Post-fire Risk Reduction in Northern California: Lessons Learned from Simulations and Practice

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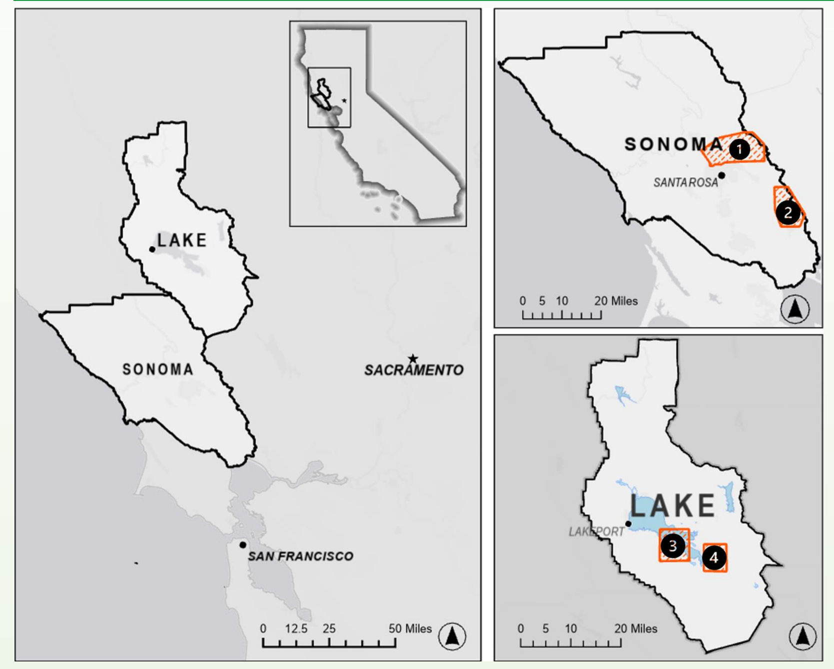
Background

The number and scale of destructive wildfires has escalated in recent decades. For the communities impacted by wildfire, the **post-disaster recovery period provides a unique opportunity to promote wildfire risk reduction** through fire-resistant building codes, land use regulations, and vegetation maintenance programs. However, the time period after disaster can also be challenging, with multiple organizations, funders, and programs working on post-wildfire recovery and risk reduction, typically with limited focus in their geography or scope. Determining the ultimate outcomes of these investments requires not only understanding individual program implementation but also **how investments in housing and vegetation combine to reduce overall risk**.

Here, we present a mixed methods study that assesses post-fire activities and outcomes in Sonoma and Lake counties in northern California. We use both interviews on post-fire programs and activities, along with modeling simulations of wildfire risk reduction outcomes in selected study areas, to consider risk reduction needs and program design. Synthesis goals include recommendations for post-wildfire risk reduction in recovery.

Study Area



Key Highlights:

- Repetitive wildfires in last decade. Federally-declared & smaller events. Significant wildfire losses.
- Common state-level policy context
- Sonoma County:
  - On average, higher income, more developed, more capacity
  - Higher rebuilding
- Lake County
  - On average, lower income, more rural, less capacity. Tribal presence.
  - Slower rebuilding

Figure 1. Sonoma and Lake counties in northern California, with insets showing four focal areas selected for modeling. In Sonoma County: (1) Santa Rosa and (2) Fetters Hot Springs-Agua Caliente; in Lake County: (3) Kelseyville Riviera, (4) Clearlake.

Research Design and Methods

We use a mixed-methods approach to gather data on wildfire risk reduction and recovery activities in the study area (2015-today). Then we explore relative risk reduction outcomes in focal areas of each county through stochastic wildfire modeling simulations.

1) Risk Reduction and Recovery Activities:

Goal: Inventory the programs, funders, and organizations responsible for local risk reduction efforts. Understand perceptions of program efficacy.

