Final Report

Wetlands Protection District: Nevada Wetlands: Monitoring and Assessment, Data Management, and Wetland Program Plan Revision: Task 2

Kenneth McGwire
Desert Research Institute, Reno, Nevada
December 30, 2024

The goal of this project was to develop an online tool that allows non-specialists to access information on the status and trends of Nevada's wetlands. This effort builds on the prior development of a toolbar for Level 1 wetland assessment in the ArcMap GIS software environment (McGwire 2021). The web-based app provides a user-friendly front end to Google Earth Engine which contains a repository of satellite imagery and climate data from NASA's Landsat satellites, the European Space Agency's Sentinel-2 satellites, and the GRIDMET climate data project that covers the last four decades. The online tool allows the user to select sites from the Nevada Priority Wetlands Inventory (NPWI, NNHP 2008), to draw their own study areas on the computer display, or the import shapefiles for study sites from GIS software. In addition to being able to view satellite imagery and aerial photography that has been collected since the 1980s, that data can be transformed into maps of vegetative vigor or inundation extent for the user. Maps can also be generated that present trends in vegetation or inundation over user-specified time periods. All these images and maps, as well as time series plots for these variables, can also be easily generated and exported to the user's local computer. The website was developed and modified based on input from project collaborators and others (e.g. McGwire et al. 2023).

The remainder of this report is the documentation that can be accessed through the tool's website:

- https://dri-apps.earthengine.app/view/ee-nv-wetlands.

In addition, a YouTube video is available that can walk the user through the various functions of the wetland assessment tool:

- https://www.youtube.com/watch?v=JWUVfr3Ue-k

This website provides an effective way for land managers and stakeholders to get quantitative data about how Nevada's wetlands have changed over time, providing a shared resource to promote understanding and agreement regarding the status and trends of these wetlands over the last forty years.

References

McGwire, K.C., 2021. Advanced remote sensing and GIS methods for restoration of the Lahontan cutthroat trout, Conference on Earth Resources and Environmental Remote Sensing/GIS Applications XII, SPIE 11863:243-247.

McGwire , K., E. Miskow, C. Iosso, 2023. Integrating Satellite Imagery, Climate Measures, Realtime Field Measurements, and Species Observations for Nevada Wetlands, NWRA Annual meeting, Reno, Jan 30-Feb 1.

NNHP (Nevada Natural Heritage Program), 2008. 2007 Nevada Priority Wetlands Inventory. E. Skudlarek (ed.) Prepared for Nevada Division of State Parks. Carson City, Nevada.

Nevada Wetlands Assessment Tool

https://dri-apps.earthengine.app/view/ee-nv-wetlands

Introduction

The Nevada Wetlands Assessment Tool is a web-based app for research and education that provides access to satellite imagery and climate data for sites in the Nevada Priority Wetlands Inventory (https://transfer.natureserve.org/download/USGS-NRMP/RecordSet5_2011-09-15/Proj178_Nevada_Priority_Wetlands_Inventory_2007.pdf) to provide information on the status, trends, and resilience of wetland sites in Nevada. Users may also draw their own study areas or import polygons from public Earth Engine Assets. Note that there may be a lag of a few seconds for the user interface to appear. A 15-minute demonstration video is available at https://www.youtube.com/watch?v=JWUVfr3Ue-k.

Methods

General Data Characteristics

The tool makes use of imagery from the Landsat and Sentinel-2 satellite imaging systems. The Landsat image archive is available from 1985 to present and includes data from the Thematic Mapper, Enhanced Thematic Mapper, and Operational Land Imager with a spatial resolution of 30 meters. Imagery from the 10-meter Sentinel-2 Multispectral Instrument is available from 2019 onwards. When requesting individual images, Landsat data is provided before 2019, and Sentinel-2 thereafter. For trend maps or charts, time series that cross 2018/2019 will use Landsat to ensure proper continuity.

Satellite image data are at-surface reflectance, masked using cloud cover and data quality flags, and each image represents the median value from a composite of up to three months of satellite imagery centered on the selected month. This ensures a high probability that the composite image will be free of clouds and wildfire smoke.

Imagery from the National Agriculture Imagery Program (NAIP) is also available. NAIP imagery is collected by aircraft at a 2-meter resolution and repeat coverage for non-agricultural areas is typically 3 years. The NAIP image that is closest in time to the specified date is presented.

Monthly precipitation and temperature data are taken from the PRISM dataset at 4 km resolution (https://www.prism.oregonstate.edu/documents/pubs/2008intjclim_physiographicMapping_daly.pdf). Palmer Drought Severity Index and the Standardized Precipitation Evapotranspiration Index datasets are from GRIDMET (Abatzoglou J. T., Development of gridded surface

meteorological data for ecological applications and modeling, International Journal of Climatology. (2012) doi:10.1002/joc.3413).

