**Bryce Canyon Water Resources**

*Monitoring Vegetation Health and Water Availability in Bryce Canyon National Park for Drought Stress Mitigation Planning*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Bryce Canyon National Park in southern Utah is renowned for spectacular views, recreational opportunities, and unique ecological communities. However, pervasive drought conditions and increased water demand from exploding tourism threaten the health of groundwater-dependent ecosystems such as aspen groves, fens, and other wetlands. This project used remote sensing to map springs and seeps, as well as to assess trends in vegetation health and climatic variables over time.

***Abstract:***

Bryce Canyon National Park is home to groundwater-dependent ecosystems (GDEs) that are threatened by a multidecadal drought and increased groundwater extraction due to a spike in tourism. These ecosystems contain unique species that are only found in areas where near-surface groundwater is present, such as aspen groves and fens. These species contribute to the high biodiversity found in Bryce Canyon, which boosts an ecosystem’s productivity and the services it provides to the park. Unfortunately, many of these GDEs are too small to identify with traditional Earth observation platforms and are difficult to physically reach for monitoring purposes. This project partnered with the National Park Service to identify springs and seeps as a proxy for GDEs within Bryce Canyon from 2013–2022. The team mapped groundwater discharge with high resolution National Agriculture Imagery Program (NAIP) and assessed park vegetation trends with Landsat 8 Operational Land Imager (OLI) and PlanetScope imagery. *In-situ* precipitation data and the Western Land Data Assimilation System (WLDAS) were used to produce time series of climatic variables. Seeps and spring locations were predicted using random forest classification and maximum entropy machine learning models.

***Key Terms:***

Groundwater dependent ecosystems, remote sensing, NDVI, NDWI, Landsat, WLDAS, high-resolution imagery, Bryce Canyon

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

***Study Location:*** Bryce Canyon National Park, UT

***Study Period:*** January 2013 – August 2022

***Community Concerns:***

* The Park boasts the highest concentration of irregular rock spires (“hoodoos”) and one of the best locations for stargazing in the world. Almost 2.7 million visitors came to Bryce Canyon in 2018, up from 890,676 in 2006. These visitors contributed $200 million to the local economy and thousands of jobs but also placed a large demand for drinking water and wastewater management.
* Groundwater and near-surface water create pockets of concentrated biological diversity with over 325 identified plants along the Podunk Creek Spring alone. These relatively lush areas serve as wildflower and pollinator viewing areas, welcoming resting places for hikers, and anchors of biodiversity.
* The current process to identify seeps and springs is physically arduous and time-consuming; Bryce Canyon staff visually scan Google Earth images of the park for features of groundwater-dependent ecosystems (GDEs) then verify them on foot. The southern half of the park’s terrain is too challenging to effectively locate GDEs in person.

***Project Objectives:***

* Map springs and seeps to identify potential GDE monitoring sites
* Visualize and quantify changes in park vegetation to understand the response to drought conditions
* Generate time series of vegetation-sensitive climate variables including soil moisture, precipitation, land surface temperature, and evapotranspiration to investigate drought trends in Bryce Canyon

**Partner Overview**

***Partner Organization:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **National Park Service, Bryce Canyon National Park** | Brett Cockrell, Chief of Resource Management; Eric Vasquez, Vegetation Biologist | End User |

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

Throughout its nearly 100-year history, staff at Bryce Canyon National Park identified 30 GDEs through direct observation. In the last year, they used Google Earth to visually identify an additional 40 “green patches”, to which survey teams hiked for verification. Bryce Canyon staff have recorded *in-situ* weather data at one location since the 1950s; they manage the visitor experience and monitor ecological systems with these data in ArcGIS Pro. However, current decision-making practices do not include remote sensing techniques beyond this scope.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Normalized Difference Vegetation Index (NDVI) | Produced vegetation change maps and analyzed health changes. |
| **PlanetScope Dove Classic PS2 and SuperDove PSB** | NDVI, Normalized Difference Water Index (NDWI) | Attempted to detect springs and seeps directly. |

