Exploring Forest Drought Mortality by Overstory Tree

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Introduction

California experienced a record setting warm drought from 2012 until 2017. In the forested Sierra Nevada, an estimated **one hundred million trees** (United States Forest Service, Region 5, 2017) perished due to drought stress and subsequent pest and disease outbreaks.

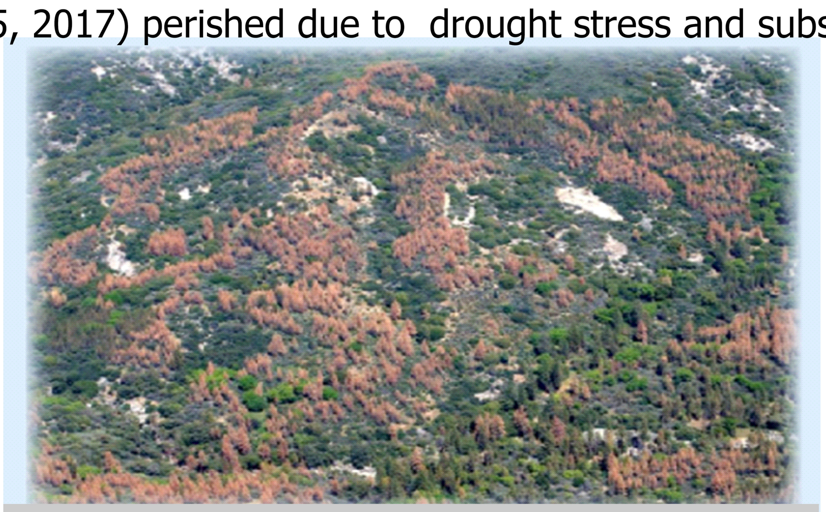


Figure 1: Drought Mortality, Sierra National Forest. Credit: USFS, Region 5

The purpose of this study is to evaluate the efficacy of mortality detection methods for overstory trees segmented by airborne lidar using orthoimagery, hyperspectral and lidar intensity data collected by the NEON program in 2017 and 2018 in the southern Sierra Nevada, California at the cessation of the drought. This analysis provides the foundation for our future research to develop mortality detection models that integrate spaceborne acquired data from systems including but not limited to LANDSAT and GEDI.

Methods

STUDY AREA and DATA: The study area is a 1,000 hectare area of the NEON Program's Teakettle airborne collection site in the Dinkey watershed in the Sierra National Forest. The site is a mixed conifer forest location from 1,800 to 2,300m in elevation (Figure 1). This study leverages the application of lidar (4-6 pulses/m2), orthoimagery (1m resolution), and hyperspectral data (1m resolution) collected in June of 2017 and 2018 for mortality detection.

FIRST: airborne lidar data were segmented into tree approximate objects (Jeronimo et al., 2018) using Fusion software (Mcgaughey 2018) and were used to estimate height, area, and biomass. Tree approximate objects (TAOs) are lidar derived features representing overstory trees and affiliated subordinate trees (Figure 3).

