17.9)	0.0198 (0.0030)	0.346
East	V–VII	33	pooled sc	132.3 (17.9)	0.0198 (0.0030)	0.346
West	I–II	649	own	191.8 (14.1)	0.0469 (0.0041)	0.420
West	III–IV	287	own	191.1 (15.2)	0.0356 (0.0032)	0.412
West	V–VII	48	pooled sc	180.7 (9.8)	0.0456 (0.0030)	0.382
Ponderosa pine						
East	I–II	32	pooled sc	45.5 (1.8)	0.0482 (0.0035)	0.114
East	III–IV	471	own	62.3 (4.2)	0.0477 (0.0047)	0.229
East	V–VII	1,215	own	43.9 (2.5)	0.0358 (0.0031)	0.133
West	I–II	3	pooled sc, reg	45.2 (1.7)	0.0492 (0.0035)	0.108
West	III–IV	7	pooled sc, reg	45.2 (1.7)	0.0492 (0.0035)	0.108
West	V–VII	3	pooled sc, reg	45.2 (1.7)	0.0492 (0.0035)	0.108
Other softwood						
East	I–II	228	own	241.6 (45.0)	0.0245 (0.0047)	0.294
East	III–IV	726	own	125.2 (9.6)	0.0299 (0.0030)	0.225
East	V–VII	393	own	81.6 (10.4)	0.0229 (0.0028)	0.224
West	I–II	129	own	247.8 (35.2)	0.0407 (0.0065)	0.591
West	III–IV	93	own	316.3 (99.9)	0.0249 (0.0064)	0.553
West	V–VII	24	pooled sc	248.7 (44.3)	0.0337 (0.0060)	0.516
Hardwoods/woodlands						
East	I–II	27	pooled sc	85.9 (8.1)	0.0607 (0.0109)	0.095
East	III–IV	189	own	95.3 (10.7)	0.0623 (0.0131)	0.148
East	V–VII	140	own	59.4 (5.6)	0.0718 (0.0152)	0.076
West	I–II	283	own	114.0 (7.7)	0.0710 (0.0069)	0.212
West	III–IV	586	own	112.3 (5.8)	0.0626 (0.0048)	0.212
West	V–VII	114	own	127.1 (17.1)	0.0433 (0.0076)	0.233

Intensive Margin: Share of Volume Removed

Back

	Share of volume removed
Wildfire exposure, 0–30 km (15-yr count)	-0.0029
	(0.0072)
Fire-season Max VPD (hPa)	0.0091*
	(0.0050)
Regrowth gap (yrs)	-0.0110
	(0.0092)
Stand age at cut (yrs)	0.0010*
	(0.0005)
Slope (%)	-0.0007
	(0.0010)
Aspect (degrees)	0.0002
	(0.0001)
Elevation (km)	0.0284
	(0.0323)
Douglas-fir forest type	-0.0549
	(0.0583)
Stand origin (base: natural)	
Planted	0.0486
	(0.1121)
Site class (base: classes 1–2)	
Classes 3–4	0.0713
	(0.0808)
Classes 5–7	-0.0167
	(0.0886)
County FE	Yes
Period FE	Yes
Observations	312
Counties (clusters)	65
R^2	0.343

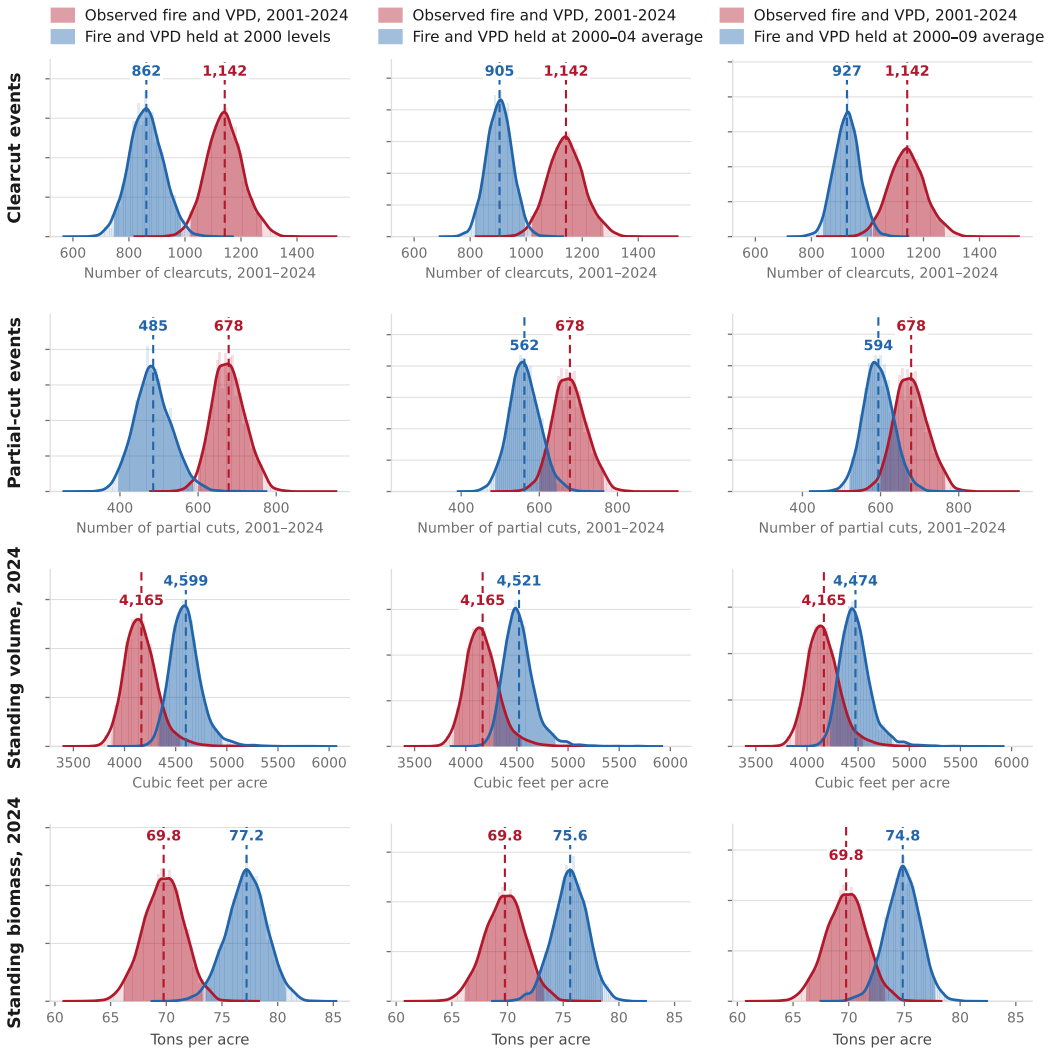
Intensive Margin: Share of Biomass Removed

