**Argentina Food Security & Agriculture**

*Crop Monitoring and Forecasting for Argentina Using NASA Satellite Observations*

**Project Team**

***Project Team:***

Ryan Lam (Project Lead)

Brooke Egley

Tyler Pantle

Sienna Templeman

Caroline Williams

***Advisors & Mentors:***

Dr. John D. Bolten (NASA Goddard Space Flight Center)

Dr. Nazmus Sazib (NASA Goddard Space Flight Center)

***Team POC:*** Ryan Lam, ryannlam@ucla.edu

***Software Release POC:*** Sienna Templeman, sienna.templeman@gmail.com

***Partner POC:*** Esteban Copati, ecopati@bc.org.ar

**Project Overview**

***Project Synopsis:***

Argentina is a major producer and exporter of soybeans, corn, and wheat in the world market. Therefore, the accurate forecasting of crop yields is crucial to national crop management and food security. This project combined crop yield data and NASA Earth observations to build three products: (1) a Normalized Difference Vegetation Index (NDVI) forecasting model, (2) a crop yield forecasting model, and (3) a time series tool for producing maps and figures of climate variables. These end products can assist partners in predicting crop yields and understanding seasonal variation in climate variables that are critical to crop development.

***Abstract:***

Early harvest information helps drive the national budget in Argentina, providing valuable planning information to identify potential food-insecure regions, anticipate transportation and storage demands, predict price fluctuations, and project commodity trends. However, crop yield estimates are currently subjective, as they are based on interviews with qualified informants (i.e., farmers and agribusiness actors). In partnership with the Buenos Aires Grain Exchange, we leveraged Terra Moderate Resolution Imaging Spectroradiometer (MODIS), Soil Moisture Active Passive (SMAP), and Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (GPM IMERG) NASA Earth observations to develop a Google Earth Engine (GEE) toolset to monitor vegetation growth. The first component of the toolset produces spatial and temporal maps of temperature, precipitation, soil moisture, and the Normalized Difference Vegetation Index (NDVI), allowing users to visualize the influence of regional climate and weather. Next, we developed an autoregressive model to predict NDVI several months in advance**.** Lastly, we created a linear regression model of crop yield and NDVI for soybeans, corn, and wheat, and input the forecasted NDVI to generate a predicted crop yield output. The NDVI model had a RMSE of 0.074 and at agricultural zone 6 produced R2 values of 0.99, 0.89, and 0.54 at two-, four-, and six-month forecasts, respectively. The crop yield model produced R2 values of 0.84, 0.90 and 0.005 respectively for soybeans, corn, and wheat in zone 3 after model calibration. This information is vital for vegetation growth monitoring by identifying areas of high growth and allocating resources to areas of lower growth to efficiently maximize crop yields.

***Key Terms:***

Normalized Difference Vegetation Index, Soil Moisture Active Passive, crop yield monitoring and forecasting, Google Earth Engine

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

***Study Location:*** Argentina

***Study Period:*** November 2012 – July 2021

***Community Concerns:***

* Argentina’s economy is dependent on its crop production. Therefore, crop yield forecasting is essential for farmers, consumers, and policymakers. Current forecasting models rely mainly on *in situ* measurements of vegetation health, soil moisture, and precipitation to evaluate growing conditions. However, these data are not widely available across the country.
* Temperature, soil moisture, and precipitation affect the growing conditions for major crops. Fluctuations in these environmental factors affect crop yield and can result in food insecurities in Argentina.
* Large datasets require wide-scale data gathering, processing, cleaning, and maintenance to maximize usefulness. This poses significant limitations surrounding technical capacity for data analysis.
* Data processing limitations can make an applicable and useful dataset unusable. A lack of data processing infrastructure limits accessibility and analytic outputs.

