Describing Evapotranspiration Reduction Following the 2020 Creek Fire in the Southern Sierra Nevada

Carrie Hashimoto

Rice University

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Why does evapotranspiration matter?

Water resource management in the face of eco-hydrological disturbance

$$Q = P - ET - \Delta S$$

- Q Runoff
- P Precipitation
- ET Evapotranspiration
- ΔS Change in storage

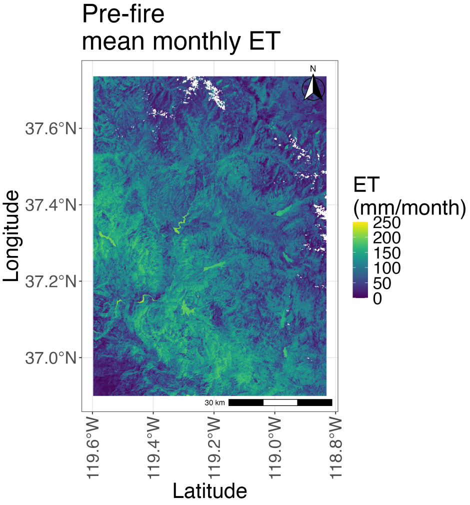


Figure 1: The pre-fire ET in the Creek Fire study area.

Wildfires and evapotranspiration

Wildfire disturbances change the water balance

The Creek Fire, 2020

- Southern Sierra Nevada
- September 4, 2020 through December 24, 2020
- 380,000 acres burned

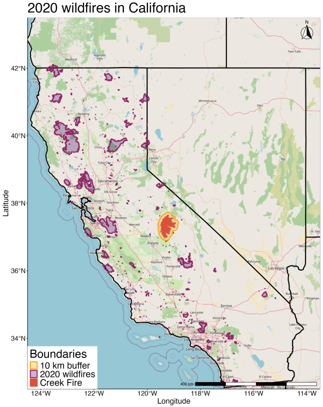


Figure 2: The 2020 wildfire season set record burn areas. (CalFire, 2024)

OpenET: High resolution modeled evapotranspiration

- 30 m resolution, aggregated from 6 models
- Primary inputs: Landsat, gridMET, Spatial CIMIS

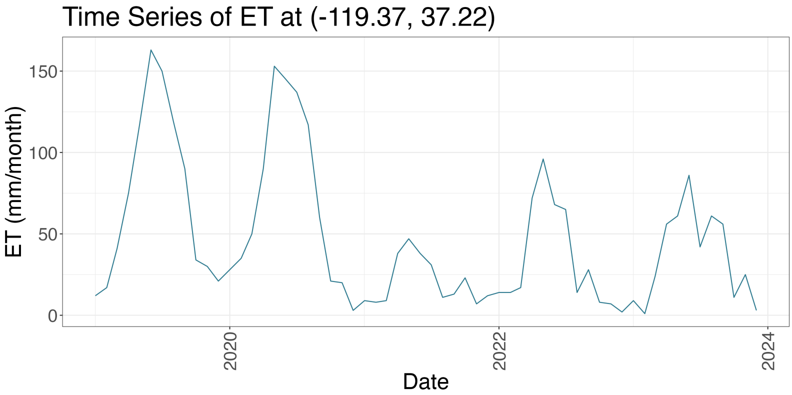


Figure 3: Monthly evapotranspiration for a point in the Creek Fire burn area (OpenET, 2024)

Other data sources

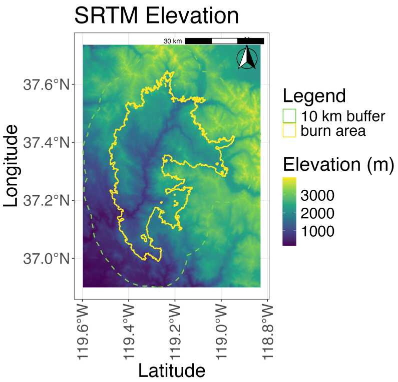


Figure 4: 30 m-res. Shuttle Radar Topography Mission data.