Back

	Share of biomass removed
Wildfire exposure, 0–30 km (15-yr count)	-0.0014
	(0.0069)
Fire-season Max VPD (hPa)	0.0088**
	(0.0044)
Regrowth gap (yrs)	-0.0105
	(0.0085)
Stand age at cut (yrs)	0.0010*
	(0.0005)
Slope (%)	-0.0006
	(0.0009)
Aspect (degrees)	0.0003*
	(0.0002)
Elevation (km)	0.0360
	(0.0326)
Douglas-fir forest type	-0.0532
	(0.0549)
Stand origin (base: natural)	
Planted	0.0362
	(0.1110)
Site class (base: classes 1–2)	
Classes 3–4	0.0913
	(0.0752)
Classes 5–7	0.0134
	(0.0839)
County FE	Yes
Period FE	Yes
Observations	312
Counties (clusters)	65
R^2	0.326

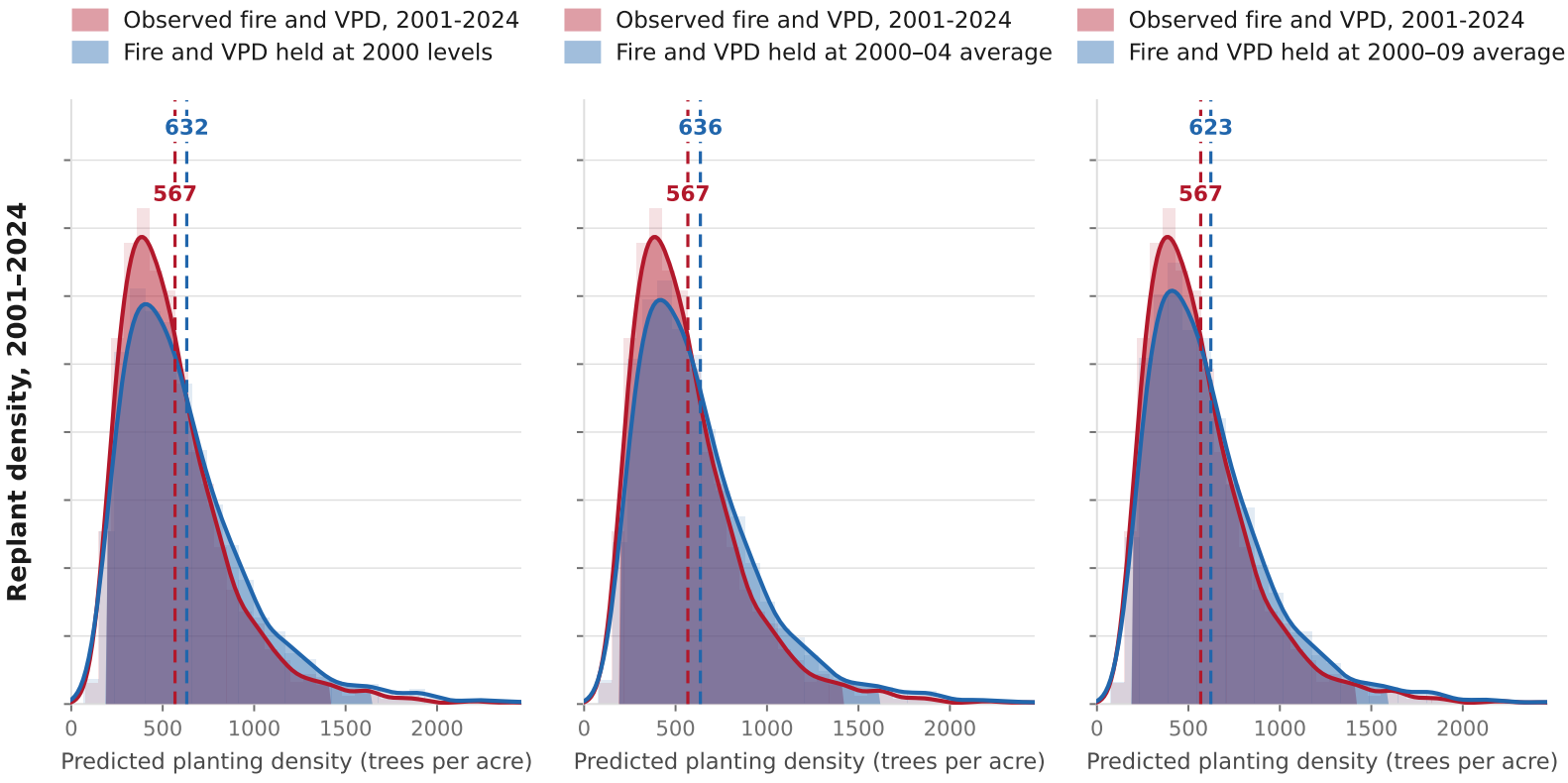
Simulated Outcomes Under All Three Counterfactuals

