Effectiveness Monitoring

Committee

CA Board of Forestry and Fire Protection

Initial Concept Proposal

Date Submitted: 05/19/2025

Project Title: Adaptive Fuel Load Monitoring Using QUIC-Fire and Satellite Indicators of Vegetation Recovery

Project # (leave blank; to be assigned by EMC):

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Project Description

Project Duration: 3 years (36 months)

Background and Justification:

In 2024, California committed $2.7 billion over five years to forest health and wildfire resilience initiatives. This investment supports mandates like Senate Bill 901 (SB 901), which prioritizes fuel reduction and resilience strategies across fire-prone landscapes. The

Effectiveness Monitoring Committee (EMC) is explicitly tasked with assessing the success of the Forest Practice Rules (FPRs), including whether current fuel treatment practices are effectively reducing wildfire hazards.

The proposed project aims to save the State of California time and money and significantly improve outcomes by aligning directly with both SB 901 and the EMC's mission through evaluating the *on-the-ground efficacy* of specific fuel treatments—such as fire use, broadcast burns, and mechanical thinning—across diverse forest types in California. Rather than assess treatments in theory, this project integrates remote sensing and fire behavior modeling to determine how post-treatment vegetation recovery trajectories influence current and future fire risk in distinct ecological zones. **By mapping and modeling actual treatment footprints and forest characteristics, the project allows decision-makers to understand when treated areas are at risk of becoming hazardous again and whether retreatment is needed**.

This has important fiscal implications. As treatment costs scale across millions of acres, avoiding redundant or unnecessary treatments becomes critical. **This project supports smart budgeting by identifying areas where vegetation has regrown to a flammable state—and equally, where vegetation is still in a low-risk condition, deferring costly re-intervention**.

The approach also improves operational efficiency. Traditional treatment monitoring relies heavily on field visits and local surveys. This project supplements those efforts using remote sensing time series (NDVI, SAR) and spatially explicit fire behavior modeling with *QUIC-Fire* —an award-winning fast-running wildfire simulation tool—stratified by forest type, seral stage, and treatment history. The result is a scalable, repeatable assessment framework that can be applied across regions and treatment types.

The outputs of this project are designed with decision-making in mind. Rather than produce a rigid, one-size-fits-all tool, the project will develop a flexible framework, specifically including interpretable maps and datasets that EMC staff and partnering agencies can consume through geospatial overlays, or direct database integration. This framework will effectively be re-useable (updatable) and supports the state's goals for science-based resource allocation and strengthens the accountability and transparency of fire resilience investments.

By connecting vegetation recovery data to simulated fire outcomes, this project gives EMC a powerful new system to assess fuel treatment effectiveness—supporting compliance with legislative mandates, reducing risk, and optimizing the use of state funds.

Objectives and Scope:

By mapping and modeling real-world treatment footprints alongside forest recovery dynamics, this project empowers decision-makers to evaluate when previously treated areas have returned to a hazardous state—and when they remain low-risk. This precision enables smarter budgeting: it highlights where retreatment is urgently needed while helping defer interventions in areas still within safe fuel thresholds, saving public resources and enhancing treatment efficiency.

The project will pursue the following goals:

- **Conduct stakeholder interviews and agency engagement** for example, with CAL FIRE, Board of Forestry and Fire Protection, USFS Region 5, CPUC Fire Threat Mapping group, and local Fire Safe Councils to:
    - Clarify region-specific threats and priorities.
    - Determine the most useful data products, maps, and formats for decision support.
- **Target example study regions** such as the Sierra Nevada foothills, North Coast forests, and portions of the Southern Cascades, selected for their combination of treatment activity, wildfire exposure, and cost sensitivity.
- **Quantify post-treatment fire risk** using *QUIC-FIRE* simulations across forest types stratified by treatment history, seral stage, and vegetation recovery rate derived from NDVI and SAR data.
- **Identify retreatment priority areas** by mapping where fuel conditions have rebounded to levels that pose fire risk and highlight where treatments remain effective.
- **Differentiate treatment effectiveness** across fuel types and methods (e.g., fire use, mechanical, broadcast burn) using historical treatment data from WFDSS and other state/federal datasets.
- **Assess risks in Wildland–Urban Interface (WUI) zones separately** to better understand fire behavior near developed areas, with the goal of protecting lives and maximizing taxpayer return on investment.