Figure 2: Map of the Study Area

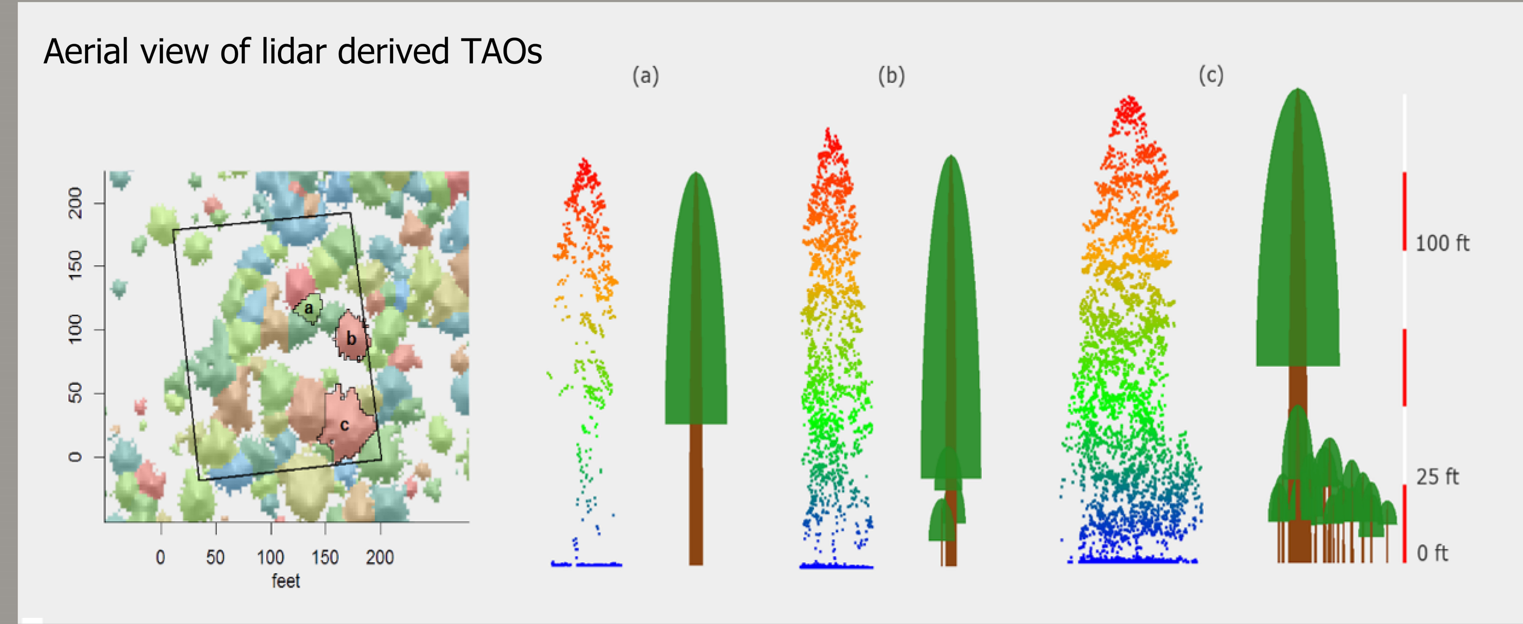
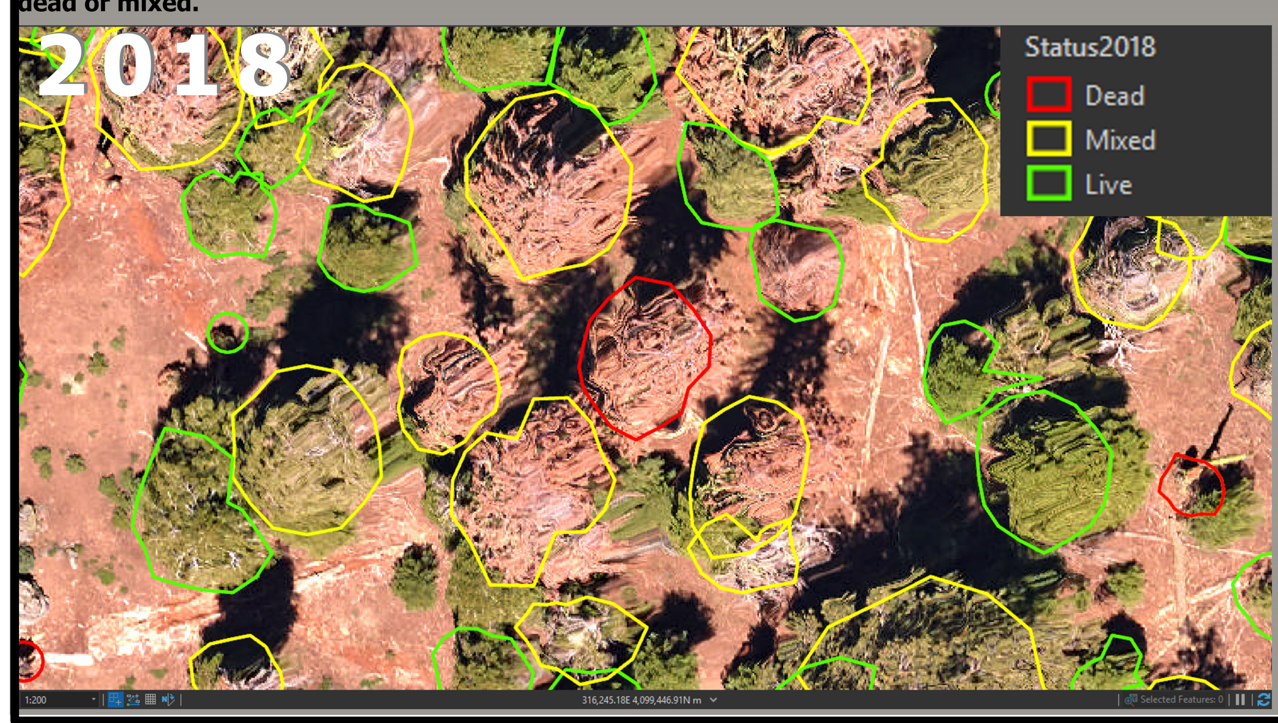


