**Delaware Basin Ecological Forecasting**

*Identifying Vegetation Trends and Atmospheric Stressors in the Guadalupe Mountains and Carlsbad Caverns National Parks*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Within the American Southwest, the Guadalupe Mountains and Carlsbad Caverns span across over 6,000 acres of public land throughout the Delaware Basin. The National Park Service (NPS) Intermountain Region has detected lower precipitation and higher temperatures within the parks in the past decade, but has yet to quantify their impact on vegetation health. This project used NASA Earth observations to create a vegetation health change map, a precipitation time series, and a water stress change map. The NPS Intermountain Region will use these end products to assess vegetation health throughout the Delaware Basin to effectively plan for their conservation and maintenance.

***Abstract:***

The Guadalupe Mountains and Carlsbad Caverns National Parks, located in the Delaware Basin in the southwestern United States, observed both a decrease in precipitation and an increase in temperature over the last decade. Furthermore, activity from local oil fields generated nitrogen dioxide (NO2) plumes that spread over the parks and augmented the effects of the drought. NO2 is a precursor for tropospheric ozone (O3) which is known to have adverse effects on vegetation and ecosystems at large. These new climate dynamics prompted the National Park Service (NPS) to collaborate with NASA DEVELOP to assess the impact on vegetation within the parks. We used NASA Earth observations including Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM+), Landsat 8 Operational Land Imager (OLI), and Global Precipitation Measurement Integrated Multi-Satellite Retrievals (GPM IMERG) to assess vegetation health, water stress, and precipitation in the affected parks. After creating a homogenous reference area in the Sierra Diablo Mountains (SDM), the team visualized vegetation health through a Normalized Difference Vegetation Index (NDVI) time series map from 2010-2021. This did not show strong evidence that the NO2 plume is causing vegetation decline. Following this, we created a water stress map with a Normalized Difference Moisture Index (NDMI) time series map from 2010-2021, which revealed a pattern of increasing water stress. We also confirmed that precipitation in the region decreased over the span of 2010-2021. These observations and findings will allow the NPS Intermountain Region to more effectively plan for the preservation and maintenance of vegetation health within the parks.

***Key Terms:*** Ecological Forecasting, Remote Sensing, Vegetation Monitoring, NO2 Impact, Drought

***National Application Areas Addressed:*** Ecological Forecasting, Water Resources, Health & Air Quality

***Study Location:*** Delaware Basin, NM, TX

***Study Period:*** May 2010 – May 2021

***Community Concerns:***

* Guadalupe Mountains and Carlsbad Caverns are both granted special air quality and visibility protections due to the Clean Air Act of 1970; despite this, there are nitrogen dioxide (NO2) plumes that could be affecting vegetation health within the parks.
* These national parks have observed decreased precipitation and increased temperatures which can affect vegetation health through high water loss.
* The effects of the drought in the southwestern United States and NO2 plumes on vegetation health are not yet quantified, making it difficult to take proper actions toward preserving the pristine environments of the national parks for the local tourism economy and the enjoyment of future generations.
* Decreased vegetation health can lead to a decrease in the quality of our national parks by having adverse effects on biodiversity, habitat quality, and water and nutrient cycles.

***Project Objectives:***

* Identify the extent of vegetation health decline in the Delaware Basin attributed to the NO2 plumes observed over the national parks and the ongoing drought in the southwestern United States
* Generate maps of NDVI and water stress
* Examine how increased temperature and decreased precipitation have impacted vegetation health from 2010-2021

**Partner Overview**

***Partner Organization:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **National Park Service,**  **Intermountain Region** | Lisa Devore, Air Quality Specialist | End User |
| **National Park Service, Guadalupe Mountains National Park** | Mike Medrano, Resource Stewardship and Science Manager | End User |
| **National Park Service, Carlsbad Caverns National Park** | Valerie Morgan, Biologist | End User |

