# Modeling and Analysis of Wildfire Behavior in New England Using FARSITE


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## Research Question

To what extent does tuning fuel model and weather inputs in FARSITE improve agreement between simulated and observed wildfire perimeters in New England? How do variations in fuels and climate conditions affect wildfire intensity across the region?

## Project Aim

The aim of this project is to develop a regionally informed evaluation of FARSITE wildfire simulations in New England by analyzing modeled fire behavior and refining model inputs through sensitivity analysis and fuel model calibration. The resulting model was then applied to assess fire behavior across varied environmental conditions, facilitating more reliable interpretation of simulated wildland fire dynamics.

## Introduction

- Wildfire risk is rising in the eastern U.S., but most fire models were built for western ecosystems (Donovan et al., 2023).
- Eastern forests have different fuels, climate patterns, and a strong spring wildfire season, requiring region-specific analysis (Price & Germino, 2022)
- Increasing fuel loads and periods of heat, dryness, and drought can create conditions for high-intensity fires even in Massachusetts (Reilly et al., 2022).

## Methodology

Modeled the **2021 East Mountain Fire (MA)** using FARSITE for validation against an observed perimeter

Used **LANDFIRE fuels and topography (30 m)** and gridded weather inputs

Initialized simulations with the **ignition point** and burn period

Conducted sensitivity tests by varying:

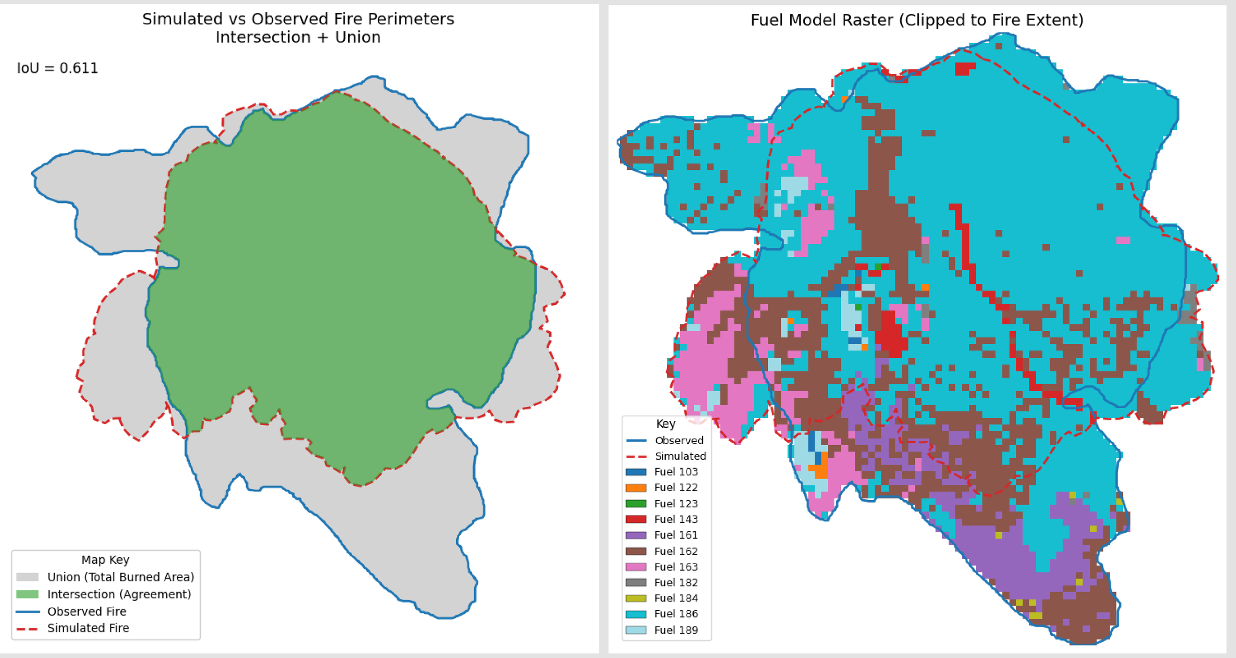
- **Wind speed (40–160%)**
- **Fuel moisture (very dry → very moist)**