Together, these activities aim to enhance the state's ability to prioritize treatments based on science, improve landscape resilience, and align wildfire risk management with fiscal accountability.

Research Methods:

This project will integrate three core research components: the ***QUIC-FIRE*** simulation model for rapid, physics-based fire behavior forecasting; a **remote sensing and land cover classification system** using Normalized Difference Vegetation Index (NDVI), Synthetic Aperture Radar (SAR), and the National Land Cover Database (NLCD)-derived datasets to capture current fuel conditions; and a **clustering algorithm** to classify and stratify forest lands based on ecological type, development stage, and treatment history. Together, these elements form a research apparatus capable of delivering operational fire risk projections for real-world forest conditions and treatment regimes.

Key research steps include:

- **Stratification of California's fire-treated forestlands** using a clustering approach that combines:
    - NLCD land cover classifications.
    - Temporal NDVI trends (e.g., growing season length, vigor).
    - Sentinel-1 SAR for structure and its temporal trend.
    - Past fuel treatment data from the WFDSS Integrated Interagency Fuels Treatment dataset.
- **Assignment of representative forest-treatment-type combinations** for *QUIC-FIRE* simulation based on cluster outputs, ensuring accurate representativeness in modeling.
- ***QUIC-FIRE* simulation modeling** for each forest-treatment cluster to estimate fire behavior metrics (rate of spread, intensity, ember potential) under standardized weather conditions.

***QUIC-FIRE* Capabilities and Advantages**

QUIC-FIRE is a fast-running, physics-informed wildland fire simulation model that couples 3D wind field modeling (via QUIC-URB) with a cellular automata fire behavior engine. *QUIC-FIRE*:

- Represents 3D fuel structure and its effect on wind flow and fire spread.
- Simulates dynamic, complex ignition patterns commonly used in prescribed fire.

- Captures coupled fire-atmosphere feedbacks, essential for assessing real-world treatment effectiveness.
- Operates efficiently, allowing for ensemble simulations under varying conditions at a fraction of the computational cost of CFD-based models.

These attributes make *QUIC-FIRE* uniquely suited to evaluate how fuel treatments—like fire use or mechanical thinning—perform under different vegetation regrowth conditions and future fire scenarios.

Finally, the combined use of *QUIC-FIRE*, remote sensing, and stratified classification allows this project to identify high-risk retreatment zones, validate treatment effectiveness, and tailor outputs for decision-makers, fulfilling both scientific and operational goals.

QUIC-FIRE was originally developed at LANL starting in 2015 by Rodman Linn (PI) under a wildfire project led by Richard Middleton (key collaborator, CARBON SOLUTIONS CEO).

Scientific Uncertainty:

This project directly addresses multiple sources of scientific uncertainty identified in Section 3.1 of the EMC's Strategic Plan, particularly the effectiveness of treatment types across varying forest structures, seral stages, and fire regimes. It also addresses uncertainty around vegetation recovery rates and their influence on long-term fire hazard, which is currently under-monitored.

Uncertainty in remote sensing classifications, treatment records, and simulation inputs (e.g., fuel structure and weather) will be mitigated through the use of well-established datasets (e.g., WFDSS, NLCD, Sentinel-1, Sentinel-2), multi-year temporal composites, and ensemble modeling with *QUIC-FIRE* under standardized conditions. The stratification approach—using clustering to define representative forest-treatment combinations—ensures ecological and management diversity is incorporated, reducing bias from site-specific anomalies.

Geographic Application:

Geographically, the project will focus on key priority regions for fire hazard and treatment activity, including but not limited to the Sierra Nevada foothills, North Coast, and Southern Cascades. However, because the clustering and modeling framework generalizes across fuel types, development stages, and treatment methods, the findings and outputs will be **Statewide** in applicability. The analytical framework will be adaptable to any forested

region with compatible input data and can be extended to all land ownership types, including federal, state, and private lands.

By directly addressing data gaps identified in the EMC Strategic Plan and generating scalable insights, this project supports informed decision-making across California's diverse forest landscapes.