Dataset Variables

1. **Remote Sensing Data**
    a. Landsat/Sentinel-2 **NDVI** - NDVI is a remote sensing index used to measure vegetation health by comparing the difference between near-infrared (which vegetation reflects) and red light (which vegetation absorbs). The index ranges from -1 to 1, where higher values indicate healthy, dense vegetation, and lower values indicate sparse or no vegetation. NDVI is widely used to monitor agricultural lands, forests, and other ecosystems.
    b. Landsat/Sentinel-2 **NDVI Trend** - The Sen's Slope trend for NDVI data is a non-parametric method used to calculate the rate of change in vegetation health over time. The Sen's Slope determines the median trend, providing a robust measure of increase or decrease in vegetation cover. This trend analysis is widely applied to monitor long-term vegetation dynamics, land degradation, and ecological changes, offering insights into environmental health and climate impact on ecosystems.
    c. Landsat/Sentinel-2 **Wetness** - The normalized difference water index (NDWI) used in this tool is a ratio of green over short-wave infrared reflectance that can indicate the absorption of light by wet areas. https://support.climateengine.org/article/100-normalized-difference-water-index-ndwi
    d. Landsat/Sentinel-2 **Wetness Trend** -The Sen's Slope trend for NDWI (green / SWIR) is a non-parametric method used to calculate the rate of change in wetness over time. The Sen's Slope determines the median trend, providing a robust measure of increase or decrease in water absorption.
    e. Landsat **Inundation** - Based on training data from across Nevada, a wetness index value >= 0.884 is useful for identifying areas that are inundated. This variable is always based on Landsat, not Sentinel-2.
    f. Landsat **Inundation Trend** - The Sen's Slope trend for inundation calculates the rate of change in inundation over time.
    g. Satellite **True Color Image** - A natural-color satellite image based on red, green, and blue bands. For years before 2019, Landsat imagery with a 30-meter spatial resolution is used. For 2019 and later Sentinel-2 imagery is used.
    h. Satellite **False Color Infrared** - A useful combination of near-infrared, red, green, reflectance displayed on the monitor using red, green, and blue brightness. This type of image incorporates near-infrared wavelengths that are not visible to

humans in which vigorous, abundant vegetation shows up as bright red. For years before 2019, Landsat imagery with a 30-meter spatial resolution is used. For 2019 and later Sentinel-2 imagery is used.

i. **NAIP True Color Image** - A natural-color satellite image based on red, green, and blue bands from aerial photography collected by the National Agriculture Imagery Program. NAIP imagery is updated approximately every three years for non-agricultural lands in Nevada, and the imagery closest to the selected date is selected.

j. **NAIP False Color Infrared** - A useful combination of near infrared, red, green, reflectance displayed on the monitor using red, green, and blue brightness. This type of image incorporates near-infrared wavelengths that are not visible to humans in which vigorous, abundant vegetation shows up as bright red. NAIP imagery is updated approximately every three years for non-agricultural lands in Nevada, and the imagery closest to the selected date is selected.

2. **Climate Data** (links to documentation in blue)
   a. PRISM **Precipitation** - Monthly total water equivalent of precipitation (rain and snow)
   b. PRISM **Min Temperature** - Monthly average of daily minimum temperature
   c. PRISM **Max Temperature** - Monthly average of daily maximum temperature
   d. PRISM **Mean Temperature** - Monthly average of daily mean temperature (calculated as (tmin+tmax)/2)
   e. GRIDMET DROUGHT **Palmer Drought Severity** - PDSI is a meteorological index that quantifies long-term soil moisture conditions based on temperature and precipitation data. The index ranges from extremely wet (e.g. +4) to extremely dry (e.g. -4), with zero representing normal conditions. Palmer Drought Severity Index (PDSI) and Palmer Z-Index - ClimateEngine.org Support
   f. GRIDMET DROUGHT **90-day SPEI** - The Standardized Precipitation Evapotranspiration Index considers both precipitation and potential evapotranspiration to assess drought severity over different time scales. It uses standard deviations to measure anomalies, allowing for analysis of both short-term and long-term droughts. This selection is based on the 90 days up to and including the selected month. Standardized Precipitation Evapotranspiration Index (SPEI) - ClimateEngine.org Support
   g. GRIDMET DROUGHT **6-month SPEI** - This SPEI selection is based on six months up to and including the selected month. Standardized Precipitation Evapotranspiration Index (SPEI) - ClimateEngine.org Support

h. GRIDMET DROUGHT **9-month SPEI** - This SPEI selection is based on 9 months up to and including the selected month. [Standardized Precipitation Evapotranspiration Index (SPEI) - ClimateEngine.org Support]

Web Application

Introduction

The web application is a Google Earth Engine Application. Earth Engine Applications are dynamic, publicly accessible user interfaces that can interact directly with the Earth Engine Data Catalog and utilize Earth Engine's analysis tools via the code editor, a web-based IDE for the Earth Engine JavaScript API. Figure 1 shows the primary components of the interface.

