** NASA DEVELOP National Program**

**Virginia – Langley**

*Project Summary – Summer 2018*

**Glen Canyon Ecological Forecasting**

*Using NASA Earth Observations to Prioritize Locations for the Further Monitoring and Management of Cultural Resources in Glen Canyon National Recreation Area*

**VPS Title:** Preserving the Past: Vegetation, Erosion, and Glen Canyon’s Archeological Resources

**Project Team**

***Project Team*:**

William Patrick Frier (Project Lead), [william.p.frier@nasa.gov](mailto:william.p.frier@nasa.gov); wpatrickfrier@gmail.com

Cecil Byles

Max Stewart

***Advisors & Mentors*:**

Dr. Kenton Ross (NASA Langley Research Center)

**Project Overview**

***Project Synopsis*:** Cultural resources and archeological sites managed by the National Park Service at Glen Canyon National Recreation Area are threatened by wind and water erosion. This project applied NASA Earth observations to identify areas of the park that are at risk for vegetation loss, a proxy for areas that are threatened by erosion. With spatial and temporal vegetation analyses for the entire region, park managers will be better equipped to focus their monitoring and management practices on the most at-risk portions of the park.

***Abstract*:**

Glen Canyon National Recreation Area (NRA) contains a diverse suite of culturally and historically significant archeological sites that are threatened by erosion and changing land cover dynamics. The National Park Service (NPS) is tasked with monitoring, studying, and preserving these archeological sites, many of which reside in extremely remote locations. At Glen Canyon NRA, perennial vegetation helps stabilize soils and mitigate erosion. The loss of such soil stabilizers is indicative of high erosion potential. This project calculated vegetation indices and generated a time series of vegetation maps across the entire extent of Glen Canyon NRA using Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) data for the years 1995 to 2017. The project team then used multiple vegetation analyses from across the study period to provide an assessment of year-to-year change in the abundance and distribution of soil-stabilizing vegetation. This approach allowed for a comprehensive assessment of vegetation and soil stabilization across a broad region that could not be assessed by traditional ground-based means. Finally, the team used these vegetation analyses to assess the rate of change of vegetation cover and to predict future vegetation distribution. Land managers and archeologists at the NPS can use the results of this work to prioritize the monitoring and management of important archeological sites that could otherwise be lost to erosion.

**Keywords:**

Landsat, Sentinel, remote sensing, National Park Service, Vegetation Index

***National Application Area(s) Addressed:*** Eco Forecasting

***Study Location:*** Glen Canyon National Recreation Area (AZ, UT)

***Study Period:*** January 1995 – January 2018; Forecasting to 2022

***Community Concern:***

* Unique cultural resources and archeological sites in Glen Canyon NRA are threatened by erosion
* Erosion rates are mitigated by the presence of naturally occurring vegetation and cryptobiotic soil crusts
* The NPS requires accurate vegetation cover trend maps to understand vegetation loss dynamics and prioritize their management and restoration of cultural heritage sites
* Field observations across Glen Canyon NRA are resource intensive and limited in scope
* Park staff are interested in monitoring vegetation loss and assessing cultural heritage sites via remotely sensed NASA Earth observations

***Project Objectives:***

* Assess spatial and temporal trends in vegetation cover and soil crusts within Glen Canyon NRA and differentiate between areas of persistent and ephemeral land cover
* Provide a reproducible method by which the NPS can assess vegetation dynamics in the future
* Evaluate park-wide vegetation dynamics and cryptobiotic soil crusts in the context of erosion
* Forecast vegetation and land cover dynamics through 2022

**Partner Overview**

***Partner Organization(s):***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Park Service, Glen Canyon National Recreation Area** | Brian Harmon, Archaeologist | End User | No |

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

The NPS is required to provide thorough documentation on the status of cultural heritage sites within the lands it manages and develop effective preservation strategies. Archaeologists at Glen Canyon NRA currently rely on ground based survey methods, in situ vegetation data, and aerial imagery to prioritize their management practices. They do not currently incorporate any park-wide vegetation data into their decision making. They are aware of NASA Earth observations, but do not currently apply them to monitor these sites.

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

This project provides historic and current vegetation maps for the entire extent of Glen Canyon NRA and places vegetation dynamics into a temporal context showing gains and losses in land cover. Collectively, this new information will allow NPS archaeologists to differentiate between persistent and ephemeral vegetation, identify sites that are most vulnerable to the effects of erosion, and allocate their scarce resources accordingly.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 5 TM** | Surface reflectance | Landsat 5 TM was used to identify vegetation, calculate vegetation indexes, and assess long-term trends. |
| **Landsat 7 ETM+** | Surface reflectance | Landsat 7 ETM+ was used to identify vegetation, calculate vegetation indexes, and assess long-term trends. |
| **Landsat 8 OLI** | Surface reflectance | Landsat 8 OLI was used to identify vegetation, calculate vegetation indexes, assess long-term trends, assess current distributions, and compare to Sentinel-2 MSI. |