Back



Simulated Replanting Density

Back



- Replanting density is about 10% lower than with fire and VPD held at 2000 levels: 567 vs. 632 trees per acre

Surface Fuels: Difference-in-Differences Specification

ΔF_{ij}: change in fuel class j on stand i between two FIA visits

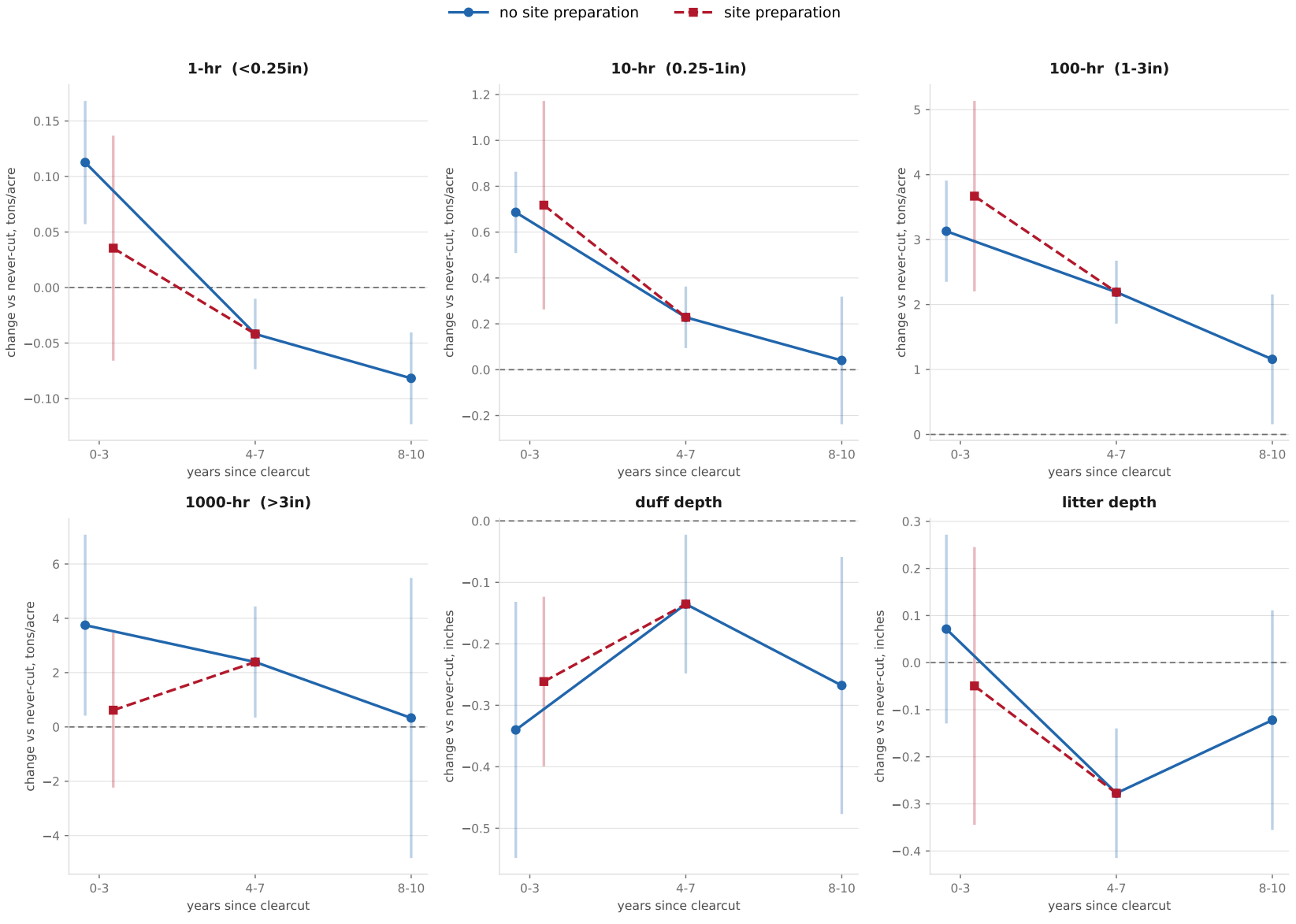
$$\Delta F_{ij} = \alpha_j + \sum_k \delta_{jk}\, CC_i \times \mathbf{1}[TSC_i \in k] + \psi_j\, CC_i \times \mathbf{1}[TSC_i \in 0\text{–}3] \times Prep_i + \phi_j' Site_i + \omega_j' Type_i + \varepsilon_{ij}$$