Methods: Semi-structured interviews via Zoom with program implementers (n=28). Inductive and deductive content analysis of programs activities, including facilitators and challenges to risk reduction outcomes. In Oct 2024, member checking of preliminary findings with key stakeholders in each county.

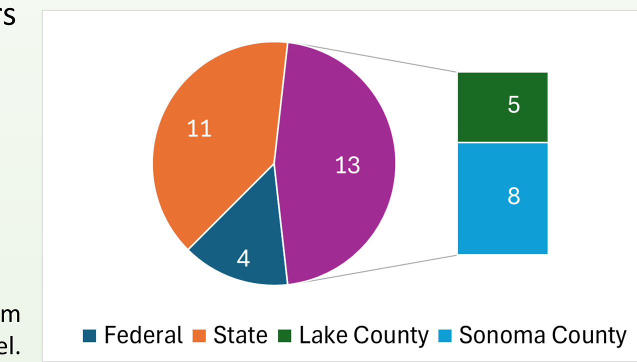


Figure 2. Number of program implementers interviewed by level.

2) Modeling Outcomes:

Focal areas: Interviews and member checking with primary stakeholders in each county drove selection of four focal areas of greatest concern where risk reduction activities were completed or under way.

Approaches: The ELMFIRE wildfire propagation model was coupled with the WU-E urban fire spread extension to compare flame length (meters) and time of arrival (hours) outputs, demonstrating changes before and after fuel treatments and building hardening scenarios. Two approaches were used: (1) a risk-based approach, and (2) a scenario-based approach, which recreates a previous wildfire.

Findings: Activities and Programs for Risk Reduction and Recovery

Participants identified **over 60 different programs and activities** (Figure 3) **that furthered risk reduction and recovery** through: a) housing recovery, b) home hardening, c) defensible space, or d) fuel treatments. Another 10 programs furthered less tangible aims such as promoting social cohesion, public education, or the formation of new entities to plan and administer these efforts.

Most programs that focused on a single intervention type were fuel treatments (n=13), followed housing recovery (n=6) and home hardening (n=5). Home hardening and defensible space were often addressed together (n=6), given their common of preventing ember entry and ignition. **Programs addressing more than two goals were rare.** Programs ranged from **hyper-local, informal collaborations at the neighborhood level** to federally- and state-funded efforts with broad goals.