Compared simulated and observed perimeters using **Intersection over Union (IoU)**

Evaluated changes in **total burned area** and **fuel-specific bias**

## IoU Calculation

$$IoU = \frac{A_{sim} \cup A_{obs}}{A_{sim} \cap A_{obs}}$$




## Model Output

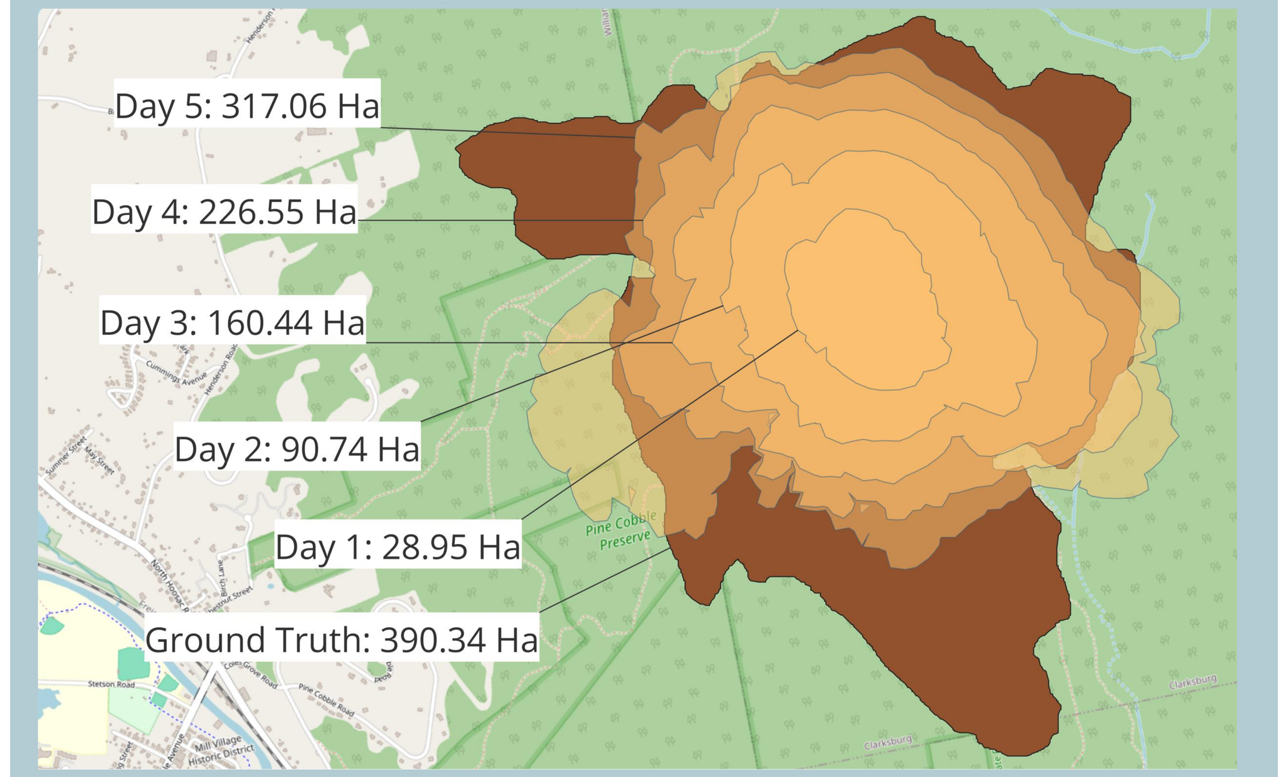



**Figure 1.** *Daily burn perimeters generated by FARSITE for the 2021 East Mountain Fire compared against the mapped ground-truth perimeter (brown).* The simulation captures the general outward expansion pattern but underestimates the total area burned and shows spatial mismatch in several directions.

