**Aconcagua Basin Agriculture**

*Analyzing Hydrological Norms, Soil Moisture, Evapotranspiration, and Vegetation Indices to Assess Crop Water Demand and Water Usage in Chile’s Aconcagua Basin*

**Project Team**

***Project Team:***

Javiera Canales (Project Lead)

Daniela Quintero

Carmen Petras

***Advisors & Mentors:***

Dr. Kenton Ross (NASA Langley Research Center)

Dr. Venkataraman Lakshmi (University of Virginia)

Lauren Childs-Gleason (NASA Langley Research Center)

***Fellow:***

Olivia Landry (Virginia – Langley)

***Team Contact:*** Javiera Canales, jbcanalesv@gmail.com

***Partner Contact:*** Felipe Antonio Arróspide Alarcón, farrospide@ciren.cl

***Partner Contact:*** Fernando Vasquez, fernando.vasquez@minagri.gob.cl

**Project Overview**

***Project Synopsis:***

This project informs agriculture and water allocation decisions using earth observation analysis in Chile’s Aconcagua River Basin (ARB). The DEVELOP team focused on hydrological norm variables, soil moisture, evapotranspiration, and vegetation indices to comprehensively view water usage during the current drought. The results displaying exaggerated water use in several subregions compared to others are useful for our partners to determine highly irrigated areas and inform water allocation plans.

***Abstract:***

The Aconcagua basin has experienced a prolonged drought since 2010, posing a significant concern to the agricultural sector, which contributes to 12% of the national agriculture output. Reduced precipitation and warmer conditions have led to water constraints for agricultural activities. As the agriculture sector relies more on irrigation, there has been a decline in surface water availability and a shrinking groundwater supply, both primarily sourced from snow and glacial melt. This study focuses on evaluating crop water demand and water usage in the Aconcagua Basin, leveraging in-situ and available satellite data from Aqua and Terra Moderate Resolution Imaging Spectroradiometer (MODIS), 1-km downscaled Soil Moisture Active Passive (SMAP), Global Precipitation Measurement Mission IMERG (GPM), and Landsat 8 Operational Land Imager (OLI). Remote sensing hydrologic norms from pre and intra-drought conditions provided a baseline for our water use analysis. We have identified areas of the basin where water usage is exaggerated compared to other regions by analyzing soil moisture, evapotranspiration, and vegetation index trends across agricultural lands. The study highlights the presence of irrigation and exaggerated water usage categorized by crop type while normalizing the data by the quantity of water allocation (m3/s) to each subregion. The findings have the potential to assist our partners, the Centro de Información de Recursos Naturales (CIREN) and the Ministry of Agriculture, in refining water allocation approaches; showcasing the feasibility of leveraging remote sensing and earth observation datasets to monitor agricultural practices within the context of water scarcity.

***Key Terms:***

Remote sensing, soil moisture, evapotranspiration, drought, agriculture, crop demand, Chile, water allocation

***Study Location:*** Aconcagua River Basin, Chile

***Study Period:*** January 2010 to June 2023

***Community Concerns:***

* Decreased precipitation and less surface water since 2010 have caused significant water stress on the agriculture sector. This decline in precipitation and surface water causes a depletion of groundwater supplies
* The agriculture community has expressed concern regarding the reduced water supply since 2010. Farmers claim this has caused declines in crop yields in the region
* An increase in water-demanding crops such as avocado in the Aconcagua River Basin region is furthering the depletion of surface and groundwater during the drought in the region
* The exaggeration of water use in the region as well as the decreasing water table height may cause significant community concerns around drinking water insecurity and food insecurity. The Aconcagua River Basin is an agriculture hub in the region, therefore, if production can no longer take place, then food insecurity in the Metropolitan region nearby becomes problematic

***Project Objectives:***

* Compare hydrologic norms for pre- and intra-drought conditions in the ARB
* Analyze soil moisture and evapotranspiration trends in the region over agricultural lands
* Discover the presence of irrigation and excessive water usage by crop type per subregion
* Inform our partners on agricultural water usage and potential future water allocation risks in the basin by crop type during the megadrought period

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization(s)** | **Contact (Name, Position/Title)** | **Partner Type** |
| **CIREN** (Centro de Información de Recursos Naturales) | Felipe Antonio Arróspide Alarcón, Head of Water Resoucre Unit | End User |
| **Embassy of Chile, Agricultural Office** | Fernando Vasquez, Information Officer at Embassy of Chile | Collaborator |

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

**The end user of this project, CIREN, is under the Ministry of Agriculture with politically appointed leadership, as such, the conclusions from this study will be passed to other sectors of the government through CIREN. The General Directorate of Water (DGA) is responsible for the administration and control of water resources in the country and has the authority to grant and regulate water allocation. The DGA has the authority to restrict groundwater extraction in situations where there is evidence of a direct impact on groundwater levels or existing groundwater rights (GWR). This restriction may involve temporarily reducing the exercise of groundwater rights or declaring the aquifer under restriction or prohibition. Currently, GWR holders must have systems that measure water flow extraction and volume and send this information to the DGA. This self-reporting of the water extraction system has been the subject of debate and criticism due to various issues with the lack of regulation and control.**

