**Grand Canyon Water Resources**

*Employing NASA Earth Observations to Model Availability of Ephemeral Water Sources and Vegetation Change in Support of a USGS Feasibility Assessment and Management Strategy of Bison*

**VPS Title:** Wallowing in the Wild West: Impacts of the Kaibab Plateau Bison Herd

**Project Team**

***Project Team*:**

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**Project Overview**

***Project Synopsis*:**

The North Rim of Grand Canyon National Park is currently experiencing significant impacts to water resources and vegetation due to free-roaming bison (*Bison bison*). The goal of this project was to quantify those impacts using NASA Earth observations. Specifically, Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM+), Landsat 8 Operational Land Imager (OLI), Sentinel 2 MultiSpectral Instrument (MSI), and the Shuttle Radar Topography Mission version 3 (SRTM) were employed to create maps of available water sources and vegetation change. The end products support the mission of the United States Geological Survey (USGS) and the National Park Service (NPS) to effectively target resource and species management efforts.

***Abstract*:**

The United States Geological Survey (USGS) and National Park Service (NPS) are concerned by the increasing Kaibab Plateau bison population on the North Rim of Grand Canyon National Park (GRCA). Currently, within the park’s boundaries, the bison have no predators and hunting is prohibited, resulting in an increasing bison population. This growing population has led to significant impacts on resources such as vegetation, water resources, soils, and archaeological sites from extensive grazing, trampling, and wallowing behavior. Wallowing, or the act of bathing in dust or loose soil to deter insects, is one of the chief concerns of the NPS because continuous wallowing slows the recovery of vegetation in arid environments. The NPS is tasked with sustaining the health of the park for future generations, but there is limited information available to quantify the impacts of bison. This study utilized NASA Earth observation data from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM+), Landsat 8 Operational Land Imager (OLI), and the European Space Agency’s Sentinel-2 MultiSpectral Instrument (MSI) to analyze the changes in vegetation and water resources before and after intensive bison activity. Shuttle Radar Topography Mission (SRTM) version 3 data were paired with additional spectral information to model impacted resources for comparison with potential bison distribution. Final maps of water availability, vegetation change, and potential bison movement corridors will be used by the USGS and NPS to inform herd population management efforts and site level restoration.

**Keywords:**

Remote sensing, time series analysis, Random Forest, Kaibab Plateau, North Rim, Circuitscape

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

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

***Study Period:*** 1984 – 2017

***Community Concerns:***

* Water resources are scarce in this semiarid region and need to be properly allocated in order to preserve all species within the region.
* Bison, the most iconic species in Grand Canyon National Park, may soon exceed their carrying capacity and collapse due to depleted vegetation and water resources, as there are no predators in the region to regulate the population.
* Bison are charismatic megafauna which are especially contentious in the region, and proper management of the species is essential for quelling community concerns.
* Bison are impacting the aesthetic appeal of the local vegetation and fragile archeological sites.
* The ecological health of rare vegetation is being threatened, with limited water resources minimizing the potential for regeneration.

***Project Objectives:***

* Identify areas and points in time on the Kaibab Plateau where vegetation and water resources have been impacted by increasing bison activity
* Analyze the change in vegetation and water resources before and after intensive bison activity
* Map the potential seasonal movement of the bison population in relation to vegetation and water resources

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USGS, Fort Collins Science Center Ecosystem Dynamics Branch** | Dr. Kathryn A. Schoenecker, Ecologist | End User | No |
| **National Park Service, Grand Canyon National Park** | Gregory Holm, Wildlife Program Manager | Collaborator | Yes |

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

Motivated by the concerns about the growing bison population the NPS, in collaboration with the USGS, has conducted an environmental assessment (EA) to determine future action on the issue. The NPS and USGS have proposed federal action to reduce the herd to fewer than 200 individuals through lethal and non-lethal culling techniques that have demonstrated fewer impacts on the landscape, particularly on the region’s water resources. Though it is not feasible to make ground-based observations of the entire park, the damage caused by the bison is qualitatively clear from field studies. Currently, the NPS and USGS lack a quantitative assessment of bison impacts to support their decision making process. Utilizing NASA Earth observations and remote sensing techniques can improve their efforts in conserving water resources and maintaining the landscape with better time management practices.