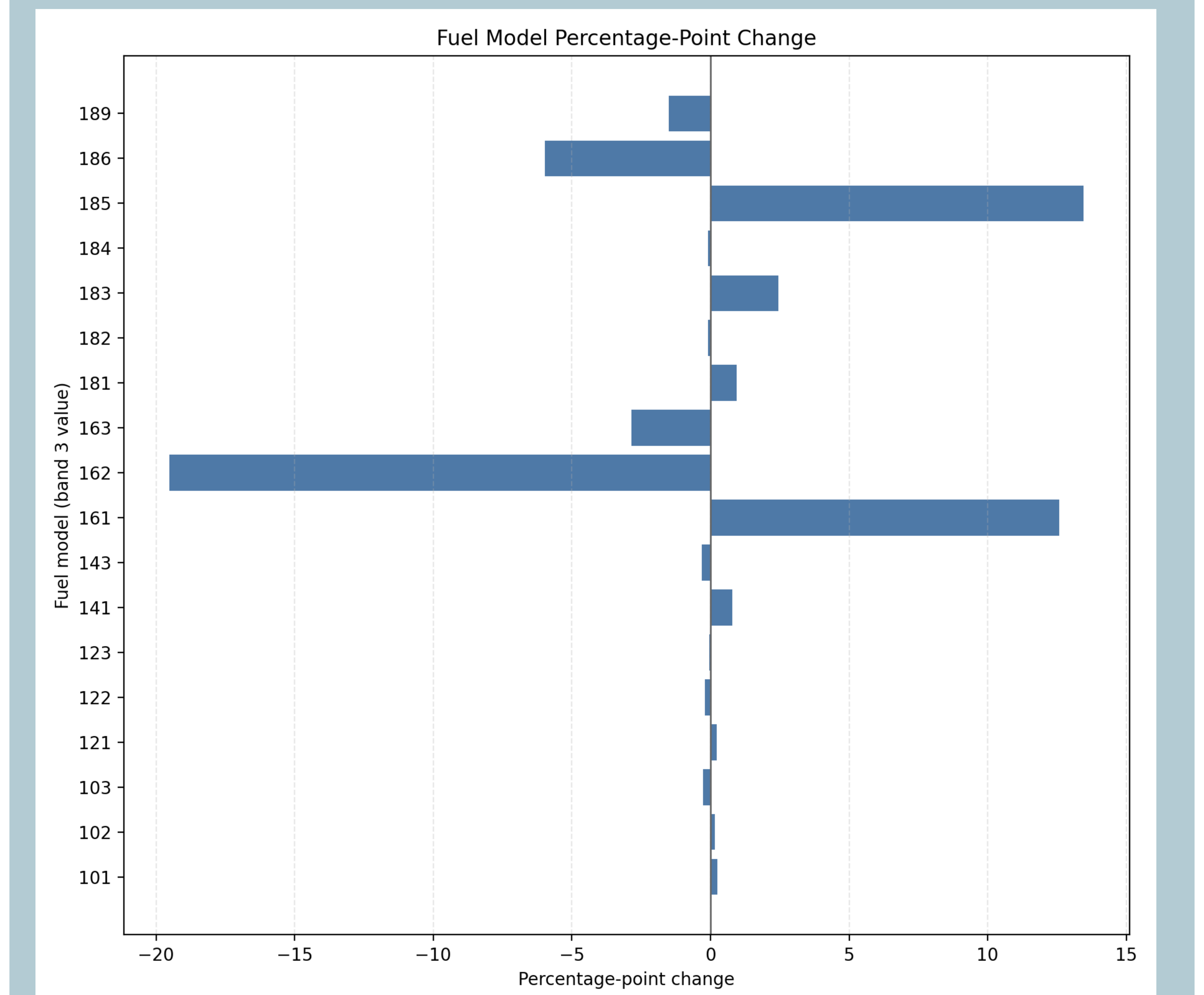



**Figure 2.** *Comparison of fuel model distributions for the same fire simulated using two temporal LANDFIRE fuel datasets (2024 vs. 2022).* The 2022 dataset contains a substantially higher proportion of shrub-influenced timber litter fuels and higher spread-potential fuels (e.g., FM 162 & 186), while the 2024 dataset shows a shift toward lower spread-potential timber litter fuels (FM 161 & 185).