Collaborations and Project Feasibility

This project is a collaboration between CARBON SOLUTIONS and UC San Diego/Los Alamos National Laboratory (LANL), combining the UCSD/LANL world-leading fire science and modeling capabilities—specifically *QUIC-FIRE*, a model developed with California ecosystems in mind—with CARBON SOLUTIONS' strengths in remote sensing, data systems, and operational tool development. This partnership ensures both scientific rigor and practical, scalable delivery, forming a proven team positioned to generate rapid, actionable results tailored to California's forest management needs.

Dr. Brooks at CARBON SOLUTIONS will oversee data acquisition, clustering, and overall project management. Dr. Linn at UCSD/LANL will lead *QUIC-FIRE* modeling and stakeholder engagement. CARBON SOLUTIONS brings proven execution and technical expertise; since its launch in 2021, the company has been competitively selected for 104 projects as Recipient/Subrecipient with $19M funding from federal and state government (70% of the portfolio), non-profits (20%), and industry (10%). CARBON SOLUTIONS was founded by Richard Middleton by spinning-out science and technology he developed at LANL.

Critical Question Theme and Forest Practice Rules or Regulations Addressed

This project addresses:

- **Theme 6 – Wildfire Hazard**, specifically:
    - **Critical Monitoring Question (c):** *Are the FPRs and associated regulations effective in managing fuel loads, vegetation patterns and fuel breaks for fire hazard reduction?*
- **Theme 12 – Resilience to Disturbance in a Changing Climate**, specifically:
    - **Critical Monitoring Question (a):** *Are the FPRs and associated regulations effective in improving overall forest wildfire resilience and the ability of*

forests to respond to climate change (e.g., drought, bark beetle), variability, and extreme weather events?

Relevant Forest Practice Rules (FPRs):

- **14 CCR § 912.7, 932.7, 952.7** – Minimum stocking standards
- **14 CCR § 913, 933, 953** – Silvicultural objectives and regeneration methods
- **14 CCR § 917, 937, 957** – Logging slash and hazard reduction
- **14 CCR § 1038** – Exemptions for removal of dead, dying, or diseased trees
- **14 CCR § 1051** – Fuel hazard reduction
- **14 CCR § 1052** – Emergency notices for fire-damaged or hazardous trees

Project Relevance:
By evaluating post-treatment fire risk and vegetation regrowth across stratified forest types using *QUIC-FIRE* and satellite data, this project directly assesses how well the FPRs and their implementation reduce hazardous fuels and promote resilient landscape conditions over time. It will identify where treatments aligned with FPR guidance are achieving desired outcomes—and where retreatments may be needed—providing a quantitative feedback loop on the efficacy of FPR-related activities. This work will inform adaptive refinement of fuel management regulations and improve the efficiency and targeting of treatment policies across California.

Requested Funding

Total:$ 841,698.00

FY 1: $148,534.90 -- Stakeholders & Data Acquisition

FY 2, $297,069.90 -- Intensive Modeling

FY 3, $ 396,093.20 -- Refinement & Engagement

The Year 1: $148,534.90 cost estimate is based on personnel costs (salaries, fringe for two employees, 50%-time, at CARBON SOLUTIONS and one, 25%-time, at UCSD), indirect rate, and computing costs. Year 1 covers stakeholder interviews, data acquisition, fuel treatment regime classification, and stratification of forest types and Areas of Interest (AOIs) for modeling.

Year 2, $297,069.90, is based on personnel costs, indirect rate, computing costs, travel, and publication costs. Year 2 represents the intensive modling phase, involving large-scale *QUIC-FIRE* simulations across treatment regimes, preliminary analysis, and mid-project presentations to stakeholders for feedback.

Year 3, $396,093.20, is based on personnel costs (salaries, fringe), indirect rate, computing costs, travel, and publication costs. Year 3 supports refined modeling based on stakeholder input, additional scenario runs for WUI-specific and climate-sensitive treatments, and the development of tailored fire management recommendations.

Final deliverables will include presentations, written guidance, peer-reviewed publications, and direct knowledge transfer to agency partners. **The budget growth reflects the increasing demands of simulation work, iterative engagement, and dissemination**.