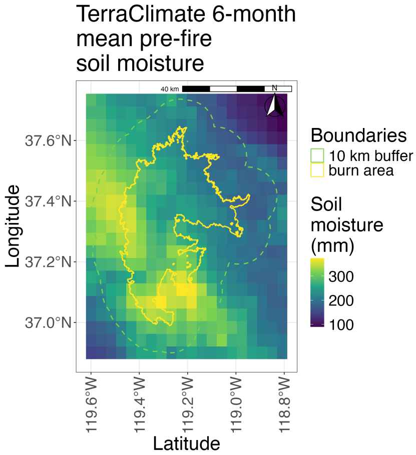


Figure 5: 4 km-res. TerraClimate soil moisture data.

Other data sources

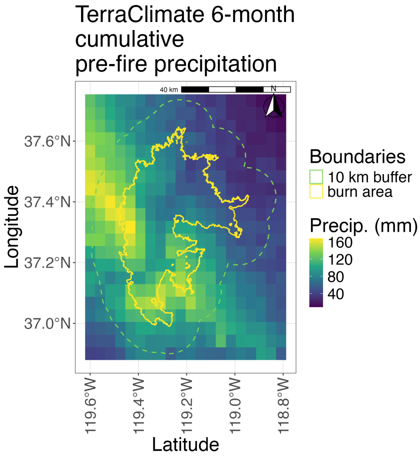


Figure 6: 4 km-res. TerraClimate precipitation data.

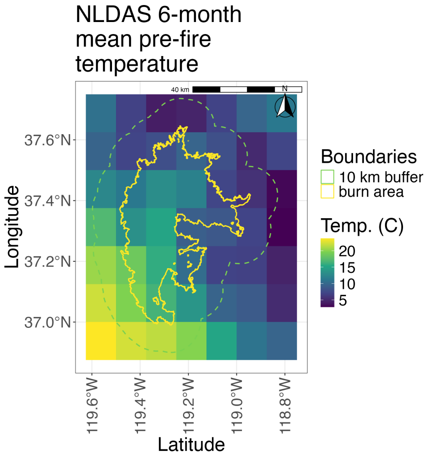


Figure 7: 12 km-res. North American Land Data Assimilation System temperature data.

Other data sources

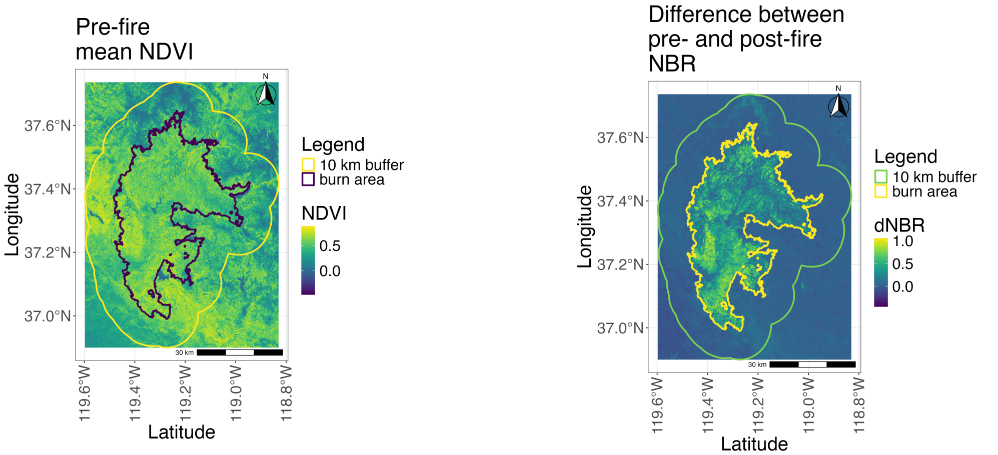


Figure 8: 30 m-res. Harmonized Landsat Sentinel-2 imagery was used to calculate vegetative health indicators.

Statistical analysis of wildfire ET change

Can statistical models use the selected environmental indicators to effectively describe the relative change in ET following the Creek Fire?

