**Marin County Wildland Fire II**

*Improving Fire Suppression Modeling to Inform Fire Prevention and Suppression Decisions in Marin County, CA*

**Project Team**

***Project Team:***

Harrison Raine (Project Lead)

Katherine Scott

Nikitha Shivakumar

Tiffany Mar

Anai Tene

***Advisors & Mentors:***

Dr. Juan Torres-Pérez (NASA Ames Research Center)

Dr. John (Jake) Dialesandro (Santa Clara University)

Britnay Beaudry (Bay Area Environmental Research Institute, NASA Ames Research Center)

***Past or Other Contributors:***

Suhani Dalal

Chandler Ross

Gabriel Rosenstein

Katera Lee

***Fellow:***

Lisa Tanh (ARC)

***Team Contact:*** Harrison Raine, harrison\_raine@berkeley.edu

***Partner Contact:*** Dr. Joshua Dimon, [josh@firefoundry.org](mailto:josh@firefoundry.org); Graham Groneman, [ggroneman@marincounty.org](mailto:ggroneman@marincounty.org)

**Project Overview**

***Project Synopsis:***

This project assesses the environmental and social risk of wildfires in Marin County and provides three tools dedicated to pre-fire strategic planning. This includes a Suppression Difficulty Score, a Potential Operation Delineations (PODs) Network, and an Evacuation Difficulty Score. Cumulatively, these tools identify potential fire management units, characterize these units with predicted suppression difficulty, and identify communities that are likely to experience wildfire evacuation challenges.

***Abstract:***

A future of increased wildfires requires greater integration of spatial analysis and local knowledge of emergency responders. We examine the application of a Potential Operational Delineations (PODs) framework for strategic pre-fire planning in Marin County. PODs are spatial units for wildfire management that combine predictive modeling and local firefighter expertise to identify potential control locations as unit boundaries and assess the difficulty of suppression within units. Additionally, this project explores the integration of road networks and social vulnerability to assess environmental justice in evacuation safety. This project constitutes a novel application of the PODs framework as it integrates expertise from Marin County senior firefighters with a Fireline Location Model (FLM) to achieve POD definition and uses a Suppression Difficulty Score (SDS) to rank each POD. The FLM uses network analysis and hydrologic modeling to identify key roads and ridgelines as boundaries and combines them with expert knowledge, in the form of

workshops, to construct PODs. Once identified, PODs are classified using SDS, which includes processed inputs such as LiDAR-derived aboveground biomass, ECOSTRESS Evaporative Stress Index, land use cover type from Sentinel-2 Imagery, and a digital elevation model. Environmental justice for evacuation safety incorporated three key road metrics such as connectivity, travel area, and exit capacity, the Social Vulnerability Index from the Center for Disease Control, and cell coverage to determine a final Evacuation Difficulty Score. Results indicate a strong link between road networks as primary POD boundaries, with ridgelines and waterways as secondary and tertiary locations. Specifically, we find 78.5% of expertise-identified POD boundaries align with FLM-determined boundaries. More validation is needed to support this process; however, initial results signal a feasible framework to integrate expertise and spatial analysis in local level strategic fire planning.

***Key Terms:***

Wildfire modeling, Potential Operational Delineations (PODs), Suppression Difficulty, Random Forest, ECOSTRESS, Network Analysis, Evacuation, Environmental Justice

***National Application Area Addressed:*** Wildland Fires

***Study Location:*** Marin County, CA

***Study Period:*** May 2018 to August 2023

***Community Concerns:***

* The Marin County Fire Department priorities are in the order of human life, property, and environment.
* Potential wildfires pose a significant threat to human life and safety within Marin County, and climate change is likely to make wildfire suppression increasingly difficult.
* Beyond human life safety, the occurrence of extreme wildfire may compromise critical infrastructure and lead to adverse effects to open space.

***Project Objectives:***

* Identify Potential Operational Delineations (PODs) to be utilized as fire management units.
* Characterize and classify risk each unit (POD) based upon a Suppression Difficulty Score (SDS)
* Develop Environmental Justice indicators for evacuation safety for vulnerable populations.

