**Marin County Wildland Fires**

*Examining Fuel Load and Land Cover Change to Inform Fire Prevention and Suppression Decisions in Marin County, CA*

**Project Team**

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**Project Overview**

***Project Synopsis:***

This project incorporated three distinct models to predict fire severity in Marin County, California to first compare outputs and test the feasibility of using these models for future severity predictions for the Marin County Fire Department. The fire severity outputs were then inputted into a fireline model that outputs where firefighters should prioritize mobilization efforts, such as creating firelines or reducing vegetation, during an active wildfire.

***Abstract:***

Heightened occurrence of severe wildfires in the Western United States is increasing the need to better understand regions of high potential wildfire severity and develop methodologies for identifying the best locations for fuels reduction and active wildfire suppression, especially in populated regions such as Marin County, California. Marin County, located in the San Francisco Bay Area, has had significant development in the wildland-urban interface and periods of highly wildfire-prone conditions. The NASA DEVELOP team collaborated with Fire Foundry, a Marin-based fire service workforce development program, to develop models to assist with fire management. Using data from Sentinel-2A, PlanetScope, ECOSTRESS, a county-wide LiDAR mapping effort, Landsat 7 Enhanced Thematic Mapper (ETM+), and Landsat 8 Operational Land Imager (OLI), the team developed a number of input data layers to three models evaluating wildfire severity. One model performed a suitability analysis with weights based on scientific literature; another utilized machine learning based on past fires in Marin and neighboring Sonoma County to predict the difference normalized burn severity; and the third inputted data layers into the FlamMap tool that outputs risk categories. The team compared model outputs and, using the best-fit model, performed a weighted overlay analysis to identify specific locations where a fireline could be constructed to interrupt the progress of an active fire. These tools will assist partners in preparing for and managing an active wildfire situation.

***Key Terms:***

Remote sensing, Sentinel-2, machine learning, fireline, fire severity, Landsat, FlamMap

***National Application Area(s) Addressed:*** Wildland Fires

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

***Study Period:*** 2018-2022 (mid May – mid November)

***Community Concerns:***

* Marin County is concerned about the safety of people, property, and the environment,prioritized in that order according to the MCFD.
* During active fires, vital infrastructure can be damaged that can result in communities unable to evacuate to seek safety.
* Fire can be destructive to communities and reduce air quality by releasing carbon dioxide, carbon monoxide, and other particulate matter into the atmosphere, which can exacerbate respiratory illnesses for residents, as well as increase greenhouse gas emissions.
* Severe fires can reduce the water infiltration rate of soils, increasing erosion and accelerating run off.
* Fires can also destroy wildlife habitats and harm vulnerable forests that have not been fire adapted.

***Project Objectives:***

* Analyze fuel load and density with vegetation indices and canopy cover data.
* Produce land cover maps that identify the topography and land cover types across the study area.
* Assess areas of interest for fire suppression activity based on the team’s fire severity model outputs.

**Partner Overview**

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

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Marin County Fire Department** | Graham Groneman, Fire Battalion Chief | End User |
| **FIRE Foundry** | Josh Dimon, Professional Development Coordinator | Collaborator |