***Ancillary Datasets:***

National Park Service, Glen Canyon National Recreation Area *in situ* vegetation data – validate land cover types from satellite imagery

USDA Forest Service ForWarn phenology dataset – compare to land cover analyses with Landsat and Sentinel

***Modeling:***

TerrSet Land Change Modeler (POC: Dr. Kenton Ross, NASA Langley Research Center)

***Software & Scripting:***

Esri ArcMap 10.5 – raster manipulation, map creation, model builder

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product(s)** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| Historic and current vegetation distribution maps | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Sentinel-2 MSI, | Vegetation distribution maps from 1995 to 2018 will be used to indicate areas with persistent or ephemeral vegetation during the study period and where the partners should focus their restoration and monitoring efforts. | N/A |
| Vegetation Loss Analysis – Trend Maps | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Sentinel-2 MSI, | Maps identifying areas of vegetation loss over the course of the study period. This will enable partners to understand what areas of the park are more at-risk for vegetation loss and better allocate scarce resources. | N/A |
| Vegetation Cover Analysis Methodology & Write-up | N/A | The methodology for vegetation cover analysis will be compiled into write-up in the style of a NPS SOP document to allow the partners to continue using this methodology in the future. | N/A |

**Project Handoff Package**

**Transition Plan:**

Handoff will be conducted virtually via video conference and include a tutorial on the project methodology for our partners from the NPS. All files, apart from Python scripts, will be transferred directly to the Resources Division of Glen Canyon NRA via email or large file transfer (NASA LFT) as per the preference of the project partners. Finalized images and all raster data will be exported in GeoTIFF format to maintain compatibility with various image processing and GIS platforms.

**Team POC:** W. Patrick Frier, william.p.frier@nasa.gov

**Software Release POC**: W. Patrick Frier, william.p.frier@nasa.gov

**Partner POC**: Brian Harmon, brian\_harmon@nps.gov

**Handoff Package:**

* Historic vegetation distribution maps for years 1995 – 2017
* Current vegetation distribution map based on 2018 Sentinel 2 MSI
* Current vegetation distribution map based on 2018 Landsat 8 OLI
* Vegetation Loss Trend Maps for years 1995 – 2018 1-year and 5-year time steps
* Forecasted vegetation cover map raster datasets thorough 2022
* Vegetation mapping methodology guide for Esri ArcMap – in style of NPS SOP document
* 2018 Sentinel 2 MSI – 2018 Landsat 8 OLI comparison/validation
* All associated Esri files compiled into geodatabases
* Example Esri map package file to demonstrate project methodology and data setup
* All Esri ArcMap models created and used throughout the project
* Standard Deliverables: Tech Paper, Project Summary, Poster, Presentation, Project Video – VPS
* NPS adapted optional deliverables: public-friendly poster, expanded long-form video

**References:**

Abdou, B., Morin, D., Bonn, F., & Huete, A. (1996). A review of vegetation indices. *Remote Sensing Reviews*, *13*, 95 120. <https://doi.org/10.1080/02757259509532298>

Belnap, J. (n.d.). Recovery rates of cryptobiotic crusts: inoculant use and assessment methods. *Great Basin Naturalist*, *53*, 8.

Huete, A. R., Liu, H. Q., Batchily, K., & van Leeuwen, W. (1997). A comparison of vegetation indices over a global set of TM images for EOS-MODIS. *Remote Sensing of Environment*, *59*(3), 440–451. <https://doi.org/10.1016/S0034-4257(96)00112-5>

Karnieli, A., Kokaly, R. F., West, N. E., & Clark, R. N. (2001). Remote sensing of biological soil crusts. In *Biological soil crusts: structure, function, and management* (pp. 431–455). Springer.

Lalley, J. S., & Viles, H. A. (2008). Recovery of lichen-dominated soil crusts in a hyper-arid desert. *Biodiversity and Conservation*, *17*(1), 1–20.

Qi, J., Chehbouni, A., Huete, A., Kerr, Y. H., & Sorooshian, S. (1994). A Modified Soil Adjusted Vegetation Index. *Remote Sensing of Environment*, *48*, 119–126. <https://doi.org/10.1016/0034-4257(94)90134-1>

Ustin, S., Jacquemoud, S., Palacios-Orueta, A., li, L., & Whiting, M. (2009). Remote sensing based assessment of biophysical indicators for land degradation and desertification. *Recent Advances in Remote Sensing and Geoinformation Processing for Land Degradation Assessment*. <https://doi.org/10.1201/9780203875445.ch2>

Weber, B., Olehowski, C., Knerr, T., Hill, J., Deutschewitz, K., Wessels, D. C. J. Büdel, B. (2008). A new approach for mapping of Biological Soil Crusts in semidesert areas with hyperspectral imagery. *Remote Sensing of Environment*, *112*(5), 2187–2201. <https://doi.org/10.1016/j.rse.2007.09.014>