***Project Benefit to End User***:

This project quantifies the impacts of the increasing bison population in Grand Canyon National Park on water and vegetation resources. The NPS and USGS will use this information to support population management efforts. Final maps and analyses of land cover change produced using NASA Earth observation and remote sensing techniques will indicate ideal locations for potential habitat restoration. Additionally, a tutorial will be created to provide a framework for future water resource monitoring and a methodology for quantifying bison impacts as a means to establish sustainable population management practices.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 5 TM** | Surface reflectance, normalized difference vegetation index, normalized difference water index | This dataset provided a 30 m spatial resolution and 16-day temporal resolution necessary to create a Landsat time series analysis. This was used to analyze changes in vegetation health and water resources in Grand Canyon National Park related to increased bison activity. |
| **Landsat 7 ETM+** | Surface reflectance, normalized difference vegetation index, normalized difference water index | This dataset provided a 30 m spatial resolution and 16-day temporal resolution necessary to create a Landsat time series analysis. This was used to analyze changes in vegetation health and water resources in Grand Canyon National Park related to increased bison activity. |
| **Landsat 8 OLI** | Surface reflectance, normalized difference vegetation index, normalized difference water index | This dataset provided a 30 m spatial resolution and 16-day temporal resolution necessary to create a Landsat time series analysis. This was used to analyze changes in vegetation health and water resources in Grand Canyon National Park related to increased bison activity. |
| **Sentinel-2 MSI** | Top of atmosphere reflectance, normalized difference vegetation index, normalized difference water index, normalized difference moisture index, normalized burn ratio, bare soil index | This dataset provided a 20 m spatial resolution and 5-day temporal resolution necessary to discern land cover type. This was used to devise a bare ground cover map for Grand Canyon National Park. |
| **SRTM** | Elevation, slope, aspect | This dataset was used to delineate high elevation bison habitat. |

***Ancillary Datasets:***

USGS National Land Cover Dataset (NLCD) – Compare vegetation classes to supervised classification

National Park Service (NPS) Vegetation Dataset – Compare vegetation classes to supervised classification

Grand Canyon National Park, Bison GPS Collar Data – Bison distribution

National Agriculture Imagery Program – 1 m high resolution aerial imagery for collecting training data

National Oceanic and Atmospheric Administration – Precipitation data

Grand Canyon National Park, Trail Camera Data – Bison sightings and locations

***Modeling:***

Random Forest – Landscape classification of bare ground, variable selection

LandTrendr – Change in vegetation health through time, cloud-free and calibrated annual composites

***Software & Scripting:***

R – Random Forest Modeling, Data Processing

Google Earth Engine API – Large scale image analysis and data acquisition, LandTrendr

Esri ArcGIS – Image processing, data analysis, map creation, end product generation

Circuitscape – Bison connectivity mapping

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Vegetation Impact Analysis Map** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, SRTM, Sentinel-2 MSI | The final analysis quantified the area of land impacted by the bison. The NPS and USGS will use this map to better inform their restoration efforts. | N/A |
| **Water Resource Impact Analysis Map** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, SRTM, Sentinel-2 MSI | The NPS and USGS will use this map to better inform their restoration efforts. The final analysis quantified the area of land impacted by the bison. | N/A |
| **Bison Population Movement Corridors Map** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, SRTM, Sentinel-2 MSI | The NPS and USGS will use this map to identify and assess points of frequent herd movement in relation to impacted vegetation and water resources. | N/A |
| **Distribution Modeling and Mapping Tutorial** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, SRTM, Sentinel-2 MSI | The NPS and USGS will be able to use this tutorial to understand how the maps were produced and be able refine and tailor the analyses to examine additional environmental conditions. | N/A |

**Project Handoff Package**

**Transition Plan:**

The team hostet a close out seminar at the end of the term to disseminate project results and handoff decision support tools to project partners. An in-person meeting was held to give the final products to the point of contact at the USGS, Dr. Schoenecker. The findings of the project and what that may imply about the impacts of bison on the park were be discussed. A short tutorial and training workshop on the use of the data followed the seminar.

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**Partner POC**: Dr. Kathryn A. Schoenecker, schoeneckerk@usgs.gov

**Handoff Package:**

* Water Availability Map
* Vegetation Change Analysis Map
* Bison Movement Corridors Map
* Distribution Modeling and Mapping Tutorial
* DEVELOP Technical Paper

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