Figure 3: Tree approximate objects (TAOs): a) single overstory tree; b) overstory tree with a few subordinate trees; c) an overstory tree with many subordinate trees in the understory. Credit: Jeronimo et al. (2018)

Figure 4 (Above): Example of TAOs manually classified with 2017 orthoimagery as live, dead or mixed mortality status. Figure 5(Below): Identical TAOs manually classified with 2018 orthoimagery as live dead or mixed.



SECOND: Randomly select TAOS and manually classify the 2,728 lidar derived TAOs by mortality status at a 1:200 scale as well as identify non-tree objects for 2017 and repeating steps for 2018 orthoimagery.

THIRD: Quality control the TAO data by removing 281 TAOs obscured by full shading and non-tree objects.

FOURTH: Prepare NEON produced hyperspectrally derived vegetation and moisture indices for analysis.

Analysis

Following the mortality status classification of TAOS for 2017 and 2018, classification and regression trees were computed to determine the most parsimonious fit of mortality detection by hyperspectral indices and total lidar intensity. The following hyperspectral indices were evaluated:

1. Atmospherically resistant Vegetation Index (ARVI)
2. Enhanced Vegetation Index (EVI)
3. Normalized Difference Lignin Index (NDLI)
4. Normalized Difference Nitrogen Index (NDNI)
5. Normalized Difference Vegetation Index (NDVI)
6. Soil-adjusted Vegetation Index (SAVI)
7. Moisture Stress Index (MSI)
8. Normalized Difference Infrared Index (NDII)
9. Normalized Difference Water Index (NDWI)
10. Normalized Multi-band Drought Index (NMDI)

Results

For 2017, a mean NDVI value of 0.44 was the most parsimonious indicator of live vs. dead TAOs with an error of 0.14. And, for 2018, a mean NDVI value of 0.42 was the most parsimonious indicator with an error of 0.3

