**NASA DEVELOP National Program**

****NASA Ames Research Center

*Summer 2017*

**Short Title: Lassen Volcanic National Park Disasters**

**Subtitle:** Understanding Fuel Loading in Lassen Volcanic National Park Through Earth Observation to Manage Wildland Fire Risk

**VPS Title:** Tree Health Time Machine

**Project Team**

**Project Team:**

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**Past or Other Contributors:**

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**Project Overview**

**80-100 Word Objectives Overview:**

This study analyzed a 30-year time series of multispectral data to predict historical tree mortality (using Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI) and modeled present day fuel loads (using Sentinel-2). Our team explored the benefits of LiDAR data as an alternative tool to measure fuel loads. We also examined ecological and environmental predictors for modelling post-fire vegetative succession and fuel bed development, centering on a case study of the 2012 Reading Fire.

**Abstract:**

Nearly three quarters of Lassen Volcanic National Park (LVNP) is designated as Wilderness under the Wilderness Act of 1964, meaning it is to be managed “to preserve its natural conditions… with the imprint of man’s work substantially unnoticeable.” This prevents land managers from clearing excess vegetative fuels that have accumulated due to fire suppression policy. Therefore, LVNP must rely on fire to restore healthy levels of vegetation. Devastation following the 2012 Reading Fire demonstrated the strength of accumulated fuel loads. Detailed cataloguing of fuel loads is necessary to predict the behavior and severity of any fire allowed to burn in LVNP. To provide these estimates, NASA Earth observations were used to generate maps of historical and present-day tree mortality, and to evaluate advantages in using LiDAR data to obtain detailed fuel load measurements. We estimated tree mortality using a linear trend regression analysis implemented in Google Earth Engine (GEE), to process time series of multispectral data from Sentinel-2 and the Landsat series (TM, ETM+, OLI). LiDAR data were related to spatial layers of species coverage and other environmental factors to estimate fuel loads. These products will help partners at LVNP to periodically update their mortality maps and fuel loading estimates in their ongoing efforts to maintain a healthy and safe Wilderness.

**Keywords:**

Fuel load, forest management, tree mortality, LiDAR, wildland fire, Landsat, Sentinel-2, Lassen Volcanic National Park

**Partner Organizations:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| National Park Service,  Lassen Volcanic National Park | Steve Buckley, Ecologist  Elizabeth Hale, GIS Specialist | End User | No |

**Community Concerns:**

LVNP is host to numerous vegetation communities but is dominated by coniferous forests. These communities have changed dramatically in the past 100 years driven largely by fire suppression policies and most recently by drought trends exacerbated by climate change that have increased large tree mortality throughout the park. As a result there is significant fuel loading in the forests, leading to a reticence on the part of park managers to allow fire to burn in the park when naturally ignited. LVNP is currently in the midst of a wilderness stewardship planning process for the nearly 80,000 acres of designated Wilderness. Because of the parks’ Wilderness designation, managers are unable to mechanically thin in these areas to reduce fuel loads. The limitations imposed by not being able to mechanically thin leaves the management of fire as the most important tool to reduce fuel load.

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

There is a large body of wildland fire research and tools developed to assist land managers with decision making for wildland fire (LANDFIRE, FlamMap, Wildland Fire Decision Support System [WFDSS]). NASA Earth Observations have not previously been utilized to enhance the study of fuel loads in Lassen. Currently, all naturally occurring wildfires are evaluated for their potential to accomplish resource objective through the Wildland Fire Decision Report process. Preference is given for natural ignition to be managed in meeting the role of fire as an ecological process when under favorable environmental and spatial conditions. Current and expected fire behavior and fire weather are among the main factors that influence a fire manager’s decision on the appropriate response to each new ignition. Fuel loading arrangement, availability and moisture also impact a fire manager’s decision to suppress or manage a fire for resource benefit. Specific community concerns include historical and cultural resources scattered throughout the areas of potential impact, as well as high use visitation areas. Rare species factor into decision making only peripherally and concern is limited to only a few areas of the park. The reintroduction of moderate and low severity fire improves ecosystem function and conditions for most rare species.

**Decision Support Tools & Benefits:**

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| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software**  **Release** |
| Historic Forest Health and Tree Mortality (model and methods) | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI | This product will be a historical catalog of tree mortality so park managers can evaluate forest health based on if the health of a pixel has increased, decreased, or remained stable. The implementation of this time series in Google Earth Engine will allow managers to periodically reproduce this product to understand changes in fuel loading and forest structure. They will implement these methods every 3 to 5 years, or as needed under drought conditions. This also provides managers a way to assess resistance and resilience at the landscape or patch level. | III |
| Present Day Tree Mortality | Sentinel-2 (ESA), Landsat 8 OLI | This will assist in the classification of fuel loading across the park. It will aid park officials in planning for careful introduction of fire in Wilderness areas and give them a detailed understand of total biomass (tons per acre). This product will also be combined with LiDAR data. (see LiDAR Case Study End Product) | I |
| LiDAR Case Study | G-LiHT, Sentinel-2, Landsat 8 OLI | Combining LiDAR near the park with the present-day tree mortality product park managers will be able to gain a better understanding of what the vegetation structure is from the understory to the tree tops. This case study demonstrates the benefits of flying LiDAR for the entire park. | I |