Using the Interface

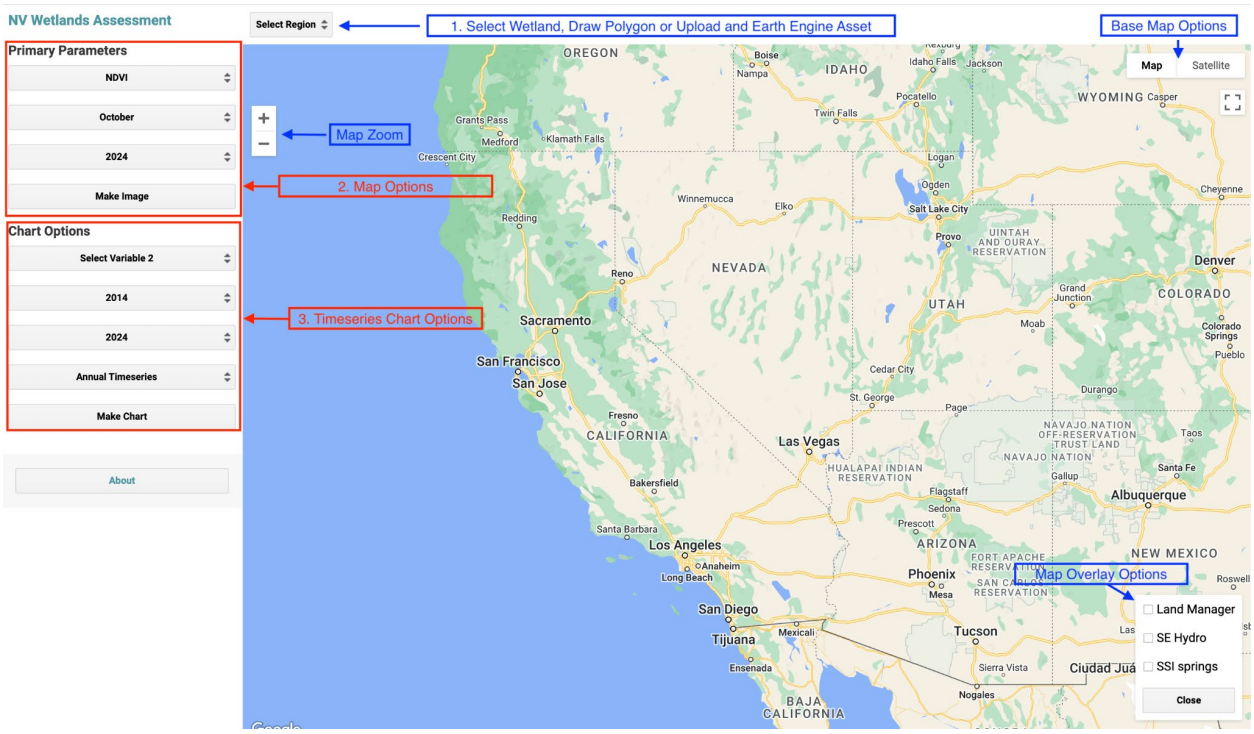

Figure 1: Components of the web-based interface

1. Selecting a Region of Interest

You can generate a map without first selecting a region of interest first, but charting functions do require a region to be selected. To do so, you can: a) Choose a Wetland from a list, b) Draw a custom polygon, or c) Upload an existing public Earth Engine asset.

a) Selecting a Wetland from the dropdowns or the map

When you choose “Select Wetland” from the “Select Region” dropdown, the “Select Site” pulldown menu will display the list of sites from the Nevada Priority Wetlands Inventory (NNHP, 2008), and you will see several filter options and the Wetlands overlay on the map. You can choose a wetland directly or using the filter dropdown menus to limit the wetland list base on characteristics such as county, land management agency, or recorded sitings of watchlist species in the vicinity. Alternately, a site may be selected from the map by clicking on it (Figure 2).