## Results

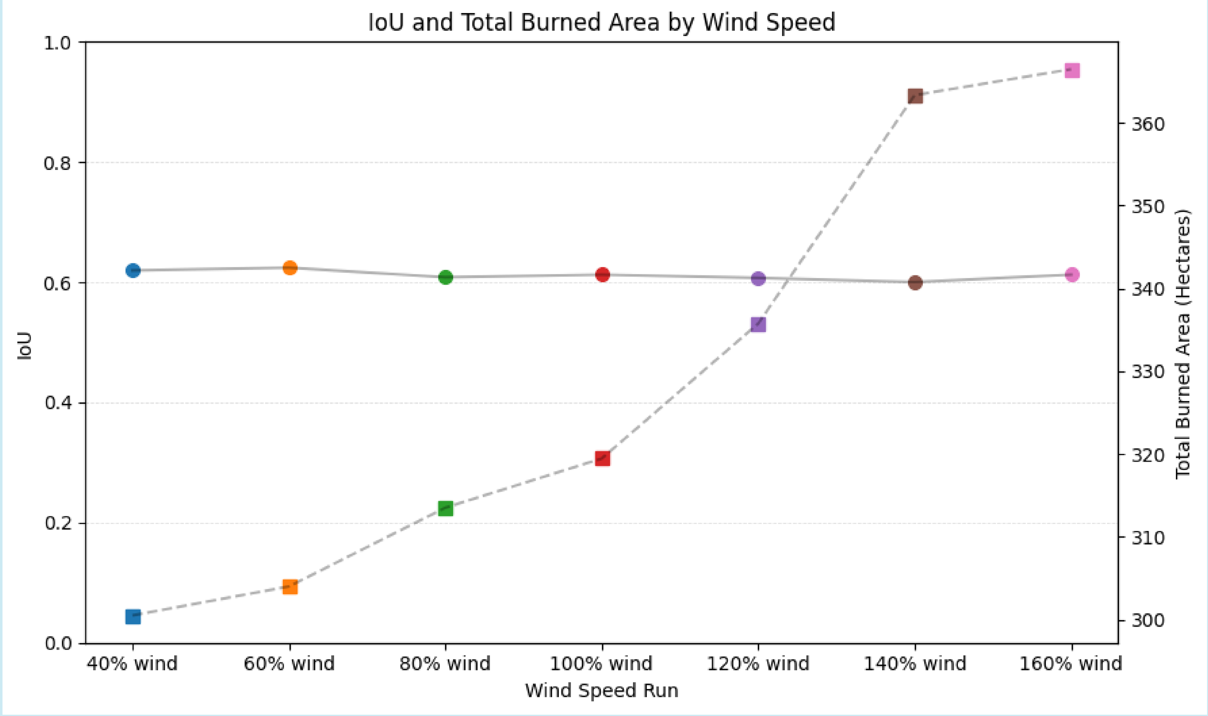



**Figure 3.** *Intersection over Union (IoU) and total burned area as a function of wind-speed scaling.* Points IoU values between simulated and observed burn perimeters for wind-speed multipliers ranging from 40% to 160% of baseline conditions, while the dashed line indicates the corresponding total burned area. Results show that increasing wind speed substantially increases predicted burn area, while IoU remains relatively stable, indicating that wind primarily affects fire extent rather than overall spatial agreement.