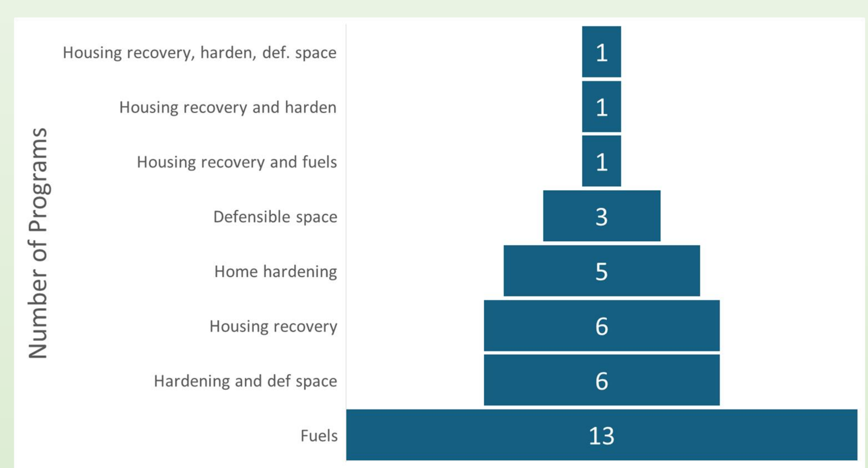


Figure 3. Numbers of program by type, Lake and Sonoma counties

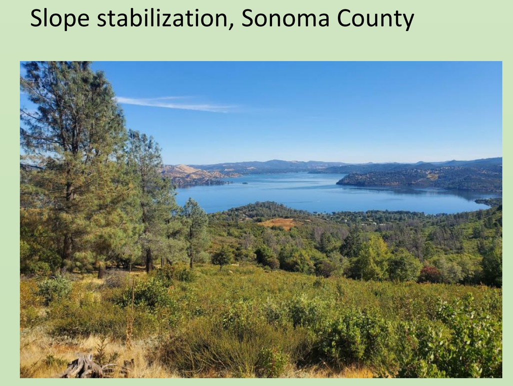
Tracking program goals and funding source over multiple levels of administration was challenging. **Larger, more comprehensive programs had much longer time frames** (five plus years), and tended to focus specifically on **unmet needs or key areas within counties** (Table 1). FEMA and HUD were key federal funders although Sonoma County had a FEMA BRIC grant that was later cancelled.

Table 1. Example programs by type, including a summary of funders and implementation partners, characteristics, and challenges.

Goals	Example – Key Program	Characteristics	Challenges
a. Housing Recovery	**CA State HCD** • Federal funding from HUD via CDBG-DR. • State runs for each county. • Both Lake and Sonoma eligible, but targets LMI /unmet need.	• State in central role. • Slow program for individual owners. • More success in multi-family housing. • Also contributes to b) and c)	• People experiencing homelessness. • Housing affordability. • Administering program by Federal Register / as feds funded it.
b. Home Hardening	**CA State California Wildfire Mitigation Program** • Joint Powers Authority (CAL OES, CAL FIRE). • Six pilot locations, state-wide. One in Lake County. • Federal funding from FEMA (HMGP) and state funding.	• One neighborhood in Lake County, selected for similar age homes and high risk. • State and local non-profit play central role in design, permitting. • Enrolling in 2025 after 2019 legislation.	• Responsibility and cost-share. • Permitting delays. • Contractor availability.
c. Defensible Space	**SoCo Adapts – Wildfire Adapted Sonoma County** • Federal funding from FEMA (HMGP) to Permit Sonoma	• 8 project areas. • Free defensible space assessment • Option to add home assessment. • Phase 2 with rebates.	• Challenging to get resident interest. • Permitting delays. • Contractor availability. • Funding timelines.
d. Fuel Treatments	**SoCo Adapts - Hazardous Fuels Reduction Project** • Federal funding from FEMA (HMGP) to Permit Sonoma	• 5 focal sites. • Private land only. • Only vegetation management, not defensible space.	• Permitting delays. • Private land coordination. • Contractor availability. • Funding timelines.

SoCo Adapts, Sonoma County

Slope stabilization, Sonoma County



Fuel treatment in Kelseyville Riviera, Lake County

https://www.ncoinc.org/about-us/news/ncos-home-hardening-initiative-holds-first-contractor-walkthrough/

Findings: Modeling Simulations

Approaches:

1. The risk-based approach explores wildfire risk over a range of potential fire scenarios using random ignition points and 'red flag day' conditions to consider how multiple mitigation strategies (i.e., home hardening and fuel treatments) influence outcomes. We employ this approach in three focal areas: Fetters Hot Springs-Agua Caliente (in Sonoma); Kelseyville Riviera and Clearlake (Lake).

2. The scenario-based approach recreates a previous wildfire using the historical ignition point and weather conditions to explore how rebuilding and mitigation strategies may influence outcomes, were the fire to happen today. Here we reburn the 2017 Tubbs Fire in Sonoma County.

Approach 1: Risk-Based Modeling, Kelseyville Riviera in Lake County

- 30-meter fuel and topography layers from LANDFIRE 2022. Fuel treatments (2018-2026) are integrated with the fuel model raster to represent post-treatment vegetation.
- Weather data (wind speed and wind direction) derived from the RTMA weather model, and we incorporated the fuel moisture content for 1-hour, 10-hours, 100-hours.
- Extracted 15 Red Flag days from FireFamilyPlus, from closest RAWS Station Data. Filter Temperature > 60°F, RH < 15%, Wind Speed > 25 mph.
- Structure data were sourced from the Microsoft (MS) Structure Footprints and National Structures Inventory datasets, encompassing a total of 4,921 structures within the area of interest (Figure 4). The simulation incorporates 23 randomly, but not uniformly, placed ignition points across the study area (Figure 4).
- ELMFIRE with WUI model, run 5,000 times each for <u>1) without fuel treatments, 2) with fuel treatments, and 3) with fuel treatments and reduced structure ignitability</u>
- Reduced structure ignition assumes 50% less ignitable, for half of all buildings within the neighborhood where home hardening pilot project is occurring.