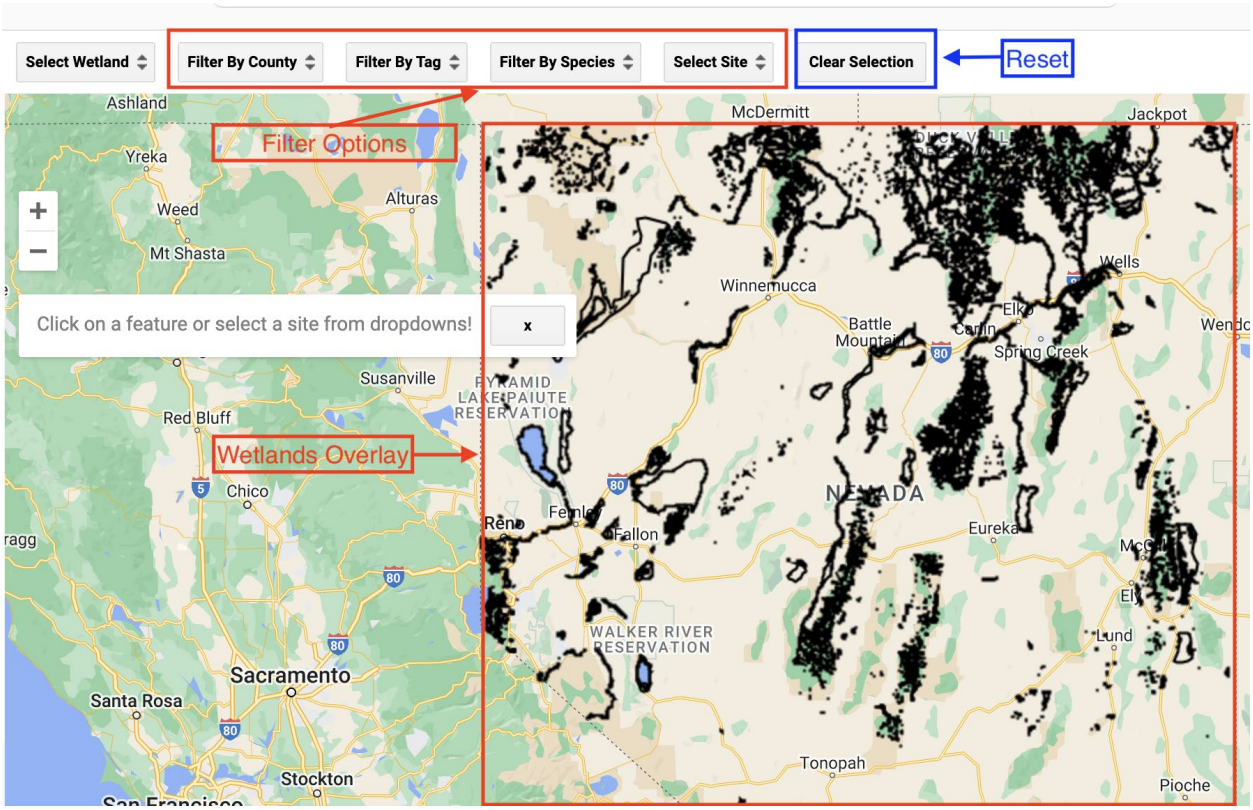

Figure 2: Filtering the NPWI list and selecting a site.

b) Drawing a custom polygon

Choose the drawing mode in the upper left corner and click on the map to define the vertices of your polygon (Figure 3). Double-click to close the polygon. If you need to get out of drawing mode, simply click on the pan mode icon at the top of the map. Note that as the polygon size increases, processing time increases exponentially.