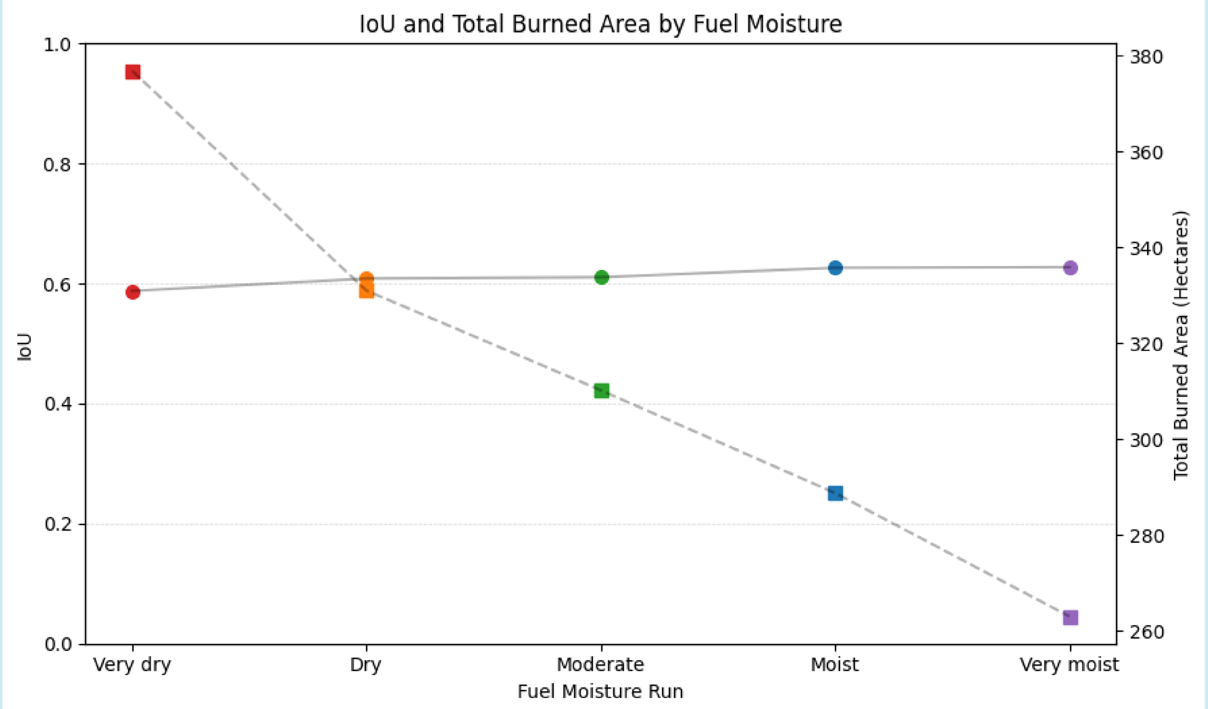



**Figure 4.** *Intersection over Union (IoU) and total burned area as a function of fuel moisture condition.* IoU values (points) and total burned area (dashed line) are shown for simulations run under very dry, dry, moderate, moist, and very moist fuel conditions. As fuel moisture increases, total burned area decreases sharply, while IoU remains comparatively consistent, suggesting that fuel moisture strongly controls fire size but has a weaker influence on spatial overlap with the observed perimeter.