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

When a wildfire breaks out in Marin County, the wildland firefighters rely primarily on firelines that fully remove a corridor of vegetation to create a buffer without fuel that will hopefully prevent the fire from spreading further. Depending on the fire severity, location, and vegetation of the desired fuel line, firefighters will cut lines with hand tools or a bulldozer. An ideal fireline is on a relatively flat slope as it is difficult to work on steep ground. Ridges or spurs, especially when covered in grass instead of trees or brush, make safe fireline locations. The top priority for the Marin County Fire Department is to protect people and property. Firefighters may let a wildfire burn in natural areas, especially if the fire is lower severity. Decisions about where to place a fireline happen in real time using a series of hardcopy and digital maps that incorporate fuels, weather, fire spread, and property data. However, this data is not updated in real time and does not reflect the complex and dynamic conditions of wildfire spread on the ground, especially since the most dangerous wildfires can only occur in Marin under circumstances of extreme wind and heat.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 7 ETM+ & 8 OLI** | Reflectance data for bands SR\_B1 to SR\_B7; dNBR | 7 band imagery was used as an input for the machine learning model and dNBR was computed on the Landsat imagery for the model to train on.  |
| **Sentinel-2A** | Reflectance data for bands B4, and B8; dNDVI  | NIR and red bands were used to calculate dNDVI for suitability model, which was used to determine the differences in vegetation moisture between fire season and non-fire season. Classified landcover types relevant to wildfire severity modeling. |
| **LiDAR Aerial Survey** | Digital Elevation Model (DEM) | Elevation, slope, and aspect metrics were used as inputs for fire severity and fireline location models. |
| **ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)** | Evaporative Stress Index (ESI) and Water Use Efficiency (WUE) | Evaporative stress index and water use efficiency data were input as the moisture parameter for the fire severity models. |
| **PlanetScope Constellation** | RGB imagery | RGB imagery was utilized as a base map for Marin County and to identify roads, trails, and grass for the fireline model.  |

***Ancillary Datasets:***

* LANDFIRE – Canopy base height, canopy cover, canopy bulk density, canopy height (LANDFIRE, 2022)
* Marin County LiDAR data – Raw ladder fuels (Marin County Vegetation and Land Cover Data, 2019)
* Marin Geohub – Roads, bikeways, and water body shapefiles (Marin Geohub, 2021)
* Monitoring Trends in Burn Severity – Woodward fire perimeter and severity (MTBS, 2022)
* U.S. Census Bureau TIGER/Line Shapefiles – Study area boundary
* CA State Park shapefiles – hiking trail locations
* National Park Service shapefiles – hiking trail locations

***Modeling:***

* FlamMap 6.2 *(Contact: Charles McHugh, Mark Finney, U.S. Forest Service, Rocky Mountain Research Station, Fire, Fuel, and Smoke Science Program, and Stu Brittan; Alturas Solutions; Missoula, Montana) -* Flame length values for the landscape during a hypothetical fire

***Software & Scripting:***

* ESRI ArcGIS Pro 2.9.3 – Used to create suitability model and all map graphics.
* Google Earth Engine - Obtain land cover classification and calculate NDVI.
* Python 3.9.1 – Process ECOSTRESS data and script machine learning model.

***End Product(s):***

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| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Fire Severity Suitability Model** | ECOSTRESS, Sentinel 2, Landsat 7 ETM+, Landsat 8 OLI , LiDAR | Highlight zones of potential high fire severity to inform fire suppression planning.  | II |
| **Fire Severity FlamMap Model** | Landsat 7 ETM+, Landsat 8 OLI  | Highlight zones of potential high fire severity to inform fire suppression planning. | N/A |
| **Fire Severity Machine Learning Model** | ECOSTRESS, Landsat 8 OLI | Highlight zones of potential high fire severity to inform fire suppression planning. | N/A |
| **Fireline Model** | ECOSTRESS, Sentinel-2, Landsat 7 ETM+, Landsat 8 OLI, LiDAR | Recommends zones with low slope angle and fire severity for construction of firelines to impede wildfire progress. | N/A |

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

The fire severity models, specifically the tutorials for the Suitability Model and FlamMap model, will benefit Marin County Fire Department and FIRE Foundry as they will be able to observe fire severity with real-time data as a metric of where to prioritize fire suppression techniques. The tutorial will allow partners to understand how the models were conceived and adjust input variables and input weights for future modeling, based on their knowledge of Marin County fires. The fireline model will improve mobilization efforts during active fires, as firefighters can utilize knowledge of fire severity when considering where to incorporate a fireline or reduce vegetation.

***Project Continuation Plan:***

The three fire severity models from this project will be updated in the next term to include human elements such as proximity to infrastructure, population density, and areas with poor egress points. Along with the updated fire severity model, there should be an update to the fireline model with more refined slopes for dozers. This term likely underestimated where dozers and hand crews can operate.

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