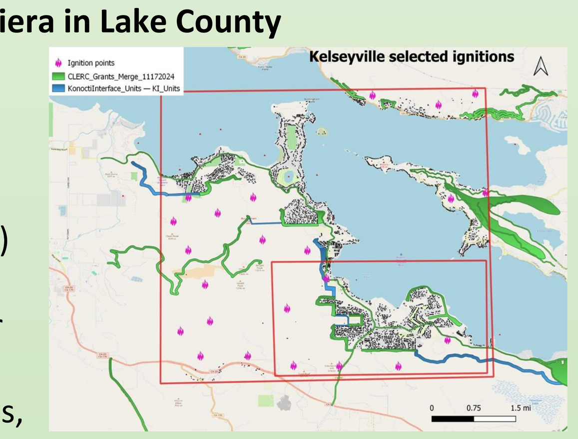


Figure 4. Kelseyville Riviera area of study, including ignitions, fuel treatments and inset box where a home hardening program is focused.

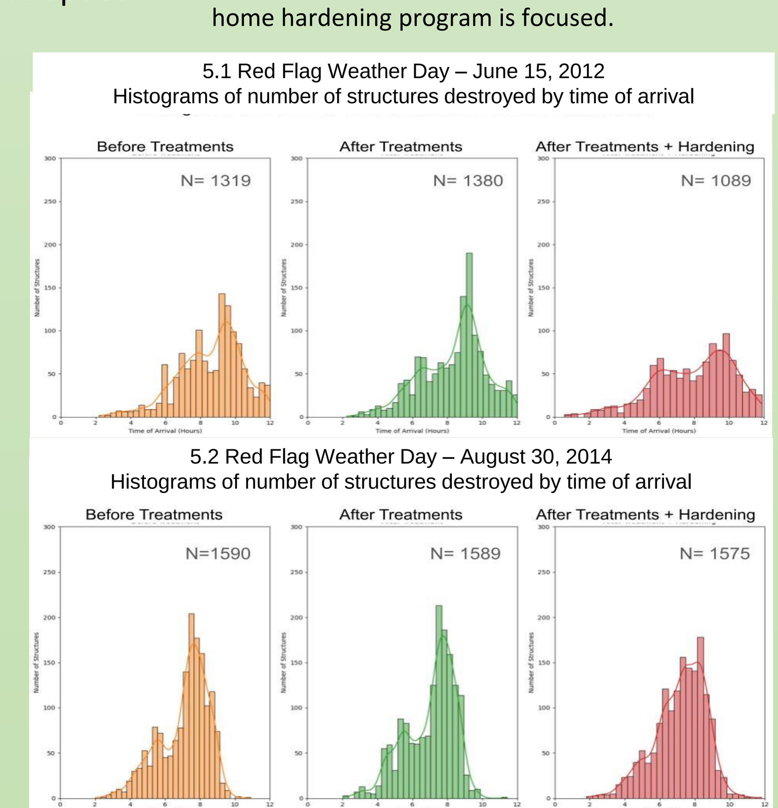


Figure 5. Time of arrival of fire and estimated number of destroyed structures (N) in Kelseyville Riviera across two different red flag days. All scenarios assume no wildfire suppression. Number of destroyed structures (out of 4,921 total structures) after fuel treatments and home hardening vary by weather conditions.