- multiple linear regression (MLR)
- generalized additive model (GAM)

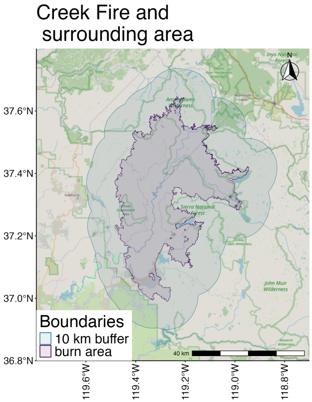


Figure 9: Map showing the affected area of the Creek Fire (CalFire, 2024)

Creek fire change in ET

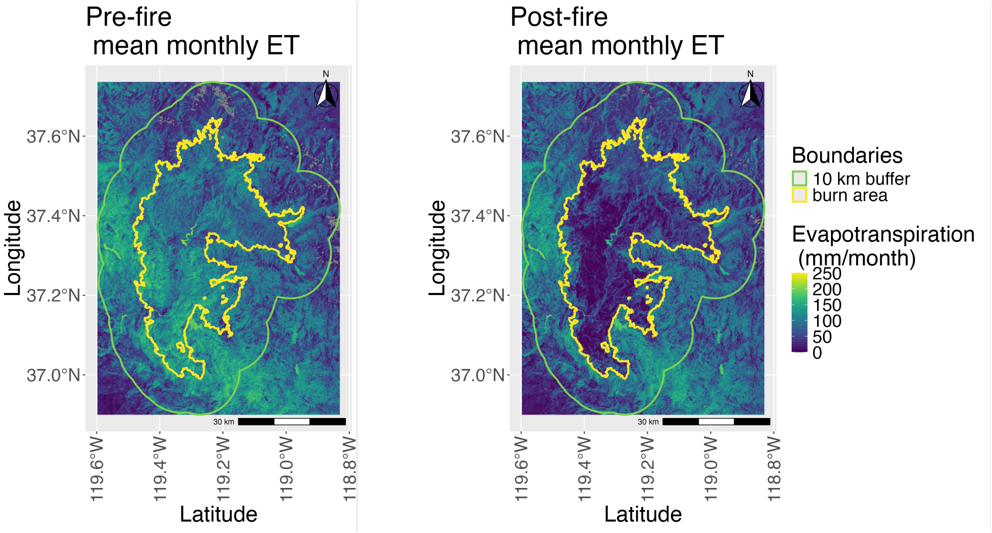


Figure 10: Pre-fire and post-fire evapotranspiration plots for the Creek Fire study area.

Exploratory data analysis

What kind of patterns are present?

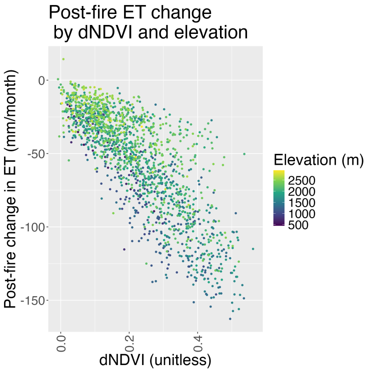


Figure 11: Difference in evapotranspiration by difference in normalized difference vegetation index and elevation.

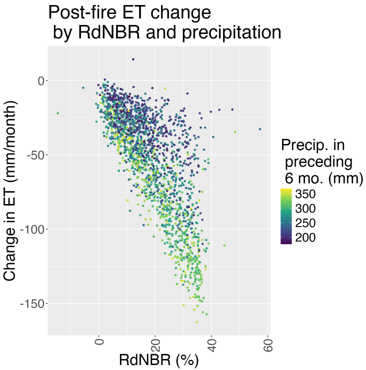


Figure 12: Difference in evapotranspiration by relative difference in normalized burn ratio and precipitation.

Multiple linear regression

- Response variable: relative difference in evapotranspiration (rET):

$$\textbf{rET} = \frac{\Delta \text{ET}_{\text{burned}} - \Delta \text{ET}_{\text{control}}}{\text{ET}_{\text{burned, pre-fire}}} \times 100\%$$

Model Performance:

- Initial MLR with 14 covariates: adjusted $R^2 = 0.576$
- Accounting for interactions improves the model: adjusted $R^2 = 0.692$
- A model with all interactions has 196 coefficients...