- CC_i: clearcut between visits; TSC_i: years since the cut, in bins $k \in \{0\text{–}3, 4\text{–}7, 8\text{–}10\}$
- $Prep_i$: site preparation after the clearcut, so $\delta_{j1} + \psi_j$ is the effect with site prep
- $Site_i$, $Type_i$: site class and forest type group
- Control group: 2,478 never-cut stands; 420 clearcuts; stands with a fire disturbance dropped
- One OLS regression per fuel class, standard errors clustered by plot
- Partial cuts: same specification with a partial cut indicator and no site prep term
- Identifying assumption: parallel trends; absent the cut, cut stands would have changed like never-cut stands

Back

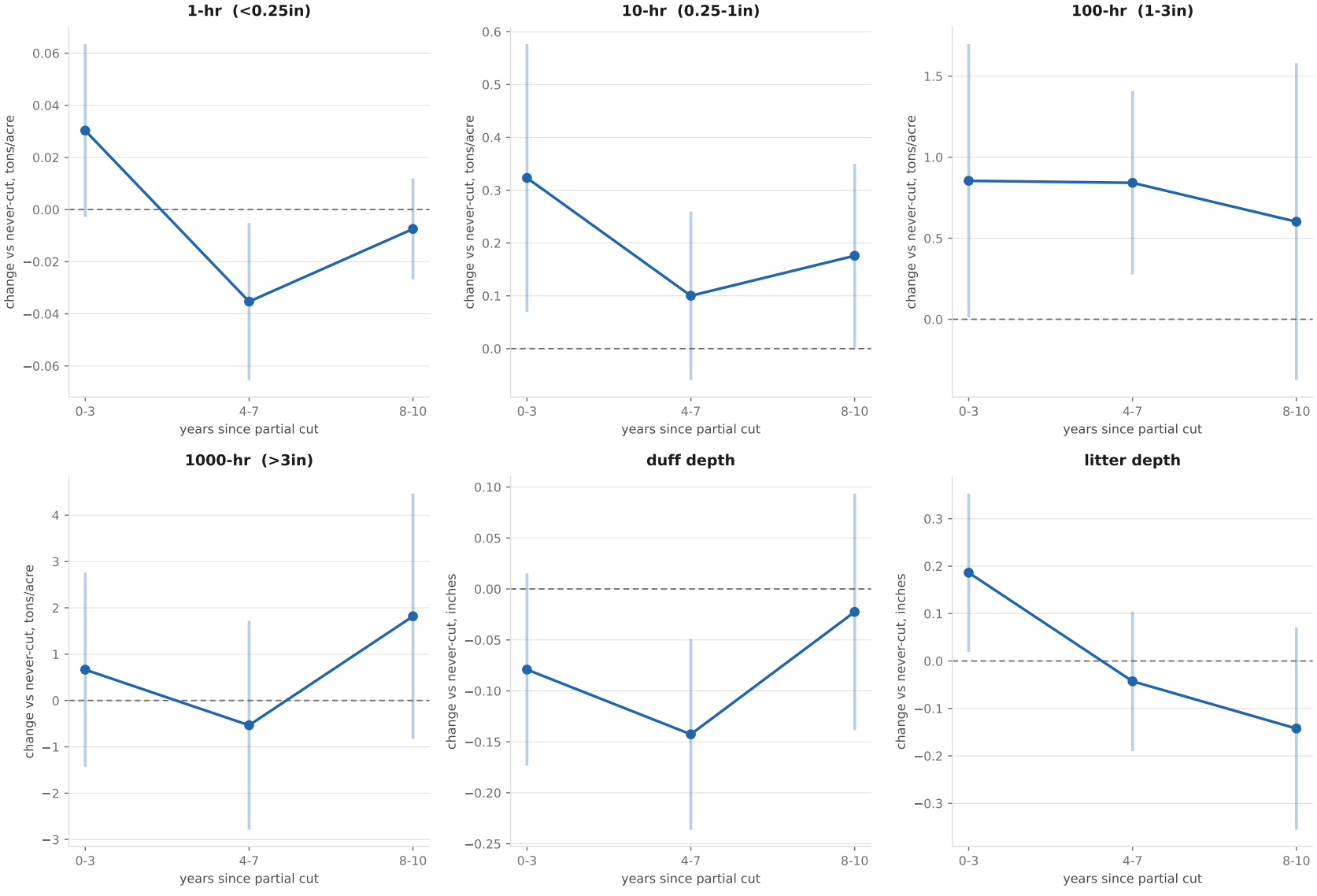
Clearcuts and Surface Fuels (All Fuel Classes)