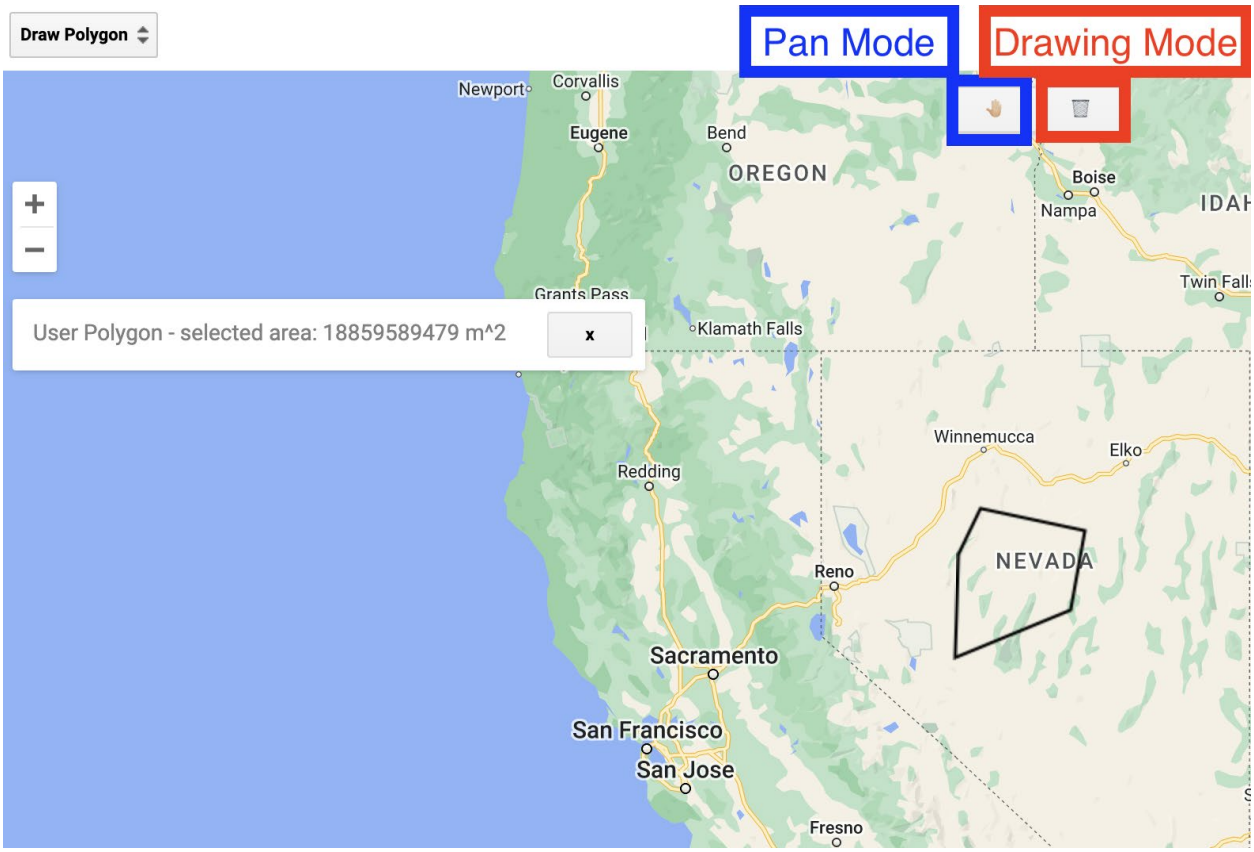

Figure 3: Drawing a polygon on the screen to create a region of interest

c) Upload an Earth Engine Asset

If you have access to Google Earth Engine, you can also upload an existing Earth Engine asset containing regions of interest. Information on how to create a Google Earth Engine account can be found at: https://earthengine.google.com. Please make sure the asset is readable by anyone (i.e. public). Figure 4 is an example of boundaries that were imported for Nevada Grazing allotments as used by the Bureau of Land Management (projects/climate-engine/featureCollections/shp_orig/ClimateEngine_US_BLM_Grazing_Allotments_NV). Just like in the case of Wetland Selection, you can either choose a region from the dropdown or click on a region on the map to select your interest region.