MLR reduced model with interactions selection

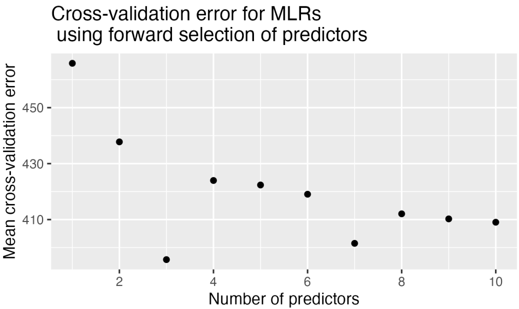


Figure 13: Average cross-validation error for reduced models chosen with forward selection.

Best subset selection for 3 predictors:

$$\begin{aligned} \text{rET} \sim \beta_0 &+ \beta_1 \cdot \text{dNBR} \\ &+ \beta_2 \cdot (\text{dNBR} \cdot \text{NDVI}) \\ &+ \beta_3 \cdot (\text{temperature} \cdot \text{elevation}) + \epsilon \end{aligned}$$

adjusted $R^2 = 0.542$

OpenET rET compared with MLR full interaction model

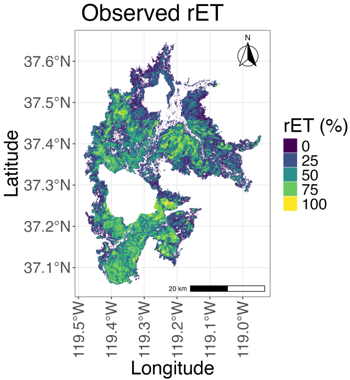


Figure 14: Response variable from OpenET data.

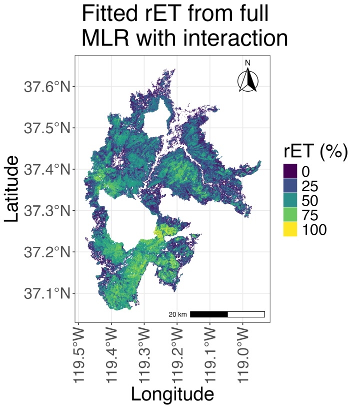


Figure 15: Fitted values from full multiple linear regression model with interactions.

GAMs - higher complexity, higher computational cost

s(dNBR)

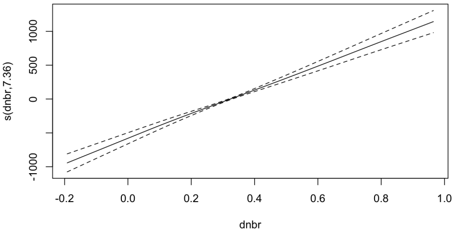


Figure 16: More "wiggliness" can fit more complex relationships, but smooths can also get penalized down to linear.

te(temperature, elevation)

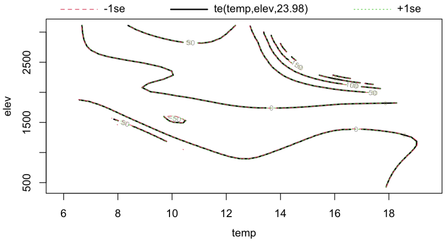


Figure 17: For temperature and elevation interaction, generalized cross-validation fitted a more complex smooth.

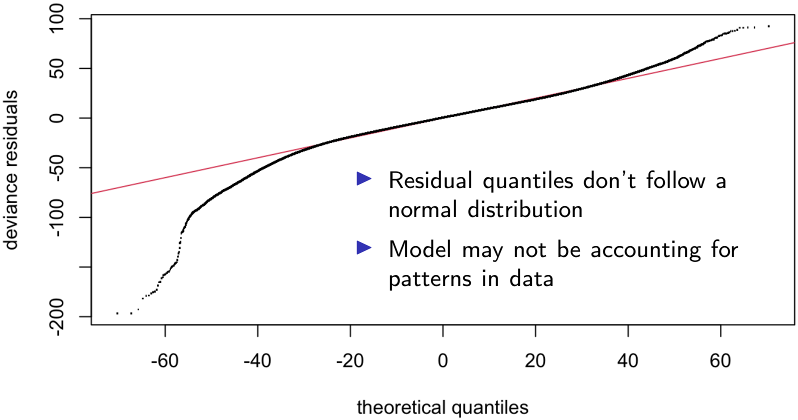
Reduced GAMs

- Initial model's adjusted $R^2 = 0.737$ is better than MLR's
- Add interactions and discard redundant predictors to refine

