Simulation and Cost-Guided Fuel Treatment Planning for Prescribed-Fire Containment

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Background

Prescribed fire is an important tool for reducing hazardous fuels, but planning a burn near roads, buildings, or other values at risk can be difficult. Managers need to decide where to strengthen containment, how much work is needed before ignition, and how to allocate limited crews and engines. These decisions are especially challenging when terrain, fuels, and wind can create localized escape pressure along the burn boundary.

This study presents a simulation-guided planning framework that combines fire-behavior modeling with treatment cost and resource constraints. The goal is not to replace expert judgment. Instead, the framework provides a structured way to test a proposed burn scenario, identify boundary locations where fire may escape, and compare alternative treatment layouts before implementation.

MANAGEMENT IMPLICATIONS

- Use simulations to identify likely escape zones before ignition. The framework highlights boundary segments where a planned prescribed fire may be most likely to cross the control line under a specified weather and ignition scenario.
- Compare treatment types before committing resources. Fuel removal and pre-wetting can be evaluated side by side to identify where each treatment is most useful for containment.
- Make resource limits explicit. The example shows how an engine-availability constraint can change the preferred treatment mix, reducing the required engine demand from six to three while maintaining simulated containment.
- Use the tool for scenario comparison, not as a stand-alone prescription. Outputs should support discussion among burn bosses, fuels specialists, and analysts, and should be checked against local experience and field conditions.
- Prioritize validation before operational use. Model assumptions, treatment effects, cost parameters, and weather scenarios should be tested against observed burns and practitioner-developed plans.

Research Overview

The framework was demonstrated on a 14.2-ha prescribed-fire unit near Mount Laguna, California. The study used QUIC-Fire, a fast-running fire-atmosphere model, to simulate a prescribed-fire scenario using local fuels, topography, roads, building footprints, ignition lines, and fixed wind conditions. The baseline simulation showed fire crossing the planned control line, which motivated targeted containment treatments.

The analysis then used a two-stage process. In Stage 1, simulated escape points along the boundary were identified and grouped into treatment zones. Zones with higher local spread pressure were assigned to fuel removal, while lower-rate zones were assigned to moisture treatment. In Stage 2, the initial layout was refined using estimated fuel-removal costs, moisture-treatment costs, potential penalties for fire escape near infrastructure, and a limit on available fire engines.

Key Findings

- The untreated baseline scenario did not maintain containment; the simulated fire crossed the downwind control line.
- Stage 1 identified 15 treatment zones along the containment boundary: nine fuel-removal zones and six moisture-treatment zones. With these treatments applied, simulated fire spread remained within the acceptable boundary.

- Stage 2 incorporated cost and resource constraints. After cost-based reallocation, the optimized configuration used 12 fuel-removal zones and three moisture-treatment zones.
- The optimized configuration reduced estimated total implementation cost from USD 97,319 to USD 95,266, a reduction of about 2.1%, while reducing fire-engine demand from six engines to three under the tested scenario.
- The results are scenario-specific. The framework should be interpreted as a planning and comparison tool until tested against observed prescribed-fire outcomes and practitioner-developed burn plans.

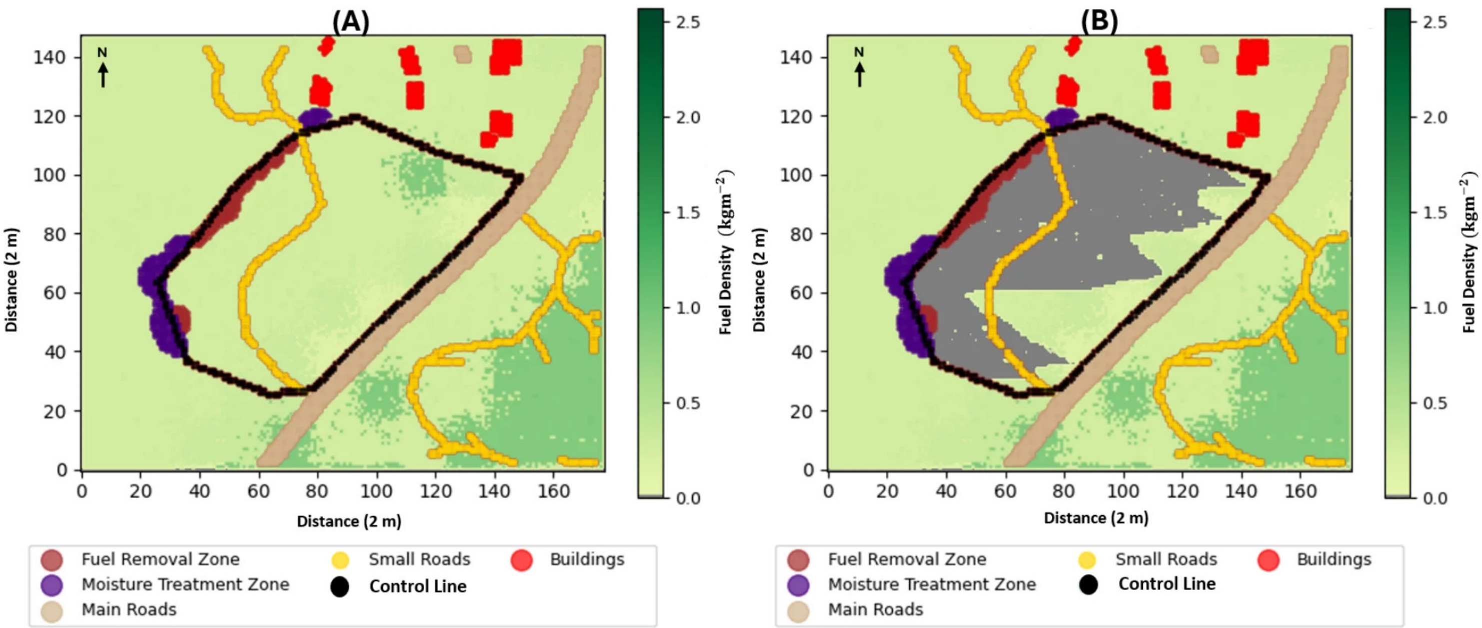

Figure 1. *Optimized treatment zoning for the Mount Laguna demonstration. Brown areas indicate fuel-removal zones and purple areas indicate moisture-treatment zones. Panel B shows the simulated burn remaining within the acceptable boundary under the optimized configuration. Adapted from Matey, de Callafon, and Altintas (2026).*

Additional Information

This brief is based on the following article:

Matey, Yeshvant, Raymond de Callafon, and Ilkay Altintas. 2026. "Simulation and Cost-Guided Fuel Treatment Planning for Prescribed-Fire Containment." Fire 9 (5): 187. https://doi.org/10.3390/fire9050187

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