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **SMAP**  | Soil Moisture | SMAP 1-km downscaled was utilized to indicate soil moisture content over croplands and identify spatial trends in the basin. |
| **Terra MODIS** | Evapotranspiration | Terra MODIS was utilized to show evapotranspiration over croplands and identify spatial trends in the basin. |
| **Aqua MODIS** | Temperature | This sensor was utilized to evaluate changes in the land surface temperature before and during the megadrought. |
| **Landsat 8 OLI** | Normalized Difference Vegetation Index | Landsat 8 was utilized to calculate NDVI trends from red and infrared bands over croplands before and during the megadrought. |
| **GPM IMERG** | Precipitation | GPM IMERG was utilized to evaluate precipitation trends before and during the megadrought. |

***Ancillary Datasets:***

* CIREN Land use type and crop cover – Field and census csv datasets were used to identify crop types and clip crops over the region
* CIREN Water allocation/rights – In-situ data was used to calculate water allocation normalized by cropland for each comuna (subregion)
* CIREN Groundwater data – In-situ observations were used to quantify groundwater depletion over time from 2010 to 2023

***Software & Scripting:***

* Esri ArcGIS Pro 3.1.2 – Study area and NDVI map making. Land classification mask creation from ancillary partner dataset
* Google Earth Engine – Land surface temperature, precipitation, NDVI, photosynthetically active radiation data download, processing, and masking
* Python with JupyterLab – Soil moisture and evapotranspiration processing and masking. Hydrological norms, crop quantity, soil moisture, and evapotranspiration visualization.

***End Product(s):***

|  |  |  |
| --- | --- | --- |
| **End Product(s)** | **Earth Observations Used**  | **Partner Benefit & Use** |
| **Monthly Hydrologic Norms Time Series** | Landsat 8 OLI, GPM IMERG, Terra MODIS, Aqua MODIS | Provides a baseline for intra-drought analysis from pre-drought conditions. |
| **Spatial Seasonal Analysis**  | SMAP and Terra MODIS | Displays spatial patterns to evaluate changes in soil moisture and evapotranspiration |
| **Seasonal Crop Type Time Series Analysis**  | SMAP and Terra MODIS | Provides seasonal trends by crop type to identify which crops have a higher water demand |
| **Water Allocation Map** | SMAP and Terra MODIS | Identifies subregions that have more water allocated to the agriculture area and indicate the area covered by each major crop out of the total agriculture area in each subregion |
| **Water Allocation to Evapotranspiration and Soil Moisture Ratios table** | SMAP and Terra MODIS | This Compares the normalized water allocated to each subregion to the evapotranspiration and soil moisture values averaged throughout each subregion. This is useful to indicate subregions that have exaggerated water use compared to others. |
| **Seasonal Relative Analysis for Evapotranspiration**  | Terra MODIS | Represents the proportion of the total accumulated evapotranspiration and water allocated to agriculture areas in each subregion compared to the total. |

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

The DEVELOP team used soil moisture, evapotranspiration, NDVI, and other climatology variables to estimate water usage and irrigation in the central region of the Aconcagua River Basin in Chile. The complicated developed method is feasible for our CIREN partners to apply to other agriculture-intensive areas in Chile as the partners are adept at coding, using GEE, and mapping Earth Observation variables with GIS. The Dirección General de Aguas (DGA) can feasibly use the information provided in this study to inform water allocation decisions based on an increase in irrigation, crop area (especially avocados), and a rapidly lowering water table. It is possible for the project methods to be adapted for any drought-threatened region of the country that has groundwater gauges and water allocation records. Monitoring irrigation and extraction on a farmer level is a sensitive topic within the water rights political discussion in Chile. As soil moisture and evapotranspiration data processing and analyzing methods developed in this study are new to our partners, they may provide additional supporting data to reallocate water usage or restrict planting in acutely drought-stressed areas with the ARB.

**References**

**Budds, J. (2012). La demanda, evaluación y asignación del agua en el contexto de escasez: Un análisis del ciclo hidrosocial del valle del río La Ligua, Chile. Revista de Geografía Norte Grande, 52, 167–184.** [**https://doi.org/10.4067/S0718-34022012000200010**](https://doi.org/10.4067/S0718-34022012000200010)

**Donoso, G., Lictevout, E., & Rinaudo, J.-D. (2020). Groundwater Management Lessons from Chile. In J.-D. Rinaudo, C. Holley, S. Barnett, & M. Montginoul (Eds.), Sustainable Groundwater Management (Vol. 24, pp. 481–509). Springer International Publishing.** [**https://doi.org/10.1007/978-3-030-32766-8\_25**](https://doi.org/10.1007/978-3-030-32766-8_25)

**Muchnik, E., Luraschi, M., & Maldini, F. (1997). Comercialización de los derechos de aguas en Chile. Naciones Unidas División de Desarrollo Productivo y Empresarial, CEPAL**