**Arizona Water Resources**

*Utilizing Aerial Imagery and NASA Earth Observations to Assess Pinyon-Juniper Tree Mortality in Flagstaff, AZ*

**Project Team**

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**Project Overview**

***Project Synopsis:***

The Arizona Water Resources project aimed to increase the capabilities of the National Park Service (NPS) to detect pinyon-juniper (*Pinus* spp.-*Juniperus* spp.) tree mortality at Wupatki National Monument in Flagstaff, AZ. The team utilized National Agricultural Imagery Program (NAIP) data and NASA Earth observation data to assess pinyon-juniper mortality in the study area between 2015 and 2021 and integrate factors such as stand density, soil moisture, precipitation, evapotranspiration, temperature, Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI), and topographic variables into analyses. Generated end products can enable targeted vegetation management, monitoring, and conservation efforts.

***Abstract:***

Pinyon-juniper woodlands (PJW) are a vital habitat and food source for several wildlife species and a source of both utility and cultural importance for Indigenous groups. In 2021, amidst a decades-long drought, an extensive juniper mortality event occurred at Wupatki National Monument (WNM) in Arizona. In response, the National Park Service (NPS) is evaluating which land management practices will be beneficial. In partnership with the NPS, the NASA DEVELOP team used remote sensing data to map PJW mortality and analyze the relation of tree mortality to stand density, climate, and topography in north-central Arizona from 2015 to 2021. To identify the extent of PJW, the team performed an unsupervised classification using National Agricultural Imagery Program (NAIP) data with validation sources including NPS-created land cover maps, Landscape Fire and Resource Management Planning Tools (LANDFIRE), NPS and United States Forest Service (USFS) vegetation maps, and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) data. Terra Moderate Resolution Imaging Spectroradiometer (MODIS), Global Precipitation Measurement (GPM) Integrated Multi-satellite Retrievals for GPM (IMERG), Soil Moisture Active Passive (SMAP), Shuttle Radar Topography Mission (SRTM), and Landsat 8-derived Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) were used to analyze factors contributing to pinyon-juniper mortality. Although no relationships were found in the broader study region, PJW mortality was weakly correlated to elevation, soil moisture, and land surface temperature within WNM. Results from this study can inform NPS vegetation management that best protects natural and cultural resources.

***Key Terms:***

remote sensing, pinyon-juniper woodlands, tree mortality, drought, National Park Service, cultural resources, Indigenous groups, vegetation management

***National Application Area Addressed:*** Water Resources

***Study Location:*** Flagstaff, AZ

***Study Period:*** January 2015 – December 2021

***Community Concerns:***

* Prolonged drought has increased water resource-related concerns and has resulted in hydrological and ecological shifts in the region.
* Drought-related pinyon-juniper tree mortality events have led to a loss of key food sources for local birds and a reduction in habitat for rare plants and wildlife such as mule deer.
* Increased pinyon-juniper tree mortality results in significant wildfire risk, which poses a threat to over 3,000 known Ancestral Puebloan cultural resource sites managed by the NPS.
* Pinyon-juniper woodlands are of current importance to the Hopi, Zuni, and Navajo tribes in the region for the trees’ cultural significance and use as fuelwood.

***Project Objectives:***

* Assess the extent of PJW mortality by mapping changes in tree canopy cover across the study area between 2015 and 2021
* Identify changes in PJW stand density, soil moisture, precipitation, land surface temperature, evapotranspiration, NDVI, and NDMI during the study period
* Provide the partners with a method for continued monitoring and detection of mortality events

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Park Service, Flagstaff Area National Monuments** | Mark Szydlo, Biologist | End User | Yes |

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

At the Wupatki National Monument in Flagstaff, Arizona, the NPS currently performs natural resource monitoring and invasive plant control along roads and buildings. However, there is no PJW management implemented within the park, as most of the monument is wilderness closed to public use. The NPS also employs geographic information systems (GIS) technicians that utilize Esri software on a daily basis and apply remote sensing and GIS techniques in support of natural and cultural resource assessments. Further, the partners work closely with the United States Forest Service at Coconino National Forest, the Arizona Game and Fish Department, and Grand Canyon National Park to monitor the local environment. The information that is acquired on local environmental conditions is also shared at organizational visitor centers and on the NPS website to relay pertinent information to the community.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI/TIRS** | Land surface temperature (LST), NDMI, NDVI | LST, NDVI, and NDMI data were used to evaluate potential effects on pinyon-juniper mortality. |
| **SMAP** | Soil moisture | Soil moisture data were used to assess changes over time and relationships with pinyon-juniper mortality. |
| **GPM IMERG** | Precipitation | Precipitation accumulation data, derived from algorithms to predict interpolated values, were used to assess precipitation over time and relationships with pinyon-juniper mortality. |
| **SRTM** | Elevation, slope, aspect | Elevation, slope, and aspect were used to map topographic characteristics of the landscape and to assess their relationship with pinyon-juniper mortality. |
| **Terra MODIS** | Evapotranspiration, burn boundary (2021) | Evapotranspiration data were used to assess changes over time and relationships with pinyon-juniper mortality. Burned area data were used for classification masking purposes. |