Partial Cuts Back



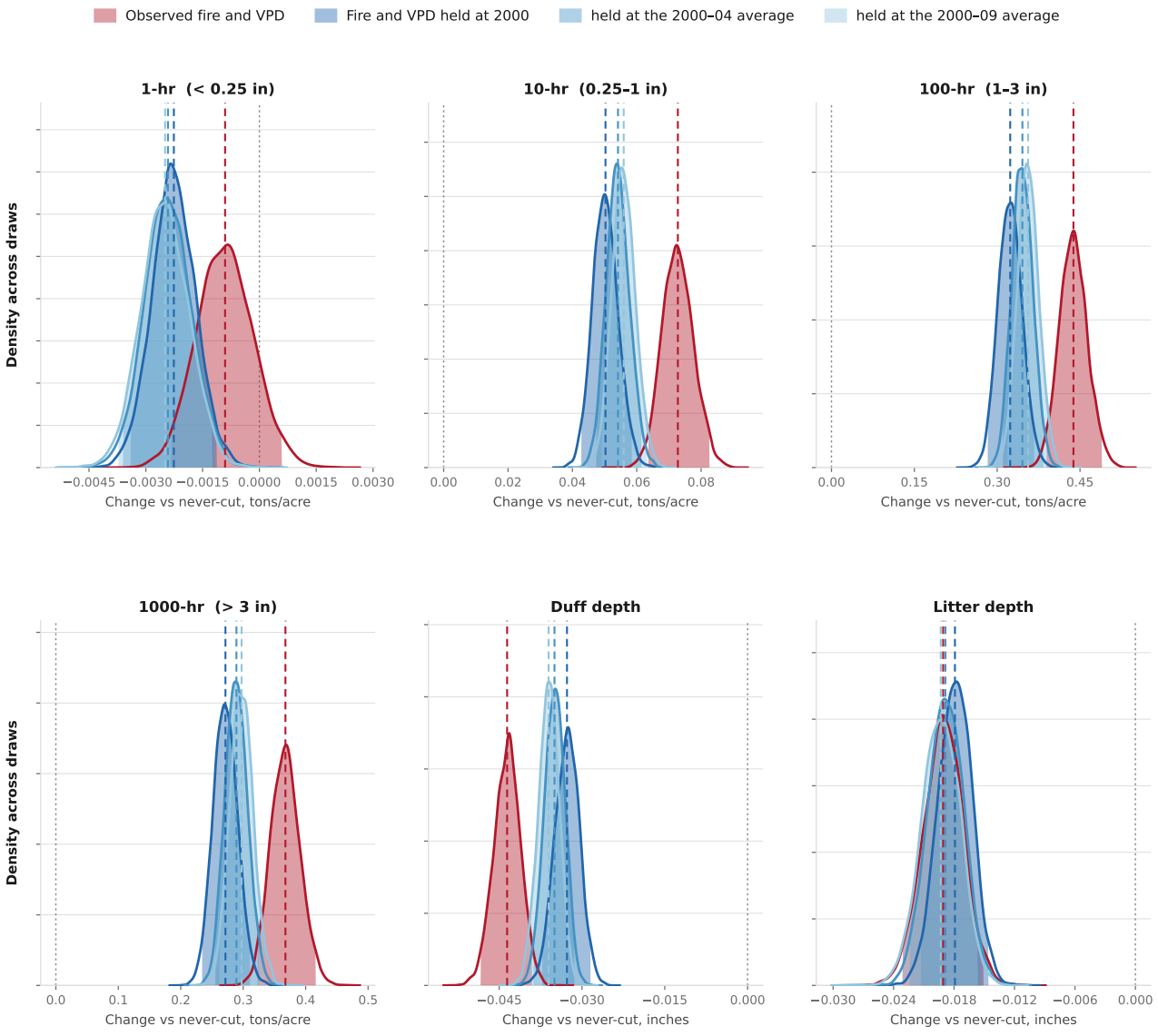
Partial Cuts and Surface Fuels (All Fuel Classes)