Approach 2: Scenario-Based Modeling, Tubbs Fire near Santa Rosa in Sonoma County

- This model utilizes 30-meter fuel and topography layers from LANDFIRE 2022. Vegetation inputs recreate what was present before Tubbs Fire.
- Inputs for weather data (wind speed and wind direction) and fuel moisture content for 1-hour, 10-hour, and 100-hour surface fuels are derived from weather modeling simulations using the Weather Research and Forecasting (WRF) model, downscaled and selected to recreate Tubbs Fire conditions.
- The ignition point placed near ignition that caused incident.
- The structures modeled represent current-day conditions based on MS footprints, NSI data, and the Sonoma County Building Permits Data (Rebuilding and Recovery) (n=13,329 buildings).
- ELMFIRE with WUI model, run 100 times for each: <u>1) buildings not hardened, 2) half of the buildings hardened, 3) all the buildings hardened.</u> Reduced structure ignition assumes 50% less ignitable.

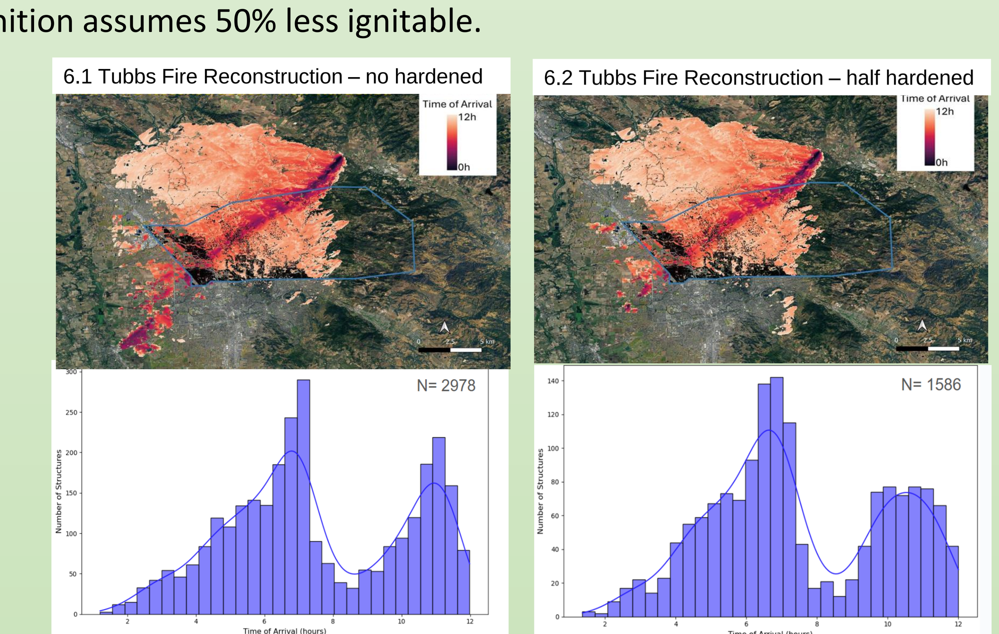


Figure 6. Time of arrival and number of destroyed structures (N) in Tubbs recreation when no buildings are hardened (6.1) and all are hardened (6.2). Assumes no suppression.

Key Findings / Next Steps:

- **Risk-based approach is dependent on red flag weather days.** Some days showed fewer buildings lost and slower time of arrival, for fuel treatments and home hardening combined, but other days showed little effects (e.g. Figure 5.1 vs 5.2).
- **Fuel treatments alone showed less effect** on buildings lost and time of arrival than fuel treatments and **home hardening** (Figure 5.1)
- For scenario-based modeling, and conditions similar to Tubbs, **hardening 50% of homes reduced potential losses reduced by ~48%** compared to no hardening (Figure 6). Not pictured, hardening 100% of the homes reduced potential losses by ~62%. Exploring current age of buildings and restricting hardening to pre 2008 (20%) reduced losses by 8%
- **Next steps:** Combine findings on program implementation and design with modeling. Synthesize recommendations for future management and research.

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