**Maipo River Valley Agriculture**

*Determining Crop Coefficients Using Remote Sensing for the Maipo River Valley Basin in Chile*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:***

Crop coefficients (Kc) are helpful in calculating crop evapotranspiration and thereby assessing actual irrigation needs. Frequently used Kc estimates from the Food and Agricultural Organization (FAO) report No. 56 do not account for geographic and climatic conditions in Chile, resulting in inaccurate assessments of water requirements. This project utilized two approaches, a NDVI-based Kc and a ETc-based Kc, to generate site-specific crop coefficients for the Maipo River Valley in Chile. These techniques were implemented, validated, and compared between crop types, through growing seasons, and across the region. Study findings provided partner organizations with tested methodologies to follow for Kc calculation, application, and limitation.

***Abstract:***

Agriculture is the primary use of water in the Maipo River Valley of Central Chile, accounting for ~ 75% of the total demand. Assessment of irrigation needs for agricultural production has commonly relied on reference crop coefficients (Kc) derived from geographic and climatic conditions that differ from those of Chile. In partnership with the Centro de Información de Recursos Naturales (CIREN), this work focused on calculating site-specific crop coefficients tailored to crop production in the water-stressed Maipo River Valley. Two distinct approaches were implemented, each relying on remotely-sensed Earth observation datasets from NASA over consecutive growing seasons from 2019 to 2022. The first method estimated Kc values based on their linear relationship with the Normalized Difference Vegetation Index (NDVI) obtained from either Terra Moderate Resolution Imaging Spectroradiometer (MODIS) or Landsat 8 Operational Land Imager (OLI) surface reflectance. The second technique leveraged information from the ISS Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) by computing the ratio between actual crop evapotranspiration (ET) and potential evapotranspiration (PET). Both procedures showed promising results that can build on one another. The former approach best captured vegetation signals of annual crops while the latter appeared suited for perennials. Overall, this study provides a strong basis and novel way to accurately estimate Kc using remote sensing, with the potential for improved irrigation management and reduction in water consumption.

***Key Terms:***

crop coefficient, evapotranspiration, Landsat, MODIS, ECOSTRESS, irrigation needs, water scarcity

***National Application Areas Addressed:*** Agriculture, Water Resources

***Study Location:*** Maipo River Valley, Central Chile

***Study Period:*** 2019 to 2022 (November to February)

***Community Concerns:***

* The Maipo region is an agricultural hub. However, annual precipitations are concentrated in the winter months, causing the agricultural sector todepende on irrigation, using roughly three-quarters of the basin’s water.
* Most of the irrigated areas depend on water withdrawals from surface flows. Climate related changes in runoff and streamflow are predicted to result in water supply shortages in this semi-arid region.
* Chile has been experiencing a megadrought beginning in 2010 and extending to present (August 2022). Combined with the potential aridification of the region, the ongoing drought stresses water availability for cities, hydropower generation, and agriculture. More competition across sectors for water withdrawal is putting irrigated agriculture at risk in the Maipo River Valley.

***Project Objectives:***

* Leverage NASA Earth observation datasets to obtain crop coefficients specific to the geographic and climatic conditions of the Maipo River Valley
* Compare different Kc methodologies and confirm Kc estimates between crop types, through growing seasons, and across the region
* Assess actual evapotranspiration and water demand of agricultural production based on remotely-sensed information

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Centro de Información de Recursos Naturales (CIREN)** | Fernando Neira, Engineer | End User |
| **Embassy of Chile, Agricultural Office** | Fernando Vasquez, Agriculture Information Officer; Andrés Rodriguez, Vice President of Geographic Information, Environment, Territorial and Urban Planning | Collaborator |

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

Through the use of geospatial technologies and applications, CIREN contributes to land-use planning, resource management, and public decision-making. In 2021, CIREN performed a study examining the demand for water of agricultural production among four watersheds including the Maipo River Valley. In that process, there were concerns about relying on standardized crop coefficients from the FAO Irrigation and Drainage Paper No. 56. These reference Kc values were based on areas with differing geographic and climate conditions than those of Chile, resulting in potentially inaccurate calculations of crop irrigation requirements and water allocations. CIREN identified a need for linear models and Kc values applicable to the Maipo region, which would enhance their current approach for assessing irrigation needs.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 8 OLI** | Surface Reflectance | Surface reflectance data bands were used to calculate NDVI. A relationship was thereafter developed between calculated NDVI and reference Kc values (from the FAO) to obtain site-specific Kc values. |
| **Terra MODIS** | PET | Potential evapotranspiration (PET) was multiplied by crop coefficients (either reference or site-specific) to obtain estimates of evapotranspiration (ET) and irrigation requirements. |
| **ISS ECOSTRESS** | ET, PET | ET values were divided by PET values to approximate site-specific Kc. |

***Ancillary Datasets:***

* CIREN uso de suelo actual cuenca del Río Maipo – Geospatial database of parcel extents and crop types for agricultural production in the Maipo River Valley for informing site selection (privately shared data)
* CIREN calendario de fenología de cultivos dentro de la cuenca del Río Maipo – Phenological calendar that provided timeframes ~~for~~ of t growth stages for agricultural production in the Maipo River Valley
* Infraestructura de Datos Geoespaciales de Chile (IDE Chile) límite de la cuenca del Río Maipo – Boundary limits of the Maipo River basin for examining watershed extents.
* NASA's Shuttle Radar Topography Mission (SRTM) – Digital Land Elevation Data for informing site selection
* FAO irrigation and drainage paper No. 56 Tables 11 and 12 – Lengths of crop development stages and typical values of crop coefficients for creating reference curve

***Software & Scripting:***

* Google Earth Engine API – Data acquisition and manipulation, vegetation index calculation
* Python 3.7.13 through Google Colab – Data visualization, sampling and averaging cells, spatial and temporal analyses, linear regression fitting, computation of coefficients of determination and errors, model validation, residual/bias analysis, Kc calculation, ET estimation, plot creation
* Esri ArcGIS Pro 2.9.3 – Data visualization, site selection, map creation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **NDVI–Kc Crop Coefficient Methodology** | Landsat 8 OLI Terra MODIS | The NDVI-based Kc crop coefficient approach will provide partners with a methodology to calculate Kc by evaluating the linear relationship between NDVI and reference Kc during the growing season. | N/A |
| **ETc–Kc Crop Coefficient Methodology** | ISS ECOSTRESS | The ETc-based Kc crop coefficient approach will provide partners with a methodology to calculate Kc through the ratio between actual crop evapotranspiration (ETc) and reference potential evapotranspiration (ETr). | N/A |
| **Comparison Analysis** | Landsat 8 OLITerra MODISISS ECOSTRESS | The comparison between the NDVI-based Kc and ETc-based Kc crop coefficient approaches will inform partners of the benefits and potential limitations of the two methodologies. | N/A |

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

The two developed methodologies will provide CIREN with site-specific crop coefficients based on remote sensing information. It is a basis to assist CIREN in evaluating water demands and improving irrigation management approach in Chile's agricultural regions. To further alleviate water scarcity and provide greater community resilience, these end products will also be shared with other organizations such as the Comisión Nacional de Riego (CNR) and the Fundación Para la Innovación Agraria (FIA) in support of their decision making around agriculture and irrigation.

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