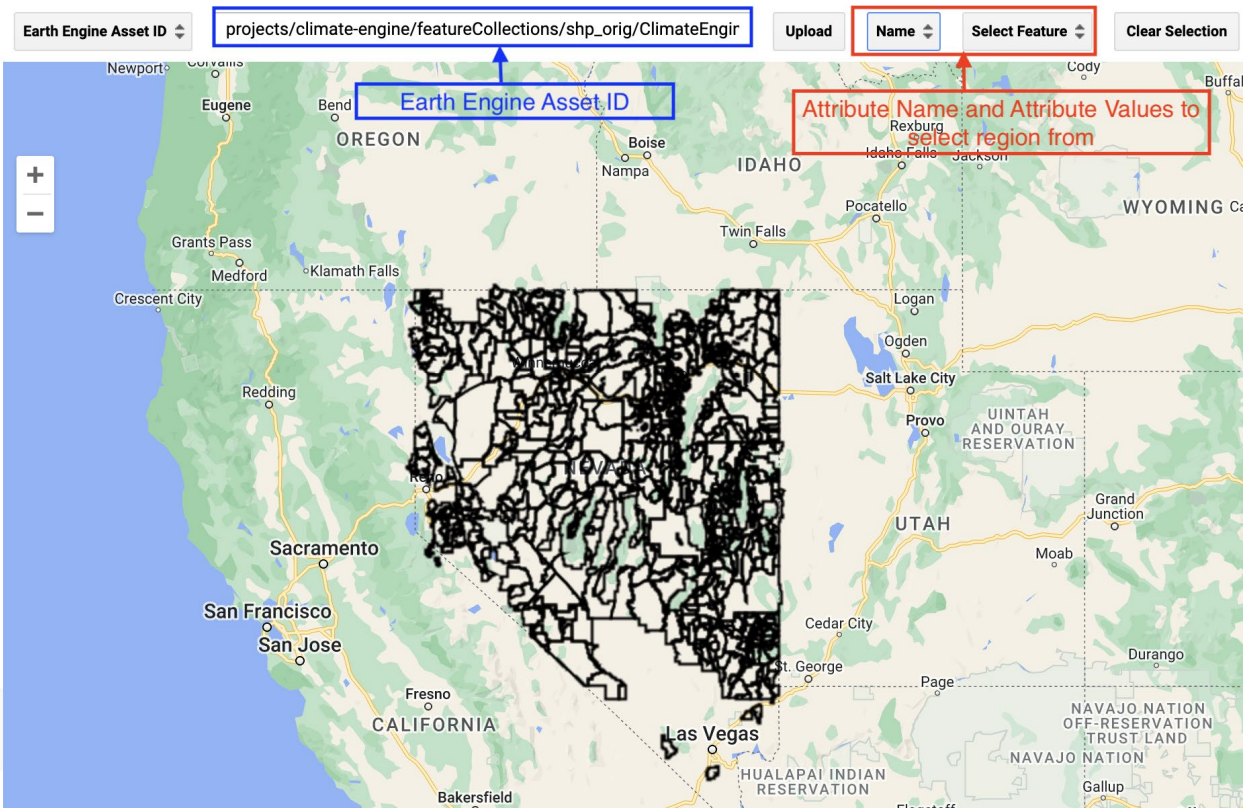

Figure 4: Imported a shapefile of grazing allotment polygons as an Earth Engine asset.

2. Selecting Map Parameters

The map options are defined in the “Primary Parameters” section. Pulldowns allow the user to select the variable to be displayed for a given month and year. For satellite imagery from dates prior to 2019, or for trend maps that include years before 2019, 30-meter resolution Landsat imagery is used. For dates 2019 and later, higher-resolution 10-meter Sentinel-2 data is used. In order to provide a cloud and smokefree image, the median value from multiple satellite overpasses is calculated. Landsat overpasses are approximately twice per month which is not frequent enough to ensure a cloudfree image, so the returned image is the median of a three-month window (i.e. July button selection is the median of June, July, and August). Sentinel-2 imagery from 2019 onwards has an overpass every five days, so for that imagery the returned image is the median value from just the selected month. Climate variables are for the selected month, or aggregated value ending in that month (i.e. 6-month SPEI with August selected is April – August).

Figure 5 demonstrates Normalized Difference Vegetation Index (NDVI) data that indicates the amount and vigor of vegetation for the NPWI site called Warm Springs Ranch for July 2024. Since this is after 2019, it uses Sentinel-2 data with a 10-meter spatial resolution and represents a composite of images just from that month.

