**Grand Canyon Ecological Forecasting**

*Using NASA Earth Observations to Monitor and Model Juniper Woodland Mortality in Grand Canyon National Park*

**Project Team**

***Project Team:***

Scarlet Jackson (Project Lead)

Michael Hitchner

Joe Miotke

Miriam Ritchie

***Advisors & Mentors:***

Dr. Paul Evangelista (Colorado State University, Natural Resource Ecology Laboratory)

Dr. Catherine Jarnevich (USGS, Fort Collins Science Center)

Dr. Anthony Vorster (Colorado State University, Natural Resource Ecology Laboratory)

Peder Engelstad (Colorado State University, Natural Resource Ecology Laboratory)

Nicholas Young (Colorado State University, Natural Resource Ecology Laboratory)

Brian Woodward (Colorado State University, Natural Resource Ecology Laboratory)

***Team POC:*** Scarlet Jackson, sij@email.arizona.edu

***Partner POC:*** Lonnie Pilkington, lonnie\_pilkington@nps.gov

**Project Overview**

***Project Synopsis:***

Juniper is a widespread and emblematic tree native throughout much of the American southwest. Despite their adaptations for survival in the rugged semi-arid landscapes of the southwest, juniper trees have been experiencing increased die-off, possibly as a result of ongoing drought in and around Grand Canyon National Park in northern Arizona. The goal of this study was to examine past and present conditions in the region to identify patterns between environmental and topographic characteristics and locations of die-off to forecast future impacts, enhance targeted field surveys, and inform conservation strategies for the species and habitat.

***Abstract:***

Significant die-offs of the drought tolerant species Utah juniper (*Juniperus osteosperma*) and one-seeded juniper (*Juniperus monosperma*) have been observed throughout central and northern Arizona, including Grand Canyon National Park (GCNP). As climate models project rising temperatures and continuous drought, land managers are concerned for the future of juniper in and around GCNP. This project incorporated data from Landsat 8 Operational Land Imager (OLI), the Shuttle Radar Topography Mission (SRTM), and ocular samples of the National Agriculture Imagery Program (NAIP) in a random forest model to identify patterns between characteristics of the landscape and locations of juniper woodland mortality and to model areas subject to vulnerability. This study found no significant correlation between ocularly sampled juniper tree mortality and remotely sensed environmental variables used thus, accurately modeling mortality vulnerability in the future was not feasible. The ocular sampling, however, allows the partners at the GCNP’s Science & Resource Management Division to better understand areas of juniper tree woodland mortality and the relative amount of mortality in the park. Additionally, the areas of juniper tree mortality found in this project provide the partners with guidance for future field sampling.

***Key Terms:***

remote sensing, random forest, juniper woodland stress, ocular sampling, NAIP

***National Application Areas Addressed:*** Ecological Forecasting

***Study Location:*** Grand Canyon National Park, AZ

***Study Period:*** January 2010 – December 2021; Forecasting to 2030

***Community Concerns:***

* GCNP is concerned with how die-off will affect wildlife and plant communities, fire regimes, and thinning projects.
* Dead and dying juniper stands can affect fire regimes by increasing the amount of flammable fuel available for catastrophic wildfires.
* The Vegetation Program within GCNP is concerned about invasive species that may colonize in the areas of juniper die-off, including cheatgrass and red brome.
* The Havasupai tribe relies on Utah juniper berries as a food source, as well as for cultural and medicinal practices like preventing rheumatism and improving memory. Juniper die-off may inhibit continuation of these practices.

***Project Objectives:***

* Analyze environmental factors associated with juniper woodland mortality
* Identify patterns between landscape characteristics and the locations of juniper woodland mortality
* Model landscape most susceptible to future juniper woodland mortality

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Park Service, Grand Canyon National Park, Science & Resource Management Division** | Lonnie Pilkington, Vegetation Program Manager | End User | No |

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

The National Park Service monitors tree health in and around GCNP by hand and has programs in place to treat and remove dying trees, but efforts are limited by the size and accessibility of some parts of the park. GCNP staff have also identified climate change adaptive planning as a priority in the coming years and are implementing climate change scenarios into their decision-making. The partner is aware of the capabilities of remote sensing technologies, but does not currently have the capacity to utilize them.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Spectral vegetation indices | This dataset provided the temporal (16 days) and spatial (30 m2) resolution needed to derive spectral indices for mapping the current extent of juniper. |
| **SRTM** | Topography | This dataset provided the spatial (30 m2) resolution needed to derive topographic variables (e.g., elevation, aspect, slope) to identify areas most susceptible to future die-off. |

***Ancillary Datasets:***

* National Park Service Grand Canyon Vegetation Classes – A partner-provided shapefile of vegetation classes used for study area delineation and guided ocular sampling
* U.S. Forest Service Field Data – Juniper mortality field data provided by the Forest Service and used to calibrate before ocular sampling.
* U.S. Department of Agriculture National Agriculture Imagery Program (NAIP) – Imagery with 30 m2 resolution used to derive ocular samples across the landscape for mapping the current extent of juniper

***Modeling:***

* Random forests (POC: Anthony Vorster, Colorado State University) – model used to attempt to map the current extent of dead juniper and to project where future die-offs are likely to occur

***Software & Scripting:***

* R 4.1.2 – Statistical analyses, raster processing, and random forest modeling
* Google Earth Engine JavaScript API – Large-scale image analysis and data acquisition of environmental variables
* Esri ArcGIS Pro 2.9 – Image processing and end product generation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Analysis of Juniper Mortality and Associated Patterns** | Landsat 8 OLI  SRTM | An analysis of the topography and environmental factors associated with observed juniper mortality gives the partner insight into where and why juniper woodland mortality occurs, allowing it to improve  protection and restoration efforts. | N/A |
| **Juniper Woodland Observed Mortality Maps** | N/A | A map of areas in the park where juniper woodland mortality was observed. An observed mortality heat map will also be included to highlight the areas that have higher mortality in relation to the number of points sampled. These maps will hopefully guide the “first steps” in field sampling methods. | N/A |
| **Juniper Woodland Observed Mortality Distance to Roads** | N/A | The table with ocularly sampled point locations, mortality percentages, and distance to roads can aid partners in targeted field sampling toward better understanding the juniper mortality phenomena. | N/A |

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

The final products will enhance targeted field sampling strategies and feasibility of studying juniper woodland mortality through remote sensing. Product #1 resulted in no significant correlations between the environmental variables and the ocular samples used in this project. This could potentially lead the partners to look for correlation in other environmental variables or tree characteristics. Product #2, an observed mortality heat map, will also be included to highlight the areas that have higher mortality in relation to the number of points sampled. These maps can enhance targeted field sampling and provide the “first steps” to ground surveys. Product #3 will pair with product #2 in providing mortality percentages at each sample point as well as the points distance from an accessible road. Feasibility of surveying the ocular sampling points can be considered when looking at accessibility to the mortality points.

**References**

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