2017

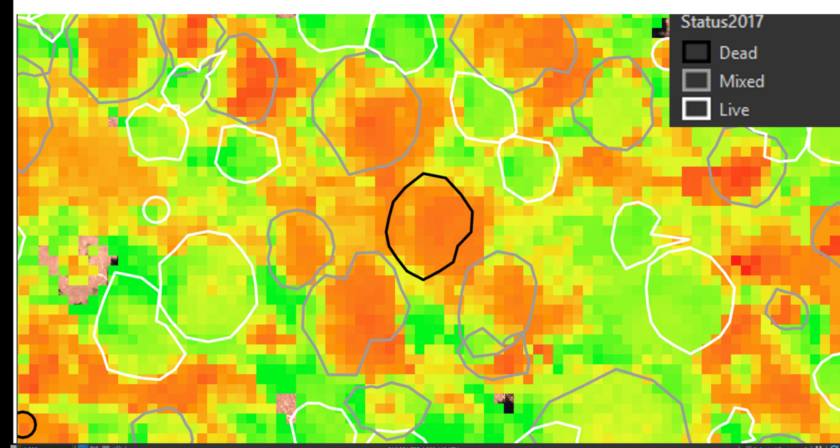


Figure 6: NDVI and TAOS, 2017

Figure 7: Orthoimagery and TAOS, 2017

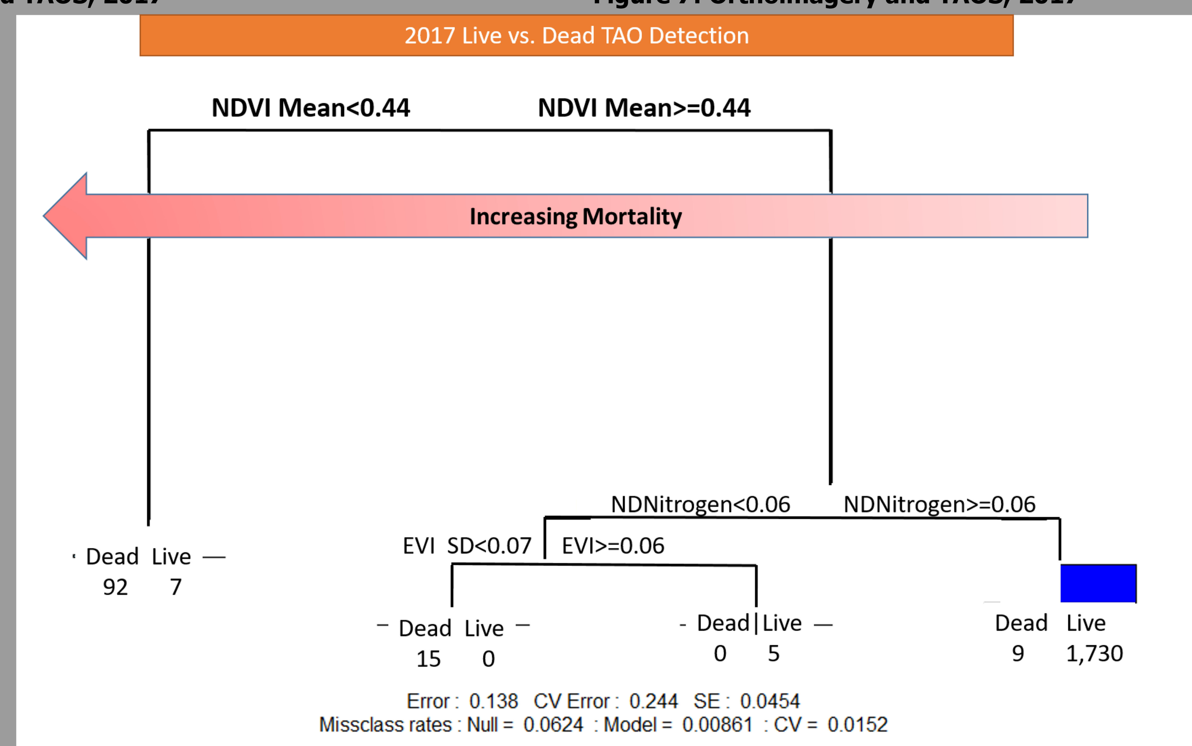


Figure 8: Results of the CART for the 2017 TAOS by live or dead status

2018

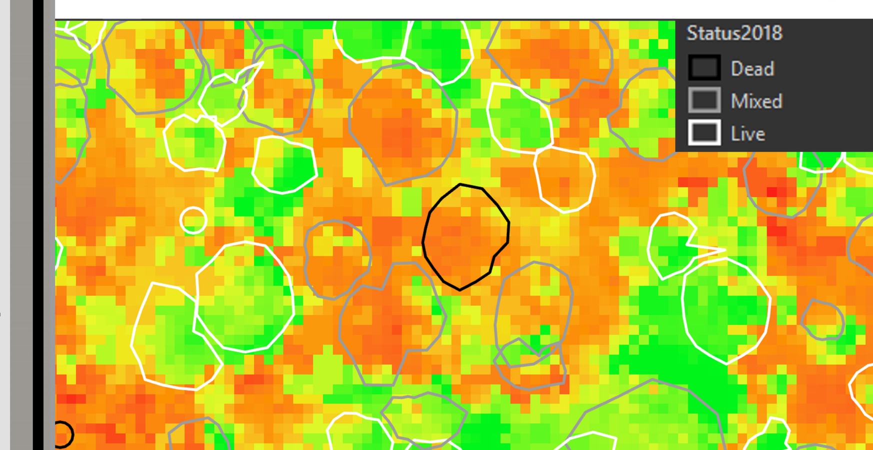


Figure 9: NDVI and TAOS, 2018

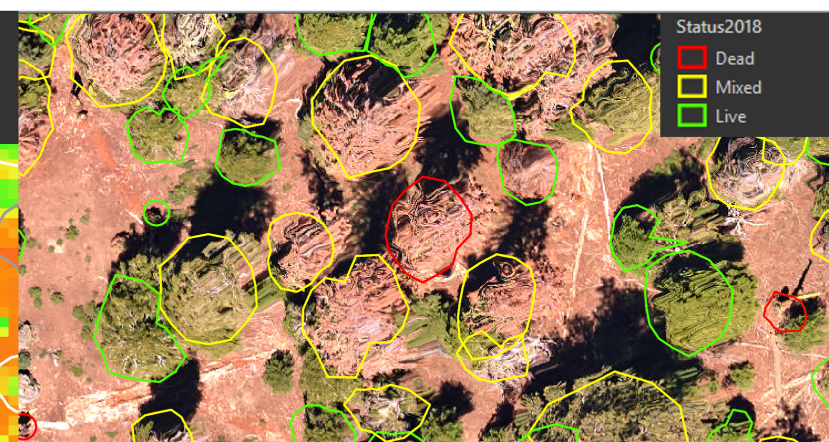


Figure 10: Orthoimagery and TAOS, 2018

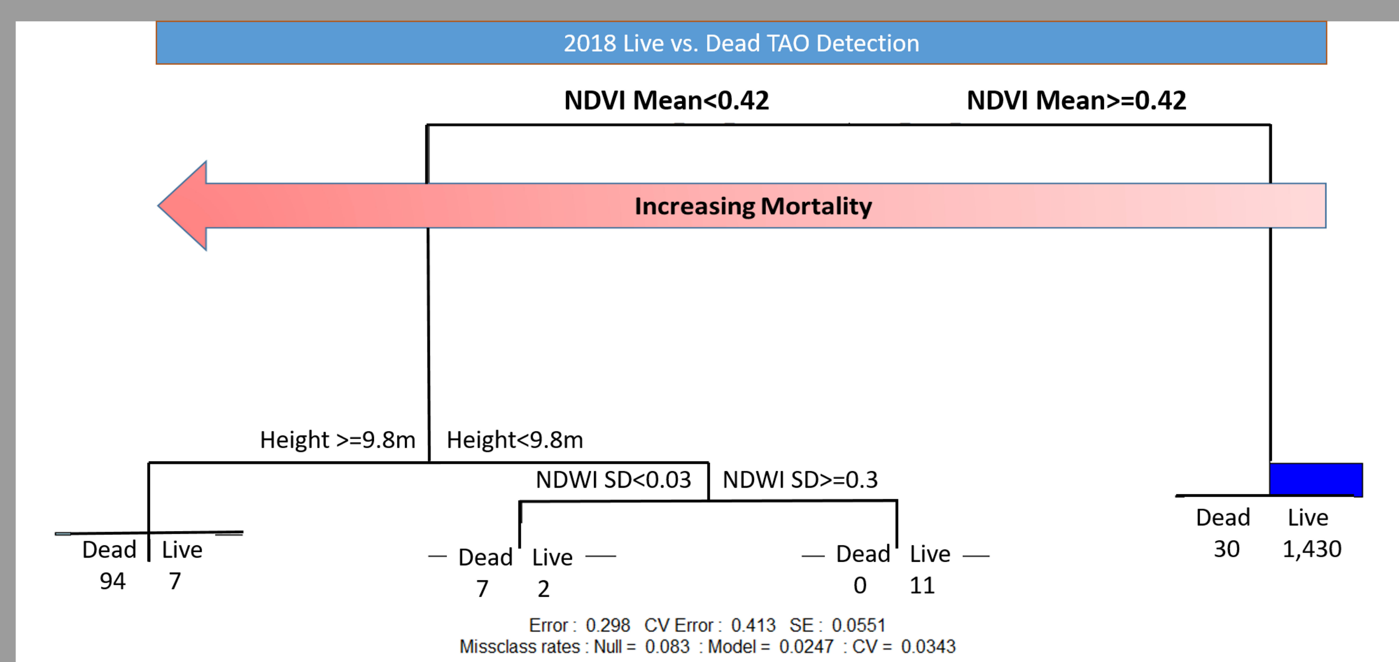


Figure 11: Results of the CART for the 2018 TAOS by live or dead status

Challenges to Address in Next Steps

CHALLENGES with LIDAR INTENSITY: The lidar intensity data applied in this examination was not a reliable predictor of the 2017 TAO mortality status. Future steps will involve examining drought mortality in locations with paired, higher density lidar and orthoimagery. In addition steps will include ensuring the lidar intensity is properly normalized.