**Project Benefit to End User**:

This project is focused on pre-fire analysis and planning in LVNP and will benefit park managers by providing updated information derived from remotely sensed imagery along with tools and methods to repeat models for decision making in successive years. The products created will help assess fuel load risks related to increasing tree mortality and vegetative overgrowth. This will give park managers with a better understanding of overall canopy density so they can work to determine potential fire behavior and add to their pre-fire predictions of severity and effects of a fire, and will also aid in planning for prescribed-burns and managing naturally occurring fires for beneficial purposes. Additionally, a major benefit to the end users will be an online tool that will allow park staff to continue generating these products annually, so current conditions are known.

**Project Details**

**Applied Sciences National Application Addressed:** Disasters

**Study Area:** Lassen Volcanic National Park, CA

**Study Period:** 1984 – 2017 (May – July)

**Earth Observations & Parameters:**

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| Landsat 8 OLI | Spectral vegetation indices, historical vegetation analysis | Spectral vegetation indices will be derived to identify vegetation health, which will inform historical map of tree mortality for the period 2013-2016. |
| Landsat 7 ETM+ | Spectral vegetation indices, historical vegetation analysis | Spectral vegetation indices will be derived to identify vegetation health, which will inform historical map of tree mortality for the year 2012 |
| Landsat 5 TM | Spectral vegetation indices, historical vegetation analysis | Spectral vegetation indices will be derived to identify vegetation health, which will inform historical map of tree mortality for the period 1984-2012. |
| G-LiHT | Present day understory vegetation density | LiDAR will be combined with Sentinel-2’s present day forest density landscape analysis to gain a more robust understand of overall vegetation density in applicable areas. This will serve as a demonstration of the utility of LiDAR for LVNP. |
| Sentinel-2 MSI | Spectral vegetation indices, Present day vegetation analysis | This will be used for the present-day fuel loading classification due to its higher 20m spatial resolution. |
| SRTM | DEM | Derive 30m digital elevation model to be incorporated into the Classification Tree Analysis. |

**Ancillary Datasets Utilized:**

* LVNP Vegetation Database – park vegetation database to help classify vegetation points and compare Classification Tree Analysis (CTA) results
* LVNP Fire polygons – polygons detailing fire history extents
* USGS National Elevation Dataset (NED) – 10 meter DEM to be incorporated into CTA
* Region 5 2002 and 2009 Strata Raster: Timber Volume, Value, & Live Tree Biomass – bring into forest health analysis for Landsat historical analysis
* NASA Goddard’s LiDAR, Hyperspectral and Thermal (G-LiGHT) Airborne Imager – LiDAR publicly available adjacent to LVNP
* Landscape Fire and Resource Management Planning Tools (LANDFIRE) – canopy cover and canopy height models for LiDAR comparison

**Models Utilized:**

* Simple Analysis of Vegetative Trends in Earth Engine (SAVeTrEE) – A linear trend time series analysis, similar to (Röder, Udelhoven, Hill, del Barrio, & Tsiourlis, 2008), implemented within Google Earth Engine by the DEVELOP LVNP Team.

**Software Utilized:**

* Google Earth Engine API – analyze the historical time series using Landsat and Sentinel-2 to look at tree mortality throughout the park.
* Esri ArcGIS – raster and vector manipulation and analysis, map creation
* ENVI – raster manipulation
* FUSION – LiDAR processing and analysis

**Project Handoff Package**

**Transition Plan:**

A formal end user handoff will take place at the end of the research term in the form of a WebEx teleconference. Results will be sent via NASA’s Large File Transfer (LFT). This project will have a software release. If the Software Release process has not completed by the time of this handoff, a future code handoff will be scheduled after the code has been released.

*Software Release Plan*:

The script (SAVeTrEE) to be provided to the partner will run in Google Earth Engine, which contains all necessary data and routines for running the script and generating outputs. The code is thoroughly commented to explain all components and the workflow to the partners. Partners have already been informed that a Google account is a requirement for using Google Earth Engine. The script will be used internally to generate the specific requested historical and present-day mortality maps, and is only planned for use by the partners at 3-5 year intervals, so some delay to software release will not impact handoff. As the script is self-contained, no additional support or materials are necessary to accommodate the delayed handoff.

*Project Continuation Plan*:

There will be a second term to this project, which will utilize methods and products developed in the first term to refine results and further inform the partners as to fuel conditions within the park.

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**Handoff Package:**

* Maps of historical tree mortality for 1984 - present, on a partner-defined interval
* Map of present day tree mortality
* Results of LiDAR case study
* SAVeTrEE script (pending Software Release)
* PDF code support documentation (pending Software Release)
* Technical Report
* Project Video