$$
\begin{aligned}
\text{rET} \sim\ & s_1(\text{latitude}) + s_2(\text{longitude}) \\
& + s_3(\text{NDVI}) + s_4(\text{dNBR}) + s_5(\text{temperature}) \\
& + s_6(\text{precipitation}) + s_7(\text{elevation}) \\
& + s_8(\text{northness}) + s_9(\text{soil moisture}) \\
& + te_1(\text{temperature, elevation}) \\
& + te_2(\text{dNBR, NDVI}) + \epsilon
\end{aligned}
$$

adjusted $R^2 = 0.754$

Reduced GAM performance



- Residual quantiles don't follow a normal distribution
- Model may not be accounting for patterns in data

Figure 18: Quantile-quantile plot suggests the residuals aren't normally distributed.

Response vs MLR vs GAM

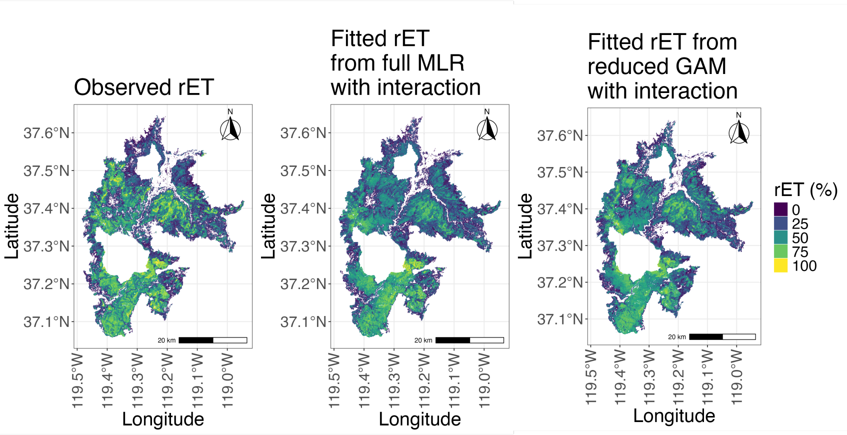


Figure 19: Comparison of observed rET and fitted values for full multiple linear regression model with interactions and reduced generalized additive model with interactions.

Conclusions: MLR vs GAMs for describing rET

- Interactions are important: dNBR and temperature, elevation
- Linear function describes dNBR-rET relationship well
- May need more model complexity to capture patterns in data variability

Table 1: Adjusted R^2 for LM and GAM Models

Model	Predictors	Adjusted R^2 (LM)	Adjusted R^2 (GAM)
Full	14	0.572	0.737
Full with interaction	196	0.692	-
Reduced with interaction	11	0.576	**0.754**
Very reduced with interaction	3	0.542	0.647

Future work - other models, other disturbances

- More predictors, higher resolution - forest structure
- Alternative models: principal component analysis
- More OpenET applications

Can we apply similar models in other watersheds to *predict* relative change in evapotranspiration after other wildfires?

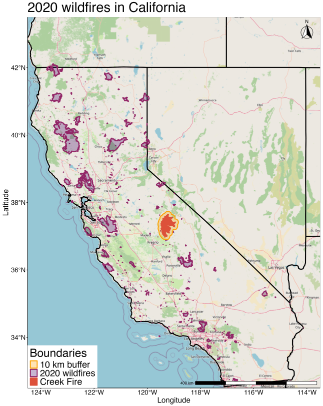


Figure 20: OpenET could be used to analyze other recent wildfires' evapotranspiration responses.

Special thanks

- **Mentorship**

  Dom Ciruzzi
  Marley Majetic

- **Support**

  NASA Early Career Research
  Jack Kaye
  Barry Lefer

- **Shoutouts**

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  OpenET team for raising my request quota

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