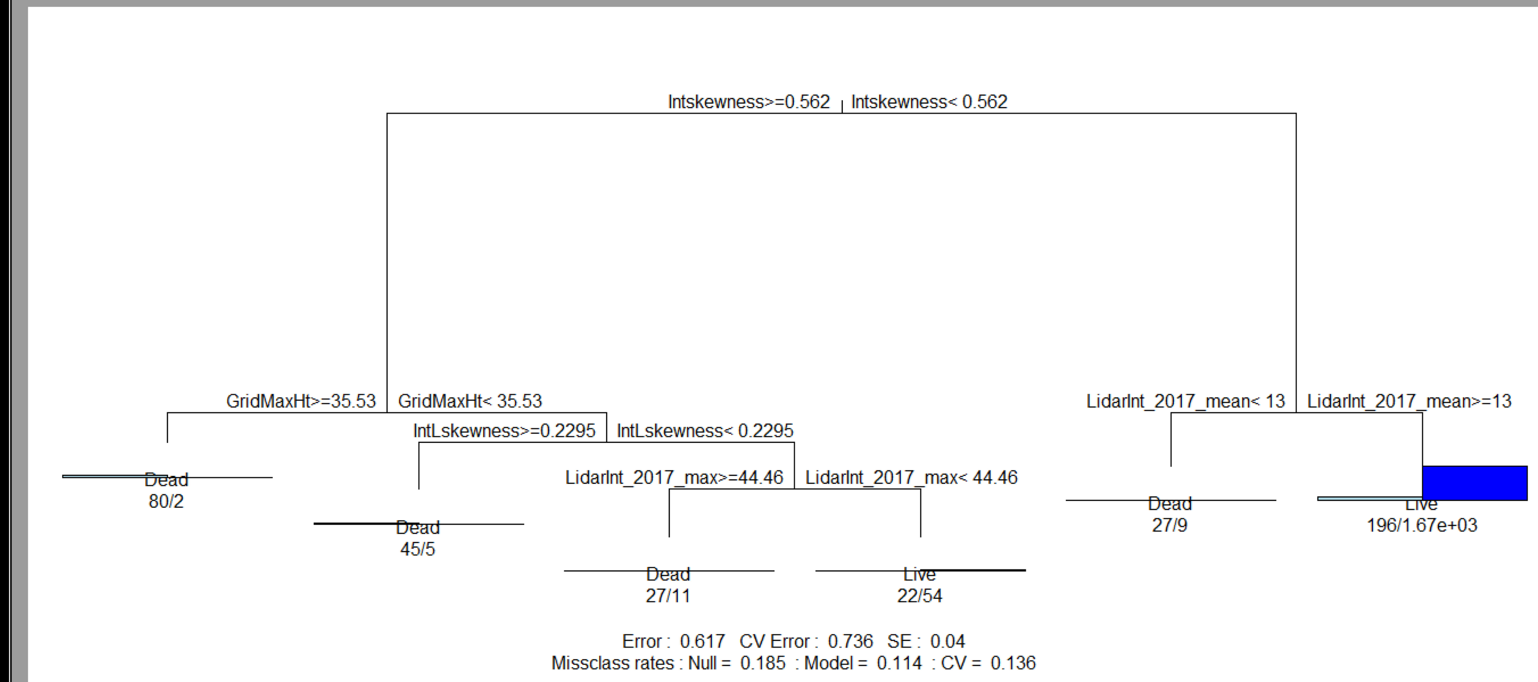


Figure 12: CART of lidar intensity metrics to predict 2017 TAO mortality status. The lidar intensity data was not normalized and was 2m resolution.

Live and dead trees within a TAO are difficult to classify as live or dead with hyperspectral imagery and may not be distinguished from TAOs that are experiencing drought stress.

Significant portions of the tree may be located outside of the TAO boundary due to the imagery being orthorectified to lidar. This results in fewer pixels of the tree being captured in the TAO and mixed TAOs.

Figure 13: Examples of considerations for applying TAOs with hyperspectral and orthoimagery orthorectified with lidar. As well classification of TAOs where live and dead trees are within the same TAO.

Summary

Mean NDVI values of 0.44 and 0.42 for 2017 and 2018, respectively, were a reliable classifier of mortality status in this study. Next steps involve refining the methods to parse coincident live and dead trees in a single TAO and possible stressed trees as well as classify probably species. And, lidar intensity data will be further explored for utility in mortality detection using higher fidelity lidar and orthoimagery data for the Sierra Nevada. Finally, these models will be leveraged with spaceborne systems including but not limited to LANDSAT and GEDI to explore mortality detection across landscapes.

Citations

Jeronimo, S.M.A., Kane, V.R., Churchill, D.J., McGaughey, R.J., Franklin, J.F., 2018. Applying LiDAR individual tree detection to management of structurally diverse forest landscapes. J. For. 116, 336–346.

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National Ecological Observatory Network. 2019. Provisional data downloaded from http:// data.neonscience.org on May 1, 2019. Battelle, Boulder, CO, USA

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