Clearcuts Back



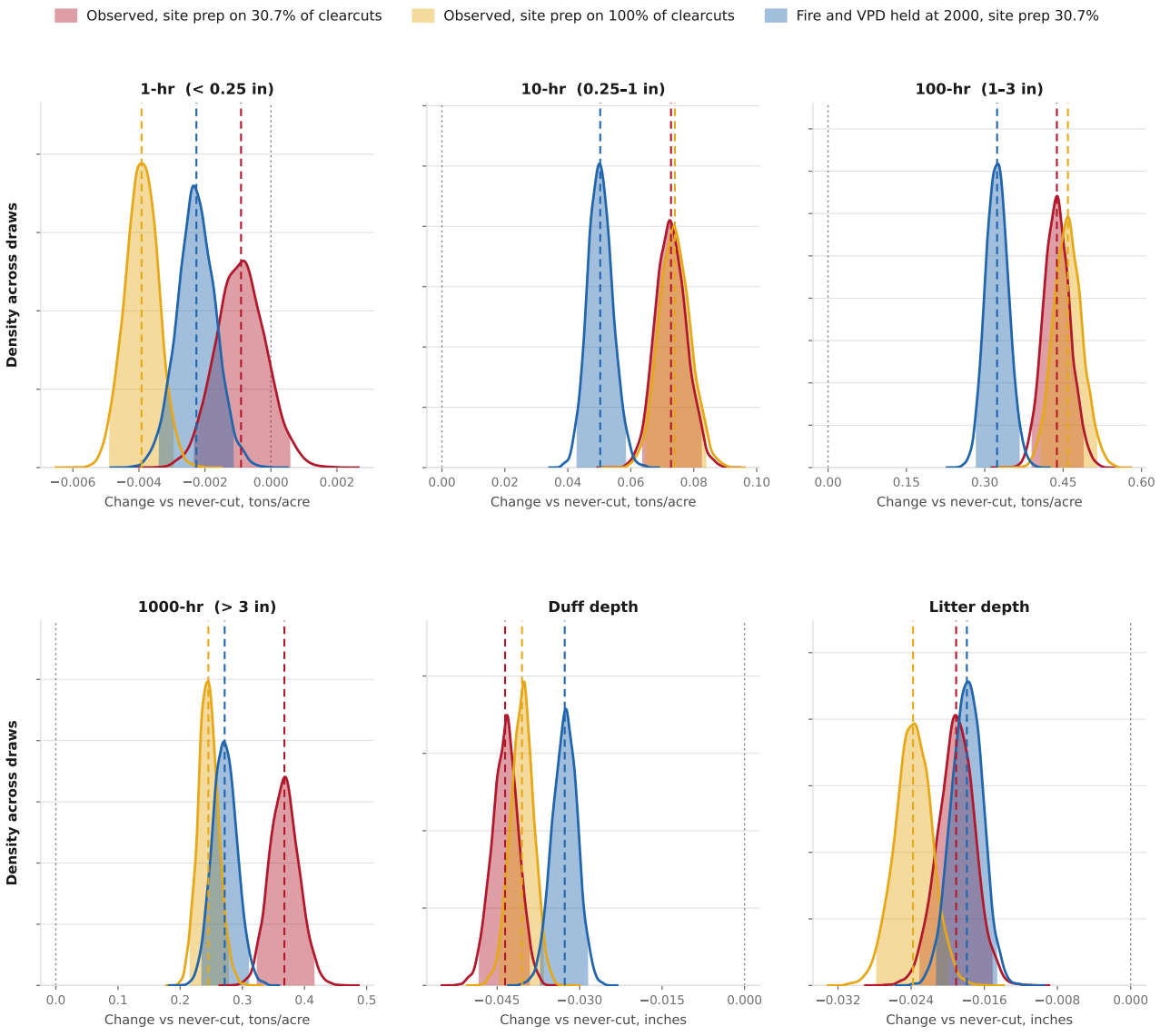
Simulated Change in Surface Fuels, 2020

Back



Universal Site Preparation and Surface Fuels, 2020

Back



FOFEM Emissions, Observed and Counterfactual Regimes

Back

Scenario	$PM_{2.5}$ (metric tons) Emitted	Difference	%	CO_2 (metric tons) Emitted	Difference	%
Panel A. 2020 fire year 85 fires, 811,714 acres						
Observed regime (baseline)	436,359	—	—	35,434,539	—	—
CF1 2000 levels	435,034	−1,325	−0.30	35,748,703	+314,164	+0.89
CF2 2000–04 average	435,126	−1,233	−0.28	35,641,725	+207,186	+0.58
CF3 2000–09 average	435,202	−1,158	−0.27	35,588,038	+153,499	+0.43
All clearcuts site prepped	435,673	−687	−0.16	35,372,366	−62,173	−0.18
Panel B. 2024 fire year 52 fires, 140,921 acres						
Observed regime (baseline)	29,409	—	—	3,505,979	—	—
CF1 2000 levels	29,267	−142	−0.48	3,612,960	+106,981	+3.05
CF2 2000–04 average	29,243	−167	−0.57	3,587,569	+81,590	+2.33
CF3 2000–09 average	29,212	−198	−0.67	3,575,162	+69,183	+1.97
All clearcuts site prepped	29,341	−69	−0.23	3,498,585	−7,394	−0.21

Fuel Changes Applied in FOFEM

Back

Fuel class	FCCS Avg. Fuel Loads	CF1 Change	CF1 %	CF2 Change	CF2 %	CF3 Change	CF3 %
Panel A. 2020 fire year							
1-hour (< 0.25 in)	0.433	0.0014	0.31	0.0015	0.35	0.0016	0.37
10-hour (0.25–1 in)	1.131	0.0225	1.99	0.0186	1.64	0.0168	1.49
100-hour (1–3 in)	1.870	0.1145	6.12	0.0924	4.94	0.0821	4.39
1000-hour (> 3 in)	20.847	0.0961	0.46	0.0785	0.38	0.0702	0.34
Duff depth	1.959	−0.0108	−0.55	−0.0086	−0.44	−0.0075	−0.38
Litter depth	0.836	−0.0012	−0.14	−0.0002	−0.03	0.0002	0.03
Crown fuels	73.111*	−4.5770	−6.26	−3.2795	−4.49	−2.6324	−3.60
Panel B. 2024 fire year							
1-hour (< 0.25 in)	0.339	0.0004	0.11	0.0005	0.15	0.0006	0.17
10-hour (0.25–1 in)	1.245	0.0284	2.28	0.0250	2.01	0.0234	1.88
100-hour (1–3 in)	1.152	0.1641	14.25	0.1451	12.60	0.1364	11.84
1000-hour (> 3 in)	9.490	0.1380	1.45	0.1225	1.29	0.1153	1.22
Duff depth	1.010	−0.0162	−1.61	−0.0141	−1.40	−0.0131	−1.30
Litter depth	0.799	−0.0057	−0.72	−0.0050	−0.63	−0.0046	−0.58
Crown fuels	69.763*	−7.4444	−10.67	−5.8623	−8.40	−5.0834	−7.29

Site Preparation vs. Adaptation: Emissions

Back

	Site prep 100% vs 30.7%		Adaptation Baseline vs CF1		Combined 100% prep vs CF1	
Pollutant	Change	%	Change	%	Change	%
Panel A. 2020 fire year	85 fires, 811,714 acres					
$PM_{2.5}$	−687	−0.16	+1,325	+0.30	+638	+0.15
CO_2	−62,173	−0.18	−314,164	−0.89	−376,337	−1.06
Panel B. 2024 fire year	52 fires, 140,921 acres					
$PM_{2.5}$	−69	−0.23	+142	+0.48	+73	+0.25
CO_2	−7,394	−0.21	−106,981	−3.05	−114,375	−3.26