***Ancillary Datasets:***

* NASA, the Desert Research Institute (DRI), and Environmental Defense Fund (EDF) OpenET, May 2022 – Satellite-based estimates of evapotranspiration used as input in predictive modeling
* NASA Western Land Data Assimilation System (WLDAS), 1979–2022 – Modeled dataset of climatic variables used to create Bryce Canyon soil moisture, land surface temperature, precipitation, and evapotranspiration time series
* National Park Service (NPS) Bryce Canyon Springs and Seeps, No Date – Ground-verified dataset of springs and seeps used to train and test detection and prediction methods
* Utah Geospatial Resource Center (UGRC) National Agriculture Imagery Program (NAIP) Aerial Imagery, 2021 – Used to calculate NDVI as input in predictive modeling
* United States Department of Agriculture (USDA) NAIP Aerial Imagery, 2018 – Used for NDWI analysis
* USDA Soil Survey Geographic Database (SSURGO), No Date – Used to calculate distance to soil type boundary as input in predictive modeling
* Utah Geological Survey (UGS) Geological Formations Maps, 2022 – Used to calculate distance to formation boundary as input in predictive modeling
* UGRC Light Detection and Ranging (LiDAR), 2018 – Used to derive elevation and slope used as input in predictive modeling

***Software & Scripting:***

* Google Earth Engine (GEE) API – Cloud-based raster manipulation and data extraction
* Esri ArcGIS Pro 3.0.2 – Predictive modeling and geospatial statistical analyses
* Python 3.9.12 – NetCDF manipulation and data visualization
* Microsoft Excel Version 2108 – Tabular data storage

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Maps of Groundwater Discharge Points** | N/A | Partners will use predicted springs and seeps to locate GDEs within the study area. | N/A |
| **Maps of Vegetation Health Indicators** | Landsat-8 OLI | Visualizing vegetation health will help inform the partners’ management efforts. | N/A |
| **Time series of Soil Moisture, Precipitation, Land Surface Temperature, and Evapotranspiration** | N/A | Park staff can make more informed water management decisions by identifying anomalies and climatological conditions contributing to changes in GDEs. | N/A |

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

This project will test the feasibility of various methods to detect and monitor springs and seeps and therefore facilitate the partner’s efforts to conserve ecologically valuable GDEs in Bryce Canyon. The maps of groundwater discharge points will inform the partners of probable locations of environments supportive of GDEs. Additionally, the maps of vegetation indices will allow the partners to assess vegetation health over time and establish conservation priorities. The time series of climatic variables will describe trends and anomalies in pervasive drought conditions. Collectively, the partners can use these end products to monitor the park’s hydrology and vegetation more efficiently.

**References**

Cantonati, M., Stevens, L. E., Segadelli, S., Springer, A. E., Goldscheider, N., Celico, F., Filippini, M., Ogata, K., & Gargini, A. (2020). Ecohydrogeology: The interdisciplinary convergence needed to improve the study and stewardship of springs and other groundwater-dependent habitats, biota, and ecosystems. Ecological Indicators, 110, 105803. <https://doi.org/10.1016/j.ecolind.2019.105803>

Densmore, P. (2018, May 14). *Bryce Canyon tourism creates over $256 million in economic benefits*. National Parks Service. [https://www.nps.gov/brca/learn/news/bryce-canyon-tourism-creates-over-256-million-in-economic-benefits.htm#:~:text=A%20new%20National%20Park%20Service%20%28NPS %29%20 report%20shows,economic%20benefit%20has%20doubled%20in%20value%20since%202012](https://www.nps.gov/brca/learn/news/bryce-canyon-tourism-creates-over-256-million-in-economic-benefits.htm#:~:text=A%20new%20National%20Park%20Service%20%28NPS%20%29%20%20report%20shows,economic%20benefit%20has%20doubled%20in%20value%20since%202012)

Hildebrand, T. (2013). Correlation between wetland and microbial community diversity of Bryce Canyon National Park’s Southern Regions - Phase I. National Park Service Report. [https://www.researchgate.net/publication/255711512\_Correlation\_between\_wetland\_and\_microbial\_community\_diversity\_of\_Bryce\_Canyon\_National\_Park’s\_Southern\_Regions\_-\_Phase\_I](https://www.researchgate.net/publication/255711512_Correlation_between_wetland_and_microbial_community_diversity_of_Bryce_Canyon_National_Park%E2%80%99s_Southern_Regions_-_Phase_I)

National parks Service. (2021). Stats report viewer: Annual park recreation visits (1929 – Last calendar year): Bryce Canyon National Park [Data set]. <https://irma.nps.gov/STATS/Reports/Park/BRCA>

United States Geological Survey. (n.d.). *Ecology of Bryce Canyon National Park*. <https://www.usgs.gov/geology-and-ecology-of-national-parks/ecology-bryce-canyon-national-park>

Wallace, J., & Schlossnagle, T. (2021, May). *The role of water quality and quantity on future development near Bryce Canyon National Park*. Utah Geological Survey. <https://geology.utah.gov/map-pub/survey-notes/the-role-of-water-quality-and-quantity-on-future-development-near-bryce-canyon-national-park>

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