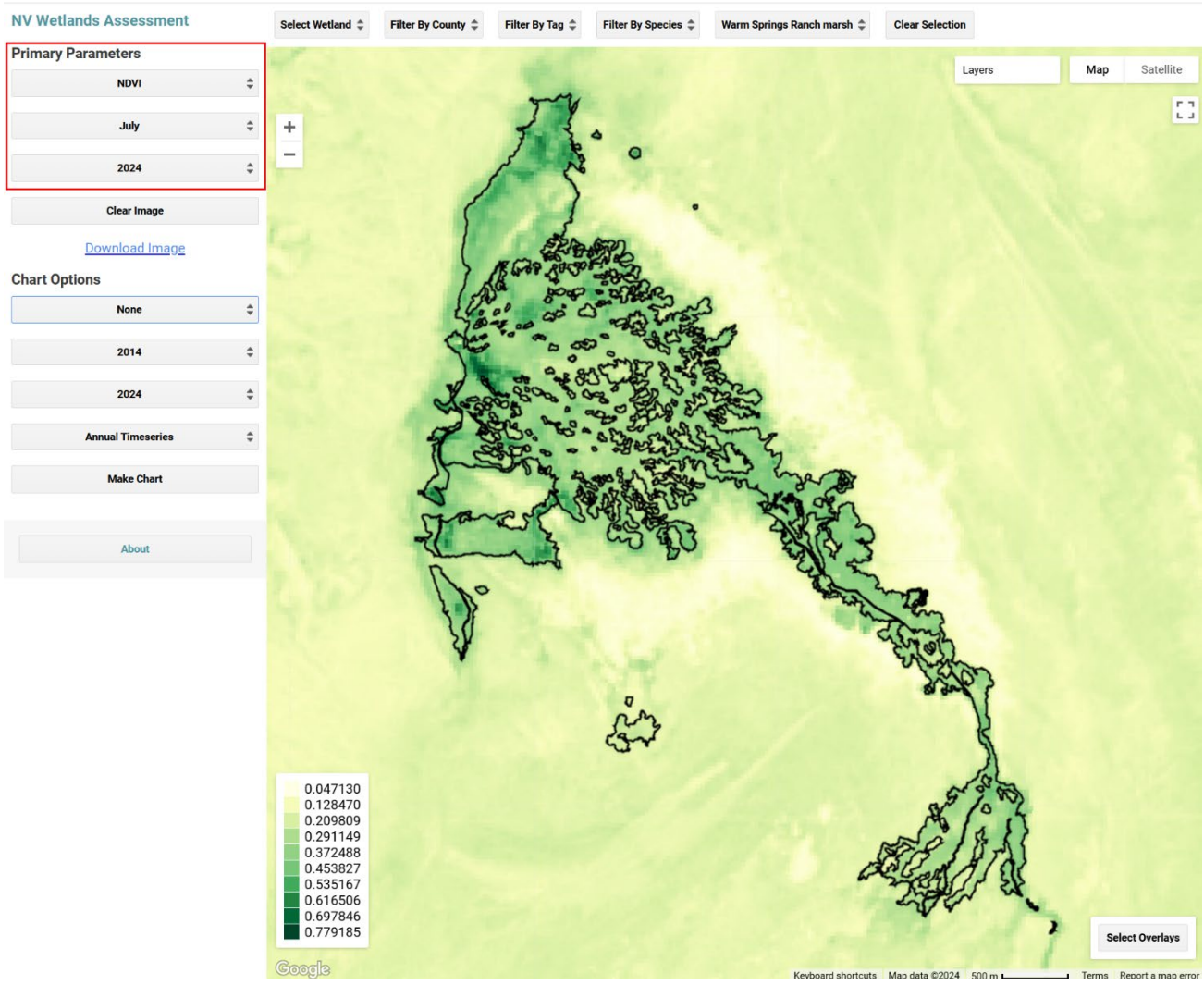

Figure 5: Normalized Difference Vegetation Index data for the Warm Springs Ranch NPWI site for July, 2024.

Once an image is rendered, it can be downloaded to the local machine using the blue link in the Primary Parameters section. The image will be downloaded to your browser's default Download Folder.

3. Selecting Chart Parameters

A time-series chart of the mean value within the selected polygon for the selected variable and month can be displayed, and that data can be downloaded to the local computer. The variable and month to be used in the plot are selected in the "Primary Parameters" section. The range of years are specified in "Chart Options" and whether the user wants an annual time series with separate values for that month in each year, or a monthly climatology that summarizes the monthly value for each month across all years. Note that trend variables that

are available in the “Primary Parameters” section cannot be charted since they have already reduced a time range to a single value.

Figure 6 shows a chart of the Normalized Difference Vegetation Index and the Palmer Drought Severity Index within the Warm Springs Ranch polygon for July in 2014 to 2024. If desired, the user can click on the “Calculate Correlation” button and Pearson’s correlation coefficient will be added to the chart. You can click on the icon on the right side of the chart (square with an arrow) to open it in larger format in a separate tab of your web browser. Figure 9 shows this expanded view and indicates that vegetative vigor within the selected area is sensitive to drought cycles and not entirely buffered from drought by springs at the site. Buttons in the expanded view also allow the user to download the chart as data values in a comma-separated values (CSV) file, or as a graphic in SVG or PNG formats.