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

The Clean Air Act of 1970 classifies Guadalupe Mountains and Carlsbad Caverns as Class I areas, which receive the highest level of air quality protection administered by the NPS. Both parks evaluate their overall health in order to inform decisions relating to oil and gas leases made by the Bureau of Land Management and state agencies. Recently, partners are concerned about potential water loss and subsequent declines in plant health due to observed decreases in precipitation and increases in temperature. The NPS Intermountain Region protects ecosystem functions and facilitates positive visitor experiences through understanding threats to vegetation health and resources. By expanding on past DEVELOP partnership work, the NPS Intermountain Region aims to gain knowledge of vegetation health status in the parks to aid in making management decisions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **GPM IMERG** | Precipitation | GPM IMERG data were used to observe  precipitation trends across the study period.  Precipitation was compared to NDVI  trends to explore the effects of drought  on vegetation. |
| **Landsat 5 TM** | Surface reflectance | Landsat 5 TM surface reflectance data were  used to calculate NDVI and evaluate vegetation  health in the parks from 2010-2012. The data were also used to calculate NDMI and evaluate plant water stress from 2010-2012. |
| **Landsat 7 ETM+** | Surface reflectance | Landsat 7 ETM+ surface reflectance data were  used to calculate NDVI and evaluate vegetation  health in the parks from 2012-2013. The data were also used to calculate NDMI and evaluate plant water stress from 2012-2013. |
| **Landsat 8 OLI** | Surface reflectance | Landsat 8 OLI surface reflectance data were used  to calculate NDVI and evaluate vegetation health in  the parks from 2013-2021. The data were also used to calculate NDMI and evaluate plant water stress from 2013-2021. |

***Ancillary Datasets:***

* US Department of Agriculture (USDA) LANDFIRE Vegetation Dataset – Robust national vegetation dataset including details for vegetation type, quality, and health within the study area
* National Interagency Fire Center (NIFC) Wildland Fire Locations Full History Dataset – National wildfire dataset including details for acres burned, location of origin of fire, and date of fire
* US Geological Survey (USGS) National Map – A national map dataset of the United States including contours and elevation

***Software & Scripting:***

* Esri ArcGIS Pro 2.9.2 – Data visualization
* QGIS 3 – Data visualization
* Esri ArcGIS Online 2.9.2 – Creation of a communicative StoryMap

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Vegetation Health Change Map**  **(2010 – 2021)** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | A vegetation health change map quantified by NDVI will allow partners to visualize and assess the health of the vegetation in the parks over the past decade. | N/A |
| **Precipitation Time**  **Series**  **(2010 – 2021)** | GPM IMERG | A time series of precipitation data will allow partners to visualize rainfall trends and understand the combined impacts of drought and high heat days in the study area. | N/A |
| **Water Stress Change Map (2010 – 2021)** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | A map of water stress change quantified by NDMI across the parks will allow partners to designate areas that have been highly impacted by drought and extreme weather. | N/A |

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

This project in conjunction with previous DEVELOP work and NPS *in situ* data will give the NPS Intermountain Region the tools necessary to assess whether NO2 plumes are significantly impacting the vegetation health and moisture content within Carlsbad Caverns National Park and Guadalupe Mountains National Park. Improved understanding of the conditions of vegetation health in the National Parks will give the NPS Intermountain Region the ability to make better-informed decisions about how to mitigate the decline of vegetation health. Map products may be used by the NPS Intermountain Region in order to communicate the effects that NO2 plumes are having on vegetation within these national parks.

**References**

Cogato, A., Pagay, V., Marinello, F., Meggio, F., Grace, P., & De Antoni Migliorati, M. (2019). Assessing the

feasibility of using Sentinel-2 imagery to quantify the impact of heatwaves on irrigated vineyards.

*Remote Sensing, 11*(23), 2869. <https://doi.org/10.3390/rs11232869>

Grulke, N. E., & Heath, R. L. (2019). Ozone effects on plants in natural ecosystems. *Plant Biology*, *22*(S1), 12–37. <https://doi.org/10.1111/plb.12971>

West, H., Quinn, N., Horswell, M., & White, P. (2018). Assessing vegetation response to soil moisture fluctuation under extreme drought using Sentinel-2. *Water*, *10*(7), 838. <https://doi.org/10.3390/w10070838>