Site Preparation vs. Adaptation: Surface Fuels

Back

	FCCS Avg.	Site prep 100% vs 30.7%		Adaptation Baseline vs CF1		Combined 100% prep vs CF1	
Fuel class	Fuel Loads	Change	%	Change	%	Change	%
Panel A. 2020 fire year							
1-hour ($<$ 0.25 in)	0.433	−0.0030	−0.70	0.0014	0.31	−0.0017	−0.38
10-hour (0.25–1 in)	1.131	0.0012	0.11	0.0225	1.99	0.0237	2.10
100-hour (1–3 in)	1.870	0.0211	1.13	0.1145	6.12	0.1356	7.25
1000-hour ($>$ 3 in)	20.847	−0.1223	−0.59	0.0961	0.46	−0.0262	−0.13
Duff depth	1.959	0.0031	0.16	−0.0108	−0.55	−0.0078	−0.40
Litter depth	0.836	−0.0047	−0.56	−0.0012	−0.14	−0.0059	−0.70
Panel B. 2024 fire year							
1-hour ($<$ 0.25 in)	0.339	−0.0031	−0.92	0.0004	0.11	−0.0027	−0.81
10-hour (0.25–1 in)	1.245	0.0013	0.10	0.0284	2.28	0.0297	2.38
100-hour (1–3 in)	1.152	0.0218	1.90	0.1641	14.25	0.1860	16.15
1000-hour ($>$ 3 in)	9.490	−0.1266	−1.33	0.1380	1.45	0.0115	0.12
Duff depth	1.010	0.0032	0.31	−0.0162	−1.61	−0.0130	−1.29
Litter depth	0.799	−0.0049	−0.61	−0.0057	−0.72	−0.0106	−1.33

References I

Abatzoglou, J. T. and Williams, A. P. (2016). Impact of anthropogenic climate change on wildfire across western us forests. *Proceedings of the National Academy of sciences*, 113(42):11770–11775.

Amacher, G. S., Malik, A. S., and Haight, R. G. (2005). Not getting burned: the importance of fire prevention in forest management. *Land Economics*, 81(2):284–302.

Auffhammer, M. and Kellogg, R. (2011). Clearing the air? The effects of gasoline content regulation on air quality. *American Economic Review*, 101(6):2687–2722.

Baylis, P. and Boomhower, J. (2023). The economic incidence of wildfire suppression in the united states. *American Economic Journal: Applied Economics*, 15(1):442–473.

Burke, M., Driscoll, A., Heft-Neal, S., Xue, J., Burney, J., and Wara, M. (2021). The changing risk and burden of wildfire in the united states. *Proceedings of the National Academy of Sciences*, 118(2):e2011048118.

References II

Burke, M. and Emerick, K. (2016). Adaptation to climate change: Evidence from us agriculture. *American Economic Journal: Economic Policy*, 8(3):106–140.

Currie, J. and Walker, R. (2011). Traffic congestion and infant health: Evidence from E-ZPass. *American Economic Journal: Applied Economics*, 3(1):65–90.

Davis, E. C., Sohngen, B., and Lewis, D. J. (2026). How much of the forest sink is passive? case of the united states. *Proceedings of the National Academy of Sciences*, 123(4):e2513588123.

Davis, L. W. (2008). The effect of driving restrictions on air quality in Mexico City. *Journal of Political Economy*, 116(1):38–81.

Dell, M., Jones, B. F., and Olken, B. A. (2014). What do we learn from the weather? The new climate-economy literature. *Journal of Economic Literature*, 52(3):740–798.

Faustmann, M. (1849). Berechnung des werthes, welchen waldboden sowie noch nicht haubare holzbestände für die waldwirthschaft besitzen. *Allgemeine Forst- und Jagd-Zeitung*, 15:441–455.

References III

Fitzgerald, S. A. (1998). Site preparation: An introduction for the woodland owner. Technical Report EC 1188, Oregon State University Extension Service, Corvallis, OR. Reprinted March 1998.

Fowlie, M. (2010). Emissions trading, electricity restructuring, and investment in pollution abatement. *American Economic Review*, 100(3):837–869.

Gellman, J., Walls, M., and Wibbenmeyer, M. (2025). Welfare losses from wildfire smoke: Evidence from daily outdoor recreation data. *Journal of Environmental Economics and Management*, 132:103166.

Greenstone, M. (2002). The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 Clean Air Act amendments and the census of manufactures. *Journal of Political Economy*, 110(6):1175–1219.

Hagmann, R. K., Hessburg, P. F., Prichard, S. J., Povak, N. A., Brown, P. M., Fulé, P. Z., Keane, R. E., Knapp, E. E., Lydersen, J. M., Metlen, K. L., et al. (2021). Evidence for widespread changes in the structure, composition, and fire regimes of western north american forests. *Ecological Applications*, 31(8):e02431.

References IV

Harris, V., Caputo, J., and Butler, B. J. (2025). Forest ownership in the conterminous United States circa 2022: distribution of seven ownership types - geospatial dataset.

Hashida, Y. and Lewis, D. J. (2019). The intersection between climate adaptation, mitigation, and natural resources: An empirical analysis of forest management. *Journal of the Association of Environmental and Resource Economists*, 6(5):893–926.