***Previous Term(s):***

Marin County Wildland Fire Term I – 2023 (ARC) – Examining Fuel Load and Land Cover Change to Inform Fire Prevention and Suppression Decisions in Marin County, CA

**Partner Overview**

***Partner Organization(s):***

|  |  |  |
| --- | --- | --- |
| **Organization(s)** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Marin County Fire Department** | Graham Groneman, Battalion Chief | End User |
| **FIRE Foundry** | Dr. Joshua Dimon | Collaborator |

***Decision-Making Practices & Policies:***

Wildfire events are becoming more extreme, making wildfire suppression an increasingly difficult task. Marin County Fire Department requires advanced tools to support pre-disaster planning and decision-support tools for managing extreme wildfire events. When a fire occurs, they often rely on personal experience of past fires, knowledge of their local area, and influences to make rapid, informed decisions. Marin County firefighters' reference that when outside fire departments enter Marin County, they lack local knowledge and experience challenges in the transfer of critical firefighting information, as most of this information is experiential and must be communicated verbally. Marin County Fire Department currently uses GIS to map past fire perimeters and delineation of fuel breaks, however there is little to no utilization of remote sensing to assess fire risk or changing environmental conditions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Sentinel-2 MSI** | Imagery | Input to Suppression Difficulty Score as an indicator for fuel classification |
| **ISS ECOSTRESS** | Evaporative Stress Index | Input to Suppression Difficulty Score as fuel moisture indicator |
| **Aerial Survey - LiDAR** | Canopy Height, Canopy Cover, Canopy Bulk Density | Processed first return points yield canopy height and bulk density, further processing provides aboveground biomass as input to Suppression Difficulty Score. |

***Ancillary Datasets:***

* Marin County GIS Portal – Road and Trail vector data for network analysis
* U.S Department of Agriculture Risk Management Assessment – Wildfire hazard products for suppression analysis
* One Tam Digital Elevation Model (DEM) – Input for Suppression Difficulty Score and ridgeline analysis
* Center for Disease Control Social Vulnerability Index – Input for Evacuation Difficulty Score
* Federal Communications Commission Cell Coverage – Input for Evacuation Difficulty Score

***Software & Scripting:***

* **ESRI ArcGIS** **Pro** 3.1.1 - Used to create Evacuation Difficulty Score, PODs, and some map graphics. The Network Analysis Toolkit was utilized for network analysis for service area calculation. The ArcHydro Toolkit – series of tools for watershed delineation
* **Python** 3.9.1 - Used to process ECOSTRESS data and use Random Forest ML algorithm to create AGB layer. Glob2, Pandas, and RioXarray libraries were used to process ECOSTRESS data. NumPy, Matplotlib, and GDAL were employed for ECOSTRESS and aboveground biomass

***End Products:***

|  |  |  |
| --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** |
| **Suppression Difficulty Score** | Sentinel-2, ISS ECOSTRESS, LiDAR | The Suppression Difficulty Score provides continuous areal coverage of wildfire suppression difficulty county-wide |
| **Potential Operational Delineations (PODs)** | LiDAR | The PODs Network provides discrete units for fire management planning and response |
| **Evacuation Difficulty Score** | N/A | The Evacuation Difficulty Score may be used to assess challenges surrounding wildfire and environmental justice |

***Product Benefit to End User:***

This project serves to provide necessary pre-fire and decision-support data that may boost our partner’s capacity to address future wildfires. The products from this project characterize risk across our partner’s jurisdiction and offer a framework for compartmentalizing risk into management units. The last of these products offers a comparative tool to support justice-centered planning for social vulnerability during evacuations. Our workflow and tutorial allow for these tools to be updated regularly in order to account for changing risk profiles across time. These tools offer multiple utilities for our partners to plan for, mitigate, and respond to wildfires across their jurisdiction.

**References**

Brown, C.F., Brumby, S.P., Guzder-Williams, B. et al. (2022). Dynamic World, Near real-time global 10 m land use land cover mapping. Sci Data 9, 251. [doi:10.1038/s41597-022-01307-4](https://doi.org/10.1038/s41597-022-01307-4)

Caggiano, M. D, Thompson, M. P., & Gannon, B. M. (2021). Forest Roads and operational wildfire response planning. *Forests*, *12*(2), 110. <https://doi.org/10.3390/f12020110>

CalFire FRAP GIS Data. (2023). <https://frap.fire.ca.gov/mapping/gis-data/>

Calkin, D. E., Cohen, J. D., Finney, M. A., & Thompson, M. P. (2014) How risk management can prevent

future wildfire disasters in the wildland-urban interface. *Proc. Natl Acad. Sci.* 111 746–51

Cell Towers, Small Cells, Fiber | Crown Castle. (n.d.). [Www.crowncastle.com](http://www.crowncastle.com/). Retrieved June 29, 2023, from <https://www.crowncastle.com/infrastructure-solutions/?level=9>¢er=-122.40494