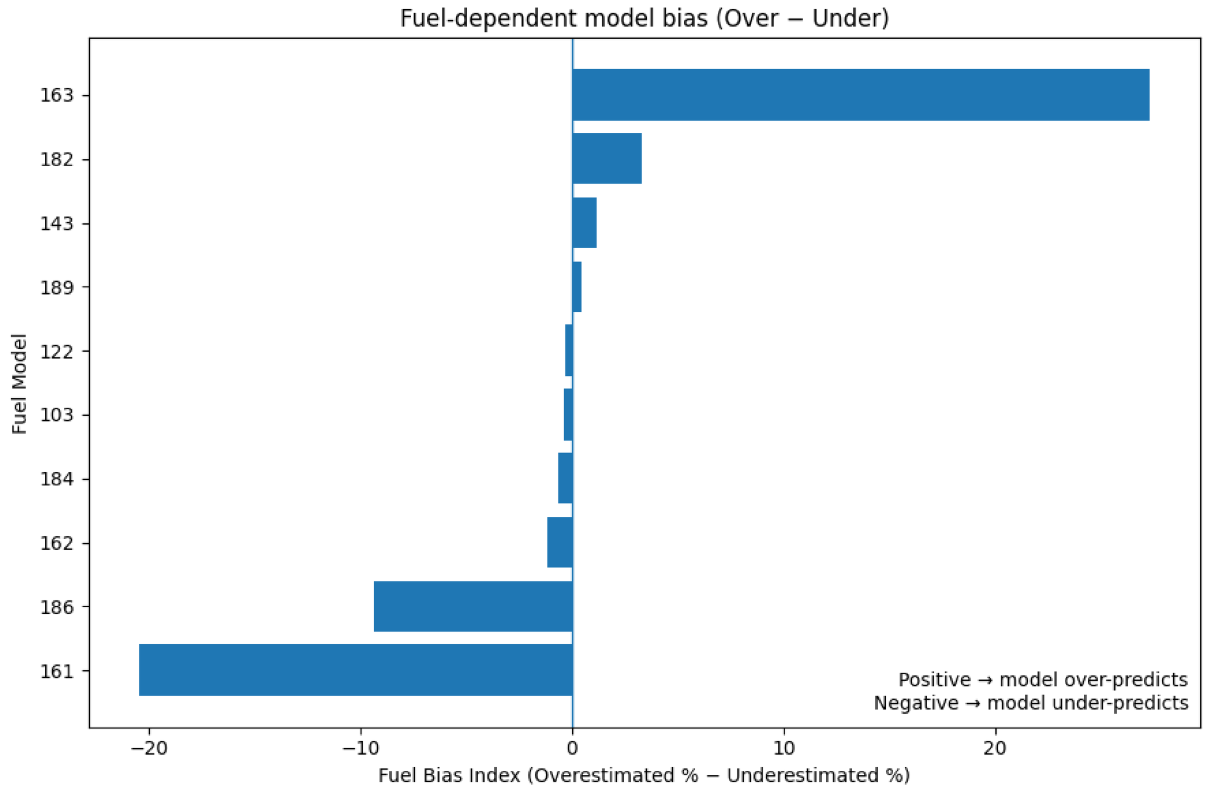



**Figure 5.** *Fuel-Model–Dependent Bias in Simulated Burned Area.* Horizontal bars show the fuel bias index for each fuel model, defined as the difference between the percentage of area overestimated and underestimated by the simulation. Positive values indicate systematic over-prediction of burned area, while negative values indicate under-prediction. Results highlight strong fuel-specific behavior, with certain shrub and timber litter models exhibiting pronounced bias compared to others clustered near zero.

