**Southwest Water Resources**

*Monitoring Surface Water Extents of Remote Stock Ponds in the Southwestern United States Using Earth Observing Systems for Enhanced Water Resources Management*

**Project Team**

Rainey Aberle (Project Lead)

Rebecca Bernat

Michael Corley

Lukman Fashina

Kyle Paulekas

***Advisors & Mentors:***

Seungbum Kim (NASA Jet Propulsion Laboratory Radar Remote Sensing)

Keith Weber (Idaho State University GIS Training and Research Center)

***Team POC:*** Rainey Aberle, raineykabe@gmail.com

***Software Release POC:*** Kyle Paulekas, kjpaulekas@gmail.com

***Partner POC:*** Matt Reeves, matthew.reeves@usda.gov

**Project Overview**

***Project Synopsis:***

In the southwestern United States, increasingly frequent drought conditions have become problematic for land managers and livestock producers. These conditions are compounded by the fact that arid ecosystems are particularly susceptible to climate change and climate variability (Archer & Predick, 2008). Stock ponds that provide critical water supply for the local environment, wildlife, and livestock are typically located in remote areas, and monitoring individual ponds can require six or more hours to complete. To address these needs, DEVELOP partnered with the US Forest Service, Arizona Department of Game and Fish, and the Diablo Trust to assess the functionality of implementing Earth observations to monitor surface water extent of hundreds of critical stock ponds in Arizona.

***Abstract:***

Due to increasingly frequent and severe drought conditions in the southwestern US, land managers and livestock producers require reduced driving time to assess water levels of remote stock ponds. This study employed Landsat 8 Operational Land Imager (OLI), Sentinel-1 Synthetic Aperture Radar (SAR), and Sentinel-2 Multispectral Instrument (MSI) to monitor surface water extent for hundreds of critical stock ponds in Arizona. Using methods adapted from previously developed image processing workflows, this project conducted a time-series analysis and created a Google Earth Engine software tool that will allow stakeholders to monitor surface water extent of stock ponds remotely. These tools will be beneficial to partners in drafting well-informed and sustainable management solutions for decades to come. This project was conducted with USDA, US Forest Service, Kaibab National Forest, Range Program; USDA, US Forest Service, Rocky Mountain Research Center; Arizona Department of Game and Fish; and Diablo Trust.

***Key Terms:***

Stock ponds, water monitoring, livestock, remote sensing, Landsat 8, Sentinel-1, Sentinel-2, Southwest US

***National Application Areas Addressed:*** Water Resources, Food Security & Agriculture

***Study Location:*** AZ

***Study Period:*** March 2013 – July 2021

***Community Concerns:***

* The ranching community depends on timely measurements of stock pond surface water extents to sufficiently manage livestock. Due to the remote locations of stock ponds, land managers and cattle producers cannot conduct *in situ* observations as frequently as necessary
* Insufficient hydrologic monitoring data may lead to mismanagement of livestock, resulting in food insecurity in surrounding communities.
* Regional stock ponds play a critical role in ecosystem health as they are also used by wildlife. If ecosystem health declines due to a lack of water resources, wildlife populations will concomitantly decline, impacting local hunters and recreation.
* Remotely sensed observations of local stock ponds’ water extent would provide a defensible record of on-site observations and allow for monitoring of regional water availability on a weekly basis as acquired satellite data becomes available (“near real-time").

***Project Objectives:***

* Develop a more efficient method for monitoring surface water extents using Earth observations
* Create a time series of delineated stock pond areal extents since 2013
* Design an accessible tool for future surface water extent change detection that enables near real-time observations of stock pond water availability

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA, US Forest Service, Kaibab National Forest, Range Program** | Iric Burden, Range Program Manager | End User | No |
| **Arizona Department of Game and Fish** | Steve Cassady, Landowner Relations Program Specialist | End User | No |
| **Diablo Trust** | Lisa Bolten, Program Manager; Kit Metzger, Board President/ Producer, The Flying M Ranch; Bob Prosser, Board Member/ Producer, The Bar T Bar Ranch | End User | No |
| **USDA, US Forest Service, Rocky Mountain Research Center** | Matt Reeves, Research Ecologist | Collaborator | No |

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

Diablo Trust collaborates with the following partners: US Forest Service, Flying J Ranch (private), Bar T Bar Ranch (private), and Northern Arizona University. Diablo Trust facilitates research about protecting and preserving working lands in the West and the open space, wildlife, and food these lands provide. Arizona Department of Game and Fish and US Forest Service Range program work with landowners and other stakeholders to manage agricultural land and water resources. Water resources management is a state prerogative, but constitutional powers are granted to the US Forest Service on federal grounds. Arizona Department of Game and Fish and cattle producers abide by state water law. Ranchers rely on precipitation and surface water runoff to replenish their ponds. US Forest Service and Arizona Department of Game and Fish have previously deployed ground-based LiDAR. Local producers rely heavily on on-site visits and measurements to evaluate the water level of their ponds.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Dynamic surface water extent, AWEIsh, TCW, MNDVI, NDWI | Surface Reflectance products available through Google Earth Engine (GEE) were used to extract spectral indices including the Automated Water Extraction Index corrected for shadows (AWEIsh), Tassled-Cap Wetness (TCW), Normalized Difference Vegetation Index (NDVI) and the Modified Normalized Difference Water Index (MNDWI). Resulting indices were then used to compute the dynamic surface water extent and to perform a time series analysis of changing stock pond surface water extents under varying levels of drought conditions in a range of arid and vegetated landscapes. The classification workflow was integrated into the surface water extent monitoring tool. |
| **Sentinel-2 MSI** | Dynamic surface water extent, AWEIsh, TCW, MNDVI, NDWI | Surface Reflectance products available through GEE were used to extract spectral indices including Automated Water Extraction Index corrected for shadows (AWEIsh), Tassled-Cap Wetness (TCW), Normalized Difference Vegetation Index (NDVI) and the Modified Normalized Difference Water Index (MNDWI). Resulting indices were then used to compute the dynamic surface water extent and to perform a time series analysis of changing stock pond surface water extents under varying levels of drought conditions in a range of arid and vegetated landscapes. The classification workflow was integrated into the surface water extent monitoring tool. |
| **Sentinel-1 SAR** | VV/VH polarization bands, instrument angle | The Synthetic Aperture Radar (SAR) Ground-Range Detected (GRD) product publicly available through GEE was used to classify surface water using a previously published workflow from Mullissa et al. (2021). Results were then integrated into the workflow as a precursor for NiSAR data in the time-series analysis, pond classifications, and tool development. |
| **Maxar High-Resolution Satellite Imagery Basemap** | Surface water extent | Maxar high-resolution imagery was used to resolve and to digitize several surface water extents and dry regions on the date of image capture. This dataset was not shared with partners or stakeholders. |
| **Surface Water and Ocean Topography (SWOT)\*** | Surface water cover | Future update of the monitoring tool would benefit from the high-resolution measurements of temporal changes in water bodies. |
| **NiSAR\*** | Water cover, soil moisture | This dataset will be used to measure surface water extents in future iterations of this work. While not launched yet, this dataset could be integrated in the future to update and maintain the stock pond surface area monitoring tool. |