***Ancillary Datasets:***

* United States Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) – High resolution aerial imagery from 2015 and 2021 used for land cover classification, validation, and stand density estimates
* LANDFIRE Existing Vegetation Type v1.4.0 – Detailed 2016 land cover classification for the study region used for masking out highly-probable ponderosa pine areas
* LANDFIRE Existing Vegetation Height v2.0.0 – Detailed 2016 classification of vegetation height used for masking out highly-probable non-PJW trees
* United States Geological Survey Protected Areas Database of the United States (PAD-US) v2.1, Public Land Boundaries – Shapefiles for the boundaries of Coconino National Forest, Wupatki National Monument, and Grand Canyon National Park as of 2020
* National Park Service (NPS) Vegetation Inventory Maps – Geospatial vegetation map products for Wupatki National Monument from 2004
* Monitoring Trends in Burn Severity (MTBS) Burned Area Maps – Shapefile with burn boundaries between 2015 and 2020 for the study region
* National Park Service (NPS) Juniper Survey Points – Ground truth PJW sites within Wupatki National Monument from 2021
* United States Forest Service (USFS) Survey Points – Ground truth PJW sites within the Coconino National Forest and Southern Kaibab National Forest from 2021

***Software & Scripting:***

* Esri ArcGIS Pro 2.9.3 – Evaluate pinyon-juniper mortality and its relation to environmental variables as well as generate maps
* Esri ArcGIS Online – Generate ArcGIS StoryMap
* Google Earth Engine API – Acquire SMAP, Terra MODIS, Landsat 8 OLI/TIRS, Landsat 8 OLI NDVI, Landsat 8 OLI NDMI, and SRTM data to evaluate relationships between tree mortality and soil moisture, evapotranspiration, land surface temperature, NDVI, NDMI, and topography
* RStudio 4.1.1 – Analyze environmental variables in relation to PJW mortality
* Tableau 2021.2 – Produce and analyze time-series plots of environmental variables

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Data Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Land Cover Maps** | NAIP | These maps will provide a deeper understanding of the composition of NPS lands and will potentially inform land management efforts. | I |
| **Pinyon-Juniper Mortality Maps for Entire Study Region and Wupatki Only** | NAIP | These maps will provide the partners with temporal and spatial information regarding the onset of extensive mortality events between 2015 and 2021. The maps will potentially inform fire preparedness and habitat and invasive plant monitoring. | I |
| **Time Series Plots of Soil Moisture, Evapotranspiration, Precipitation, Temperature, NDMI, and NDVI** | SMAP  GPM IMERG  Terra MODIS  Landsat 8 OLI/TIRS | These plots will provide the partner with a record of how these variables have changed over time across the study period given ongoing drought conditions. | I |
| **Soil Moisture, Temperature, and Elevation Maps** | SMAP  Landsat 8 OLI/TIRS  SRTM | These maps will provide the partner with visual aids of significantly related variables that identify how these variables have changed across the landscape over the study period given ongoing drought conditions and may be used to inform future monitoring efforts. | I |
| **Method for Mapping Pinyon-Juniper Mortality** | N/A | These methods will provide the partners with a framework to continue monitoring and detecting mortality events beyond the DEVELOP term. | N/A |

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

This project provided products and product development methods to the partners, helping to build the partner’s capacity to utilize NASA Earth observations and other geospatial data in their current land management practices and monitoring activities. Exploring factors such as stand density, soil moisture, precipitation, land surface temperature, NDMI, NDVI, and topography will provide a better depiction of past and future influences on drought-induced pinyon-juniper mortality. This project generated end products that provide detailed methods for the NPS staff to continue utilizing NASA Earth observations beyond the scope of this project. Further, these end products can be utilized by the NPS to inform fire risk management practices and monitoring activities within the National Park and National Forest landscapes.

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