## Validation Fire

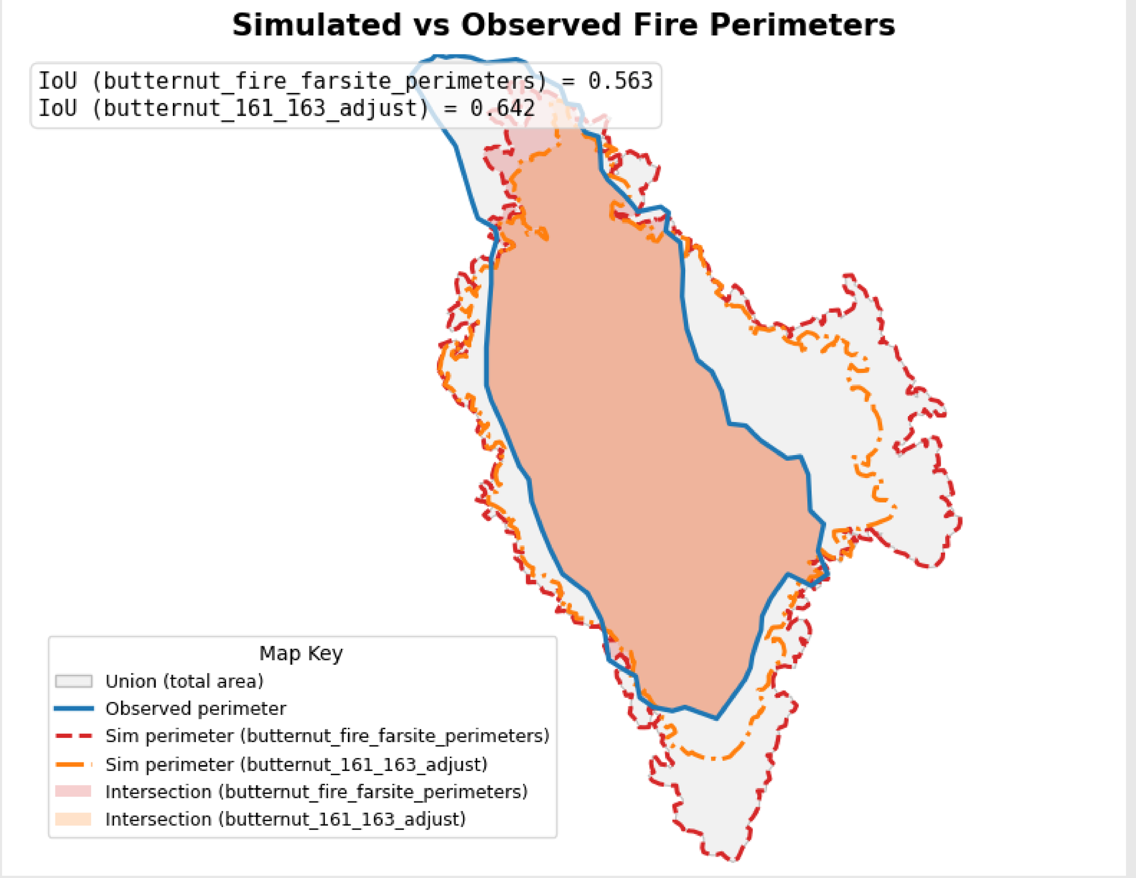



**Figure 6.** *Simulated versus observed burn perimeters for an independent test fire.* Observed fire perimeter (solid blue) is compared against two FARSITE simulations: the baseline fuel model configuration (red dashed) and an adjusted fuel model configuration incorporating modified timber litter fuels (orange dashed). Shaded regions show the spatial intersection used for Intersection over Union (IoU) calculation. The adjusted model achieves a higher IoU (0.642) than the baseline simulation (0.563), demonstrating improved spatial agreement on a fire not used during model calibration and indicating enhanced generalization of the adjusted fuel parameters.

## Conclusion

- Using FARSITE without calibration reproduced general wildfire spread patterns in New England but underestimated final burned area compared to observed perimeters (Figure 1).
- Wind speed and fuel moisture strongly influenced total burn area, yet they produced limited improvement in spatial agreement (IoU) (Figure 3 and 4).
- Model accuracy depended heavily on fuel model selection, with consistent fuel-specific over- and under-prediction (Figure 5).
- Validation on an independent fire showed that region-specific fuel adjustments improved IoU, confirming the need for eastern-focused calibration (Figure 6).

### Next Steps

- Conduct a full multi-parameter sensitivity analysis across fuels, wind, moisture, and topography.
- Calibrate fuel models using multiple New England fires to improve robustness.
- Apply machine-learning–based parameter optimization to improve spatial accuracy.
- Incorporate higher-resolution, time-varying weather and fuel inputs.