**\*Not available yet, consider for future applications**

***Ancillary Datasets:***

* US Forest Service Stock Pond Location Shapefile – used to locate and identify stock ponds located on US Forest Service land for analysis
* Bar T Bar Ranch Stock Pond Location Shapefile – used to locate and identify stock ponds within the Bar T Bar ranch for analysis

***Software & Scripting:***

* Google Earth Engine – used to create the time series of surface water extents in Arizona and to design the Surface Water Identification Forecasting Tool (SWIFT)
* Esri ArcPro 2.8 – used to digitize surface water extents for several ponds and dry areas in Maxar high-resolution satellite imagery for training the classification model

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Stock Pond Time Series Analysis Maps** | Landsat 8 OLI, Sentinel-2 MSI, Sentinel-1 SAR | End-users may implement the stock pond time series analysis to interpret seasonal to interannual spatial variations in regional stock pond water extents from 2015-2021. | N/A |
| **Surface Water Identification Forecasting Tool (SWIFT)** | Landsat 8 OLI, Sentinel-2 MSI, Sentinel-1 SAR | Partners will be able to monitor stock pond water extents at a weekly interval to determine appropriate management practices. | IV |

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

The stock pond time series maps will provide valuable insight regarding recent trends in temporal and spatial variations in stock pond water extents since 2015 throughout the region of interest. The time series maps will inform forecasting of stock pond water levels and adaptive management strategies by land managers, cattle producers, and other stakeholders. The Surface Water Identification Forecasting Tool (SWIFT) will allow end users to access near real-time observations of surface water extents, thereby greatly reducing the substantial time and cost required to monitor stock ponds through *in situ* observations. Therefore, the end products will improve the efficiency of practices and planning for stakeholders who rely on these stock ponds for essential water resources.

***Project Continuation Plan:***

The Idaho DEVELOP team conducted a virtual handoff and closeout with the partners at the end of the term. The partners received all final products, including maps, a Story Map, and a tutorial for the methods of the project. We suggest that future work includes refining the spectral index thresholds developed here for stock pond classification in the region, and incorporating data from the newly launched NASA missions, including NiSAR and SWOT, which will enable expansion of the stock pond time series analysis maps and the potential for more frequent observations implemented into the monitoring tool. Finally, there exists a potential use of this tool to aid fire managers in identifying available nearby water for wildland fire or prescribed firefighting.

**References**

Abrams, R. H. (2010). Correcting Mismatched Authorities: Erecting a New Water Federalism. *Natural Resources & Environment*, *25*, 22.

Archer, S. R. & Predick, K. I. (2008). Climate Change and Ecosystems of the Southwestern United States. *Rangelands*, *30*(3), 23-28. [https://doi.org/10.2111/1551-501X(2008)30[23:CCAEOT]2.0.CO;2](https://doi.org/10.2111/1551-501X(2008)30%5b23:CCAEOT%5d2.0.CO;2)

Crifasi, R. R. (2005). Reflections in a Stock Pond: Are Anthropogenically Derived Freshwater Ecosystems Natural, Artificial, or Something Else? *Environmental Management*, *36*(5), 625–639. <https://doi.org/10.1007/s00267-004-0147-1>

Mullissa, A., Vollrath, A., Odongo-Braun, C., Slagter, B., Balling, J., Gou, Y., Gorelick, N., & Reiche, J. (2021). Sentinel-1 SAR Backscatter Analysis Ready Data Preparation in Google Earth Engine. *Remote Sensing* 13 (10). 1954. <https://doi.org/10.3390/rs13101954>

Nguyen, N. T. (2019). An Automatic Water Detection Approach Using Landsat 8 OLI and Google Earth Engine Cloud Computing to Map Lakes and Reservoirs in New Zealand. *Environmental Monitoring and Assessment*, *191*(4), 1–12. <https://doi.org/10.1007/s10661-019-7355-x>

Yang, X., Qiming, Q., Hervé, Y., Ledauphin, T., Koehl, M., Grussenmeyer, P., & Zhu, Z. (2020). Monthly Estimation of the Surface Water Extent in France at a 10-m Resolution Using Sentinel-2 Data. *Remote Sensing of Environment*, *244*, 111803. <https://doi.org/10.1016/j.rse.2020.111803>