Hashida, Y., Lewis, D. J., and Cummins, K. (2025). Prescribed fires as a climate change adaptation tool. *Journal of Environmental Economics and Management*, 130:103081.

Hornbeck, R. (2012). The enduring impact of the american dust bowl: Short-and long-run adjustments to environmental catastrophe. *American Economic Review*, 102(4):1477–1507.

Hsiang, S. (2016). Climate econometrics. *Annual Review of Resource Economics*, 8:43–75.

Jerrett, M., Jina, A. S., and Marlier, M. E. (2022). Up in smoke: California's greenhouse gas reductions could be wiped out by 2020 wildfires. *Environmental Pollution*, 310:119888.

References V

Johnson, K. K. and Lewis, D. J. (2024). Weather variability risks slow climate adaptation: An empirical analysis of forestry. *Journal of Environmental Economics and Management*, 125:103000.

Krinsky, I. and Robb, A. L. (1986). On approximating the statistical properties of elasticities. *The Review of Economics and Statistics*, 68(4):715–719.

Lancaster, T. (2000). The incidental parameter problem since 1948. *Journal of econometrics*, 95(2):391–413.

Lutes, D. C. (2020). First order fire effects model: FOFEM version 6.7. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

Mason, C. F. and Plantinga, A. J. (2013). The additionality problem with offsets: Optimal contracts for carbon sequestration in forests. *Journal of Environmental Economics and Management*, 66(1):1–14.

Mihiar, C. and Lewis, D. J. (2021). Climate, adaptation, and the value of forestland: A national ricardian analysis of the united states. *Land Economics*, 97(4):911–936.

References VI

Mundlak, Y. (1978). On the pooling of time series and cross section data. *Econometrica*, 46(1):69–85.

Neyman, J. and Scott, E. L. (1948). Consistent estimates based on partially consistent observations. *Econometrica: journal of the Econometric Society*, pages 1–32.

Oswalt, S. N., Smith, W. B., Miles, P. D., and Pugh, S. A. (2019). Forest resources of the united states, 2017: A technical document supporting the forest service 2020 rpa assessment. Technical Report Gen. Tech. Rep. WO-97, U.S. Department of Agriculture, Forest Service, Washington Office, Washington, DC.

Patto, J. V. and Rosa, R. (2022). Adapting to frequent fires: Optimal forest management revisited. *Journal of Environmental Economics and Management*, 111:102570.

Plantinga, A. J., Walsh, R., and Wibbenmeyer, M. (2022). Priorities and effectiveness in wildfire management: evidence from fire spread in the western united states. *Journal of the Association of Environmental and Resource Economists*, 9(4):603–639.

References VII

Qiu, M., Li, J., Gould, C. F., Jing, R., Kelp, M., Childs, M., Kiang, M., Heft-Neal, S., Diffenbaugh, N., and Burke, M. (2024). Mortality burden from wildfire smoke under climate change. Technical report, National Bureau of Economic Research.

Qiu, M., Li, J., Gould, C. F., Jing, R., Kelp, M., Childs, M. L., Wen, J., Xie, Y., Lin, M., Kiang, M. V., Heft-Neal, S., Diffenbaugh, N. S., and Burke, M. (2025). Wildfire smoke exposure and mortality burden in the USA under climate change. *Nature*, 647(8091):935–943.

Reed, W. J. (1984). The effects of the risk of fire on the optimal rotation of a forest. *Journal of environmental economics and management*, 11(2):180–190.

Reinhardt, E. D., Keane, R. E., and Brown, J. K. (1997). *First Order Fire Effects Model: FOFEM 4.0, user's guide*.

Rennert, K., Errickson, F., Prest, B. C., Rennels, L., Newell, R. G., Pizer, W., Kingdon, C., Wingenroth, J., Cooke, R., Parthum, B., et al. (2022). Comprehensive evidence implies a higher social cost of co2. *Nature*, 610(7933):687–692.

References VIII

Restaino, C. M., Peterson, D. L., and Littell, J. (2016). Increased water deficit decreases Douglas-fir growth throughout western US forests. *Proceedings of the National Academy of Sciences*, 113(34):9557–9562.

Shapiro, J. S. and Walker, R. (2018). Why is pollution from US manufacturing declining? The roles of environmental regulation, productivity, and trade. *American Economic Review*, 108(12):3814–3854.

Strabo, F., Bryan, C., and Reimer, M. N. (2026). Wildfire damages and the cost-effective role of forest fuel treatments. *Science*, 392(6798):629–635.

Strabo, F. and Reimer, M. N. (2026). Before the burn: The economic benefits of fuel-reduction treatments in wildfire-prone forests. *The Economic Journal*, page ueag037.

Taraz, V. (2017). Adaptation to climate change: Historical evidence from the indian monsoon. *Environment and Development Economics*, 22(5):517–545.

Train, K. E. (2009). *Discrete Choice Methods with Simulation*. Cambridge University Press, Cambridge, 2 edition.

References IX

USDA Forest Service (2023). Future of america's forests and rangelands: Forest service 2020 resources planning act assessment. Technical Report Gen. Tech. Rep. WO-102, U.S. Department of Agriculture, Forest Service, Washington, DC.

Wang, Y. and Lewis, D. J. (2024). Wildfires and climate change have lowered the economic value of western us forests by altering risk expectations. *Journal of Environmental Economics and Management*, 123:102894.

Wooldridge, J. M. (2019). Correlated random effects models with unbalanced panels. *Journal of Econometrics*, 211(1):137–150.