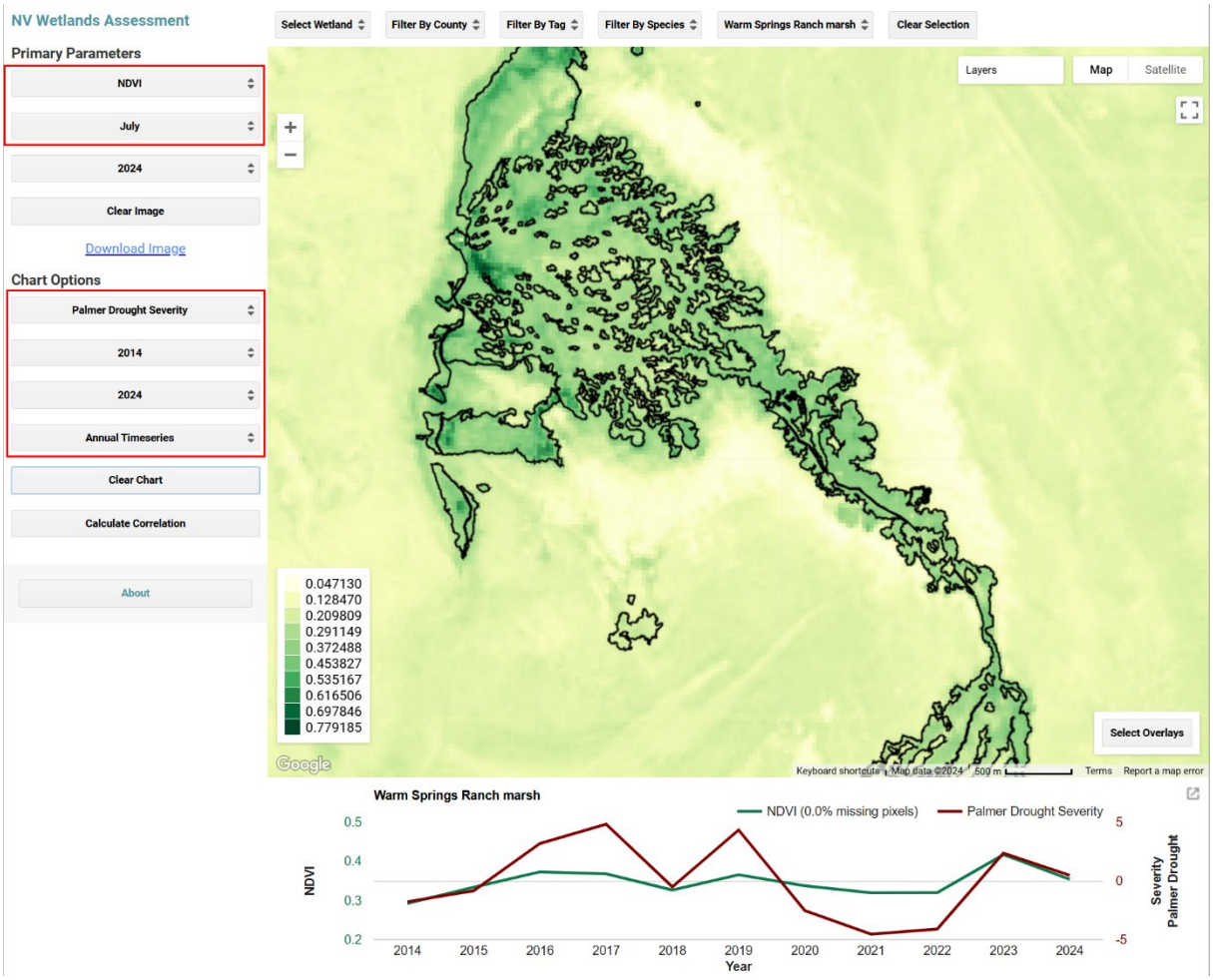

Figure 6: Normalized Difference Vegetation Index and Palmer Drought Severity Index data within the Warm Springs Ranch polygon for July in 2014 to 2024.

Figure 7: Expanded view of chart in Figure 6 as a separate tab in the web viewer including links to download the data.

If “Monthly Averages” are selected in the “Chart Options”, the mean value in each month across the specified range of years is calculated. Figure 8 shows how temperature and precipitation at Warm Springs over the past ten years (2015-2024) compares to 1985 – 2024. This data was generated using the NV Wetlands Assessment web page, downloaded as a CSV, and plotted in Excel. While ten years is a short period for climatological assessment, it appears that summer temperatures and overall precipitation were higher in the last decade.

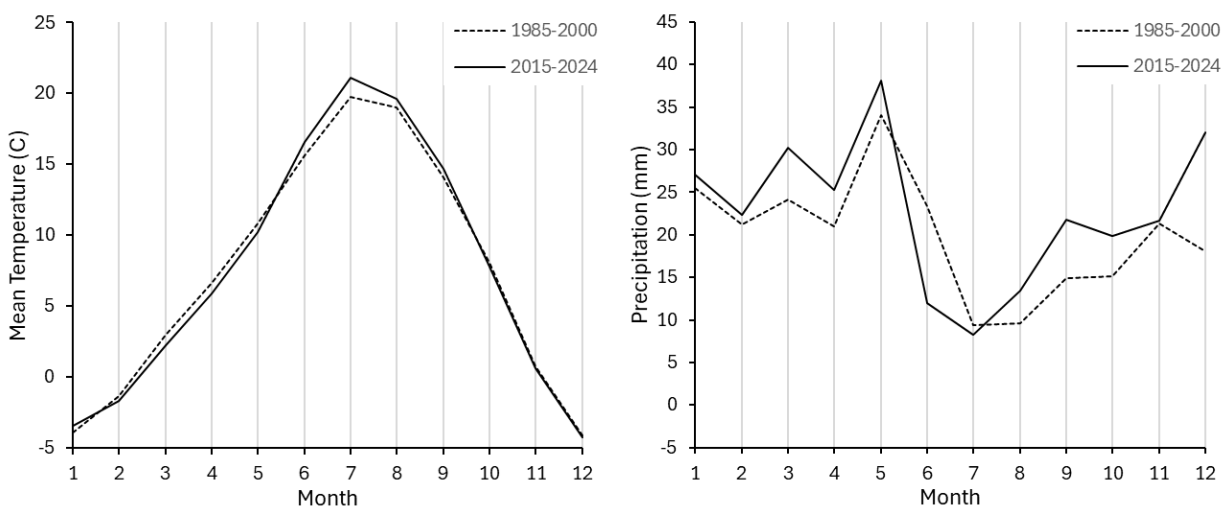

Figure 8: A comparison of the climatology of average temperature (left) and precipitation(right) at Warm Springs Ranch for 2020-2024 versus 1985-2000.