***Project Objectives:***

* Generate spatial and temporal maps and figures of temperature, precipitation, soil moisture, and NDVI
* Develop GEE tools to monitor and forecast NDVI and crop growth up to four months in advance

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Buenos Aires Grain Exchange, Agricultural Estimates Department** | Esteban J. Copati, Department Head | End User | Yes |

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

The Grain Exchange has been gathering observed crop yield data through telephone surveys funded by a United States Department of Agriculture (USDA) grant since 2010, a more efficient system than the previous data collection method of email surveys. The data management system moved from Excel spreadsheets to a database format due to the influx of data that accompanied the transition to telephone surveys. As a result of improved data collection efficiency, the Grain Exchange now has an abundance of observation data without the necessary infrastructure to analyze or process the data, particularly alongside estimations. Weekly analysis reports from the Grain Exchange are disseminated to actors within the agricultural decision-making chain and utilized by various stakeholders. The Grain Exchange has endeavored to utilize tailored satellite data to look at agricultural crop conditions and make their products more useful. However, the current decision-making process relies more heavily on observed data and ready-made data products than forecast models for agricultural crop conditions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Terra MODIS** | Vegetation indices, land surface temperature (LST) | MODIS NDVI was utilized to observe vegetation trends and project vegetation conditions. LST was obtained to calculate the land surface temperature of the region. |
| **SMAP** | Soil moisture | NASA-USDA SMAP was acquired to observe historical and existing soil moisture conditions. |
| **GPM IMERG** | Precipitation | GPM IMERG was used to examine temporal precipitation trends across the region and identify extreme precipitation occurrences. |

***Ancillary Datasets:***

* Buenos Aires Grain Exchange Agricultural Zones – Shapefile delineating 15 agricultural zones in Argentina
* Buenos Aires Grain Exchange Argentina Crop Yield Data – Regionally specific observation data for soybeans, corn, and wheat crop yields in the study area

***Software & Scripting:***

* Esri ArcGIS Pro 2.5.1 – Raster and vector manipulation and analysis, map creation
* Google Earth Engine (GEE) – Acquisition, processing, and analysis of Terra MODIS temperature and NDVI, GPM IMERG precipitation, and SMAP-based soil moisture information, as well as development of NDVI and crop yield forecasting tools
* R 4.0.2 – Statistical analyses of Terra MODIS temperature and NDVI, GPM IMERG precipitation, and SMAP-based soil moisture products

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Spatial Maps of Temperature, Precipitation, Soil Moisture, and NDVI** | Terra MODIS, SMAP, GPM IMERG | The maps will allow partners to spatially visualize climate and NDVI data across Argentina. This will help identify how temperature, precipitation, soil moisture, and NDVI vary across different regions of Argentina. | N/A |
| **Monthly Time Series Graphs of Seasonal Temperature, Precipitation, Soil Moisture, and NDVI** | Terra MODIS, SMAP, GPM IMERG | These graphs will allow partners to visualize climate and NDVI data throughout Argentina during the study period. This will help identify how annual crop yields relate to changes in temperature, precipitation, soil moisture, and NDVI. | N/A |
| **GEE Toolset to Forecast End-of-season Crop Yields in Argentina** | Terra MODIS | This model will forecast NDVI-based, end-of-season crop yields across regions of Argentina. This will assist the partners with predicting crop prices and anticipating market fluctuations. | III |
| **ArcGIS StoryMap** | N/A | This interactive deliverable will provide a clear and concise description of our project, methodology, and results. This will allow the partners to easily share information about this project. | N/A |

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

The end products will provide information on the region’s climate, soil moisture, and vegetation conditions and estimate end-of-season crop yield for the Grain Exchange. The resulting GEE toolset will reduce concerns and limitations relating to time, technical skill, and data management. The time series plots and spatial maps of temperature, precipitation, soil moisture, and vegetation health will improve the Grain Exchange’s ability to assess current crop conditions. Additionally, forecasting NDVI will help the organization estimate crop yield prior to harvest. The GEE toolset will enhance the Grain Exchange’s decision-making process as they interact with various users and actors including farmers, agricultural agencies, local government, insurance companies, producers, traders, seed companies, market analysts, and policymakers. The end products will also improve the Grain Exchange’s ability to recognize potential food insecurity concerns and better understand and predict market trends.

**References**

Hachicha, M., Louati, M., & Kallel, A. (2018). Forecasting of the normalized difference vegetation index time series in Jbeniana. *2018 4th International Conference on Advanced Technologies for Signal and Image Processing*  *(ATSIP),* 1-4. https://doi.org/10.1109/ATSIP.2018.8364499

Lopresti, M. F., Di Bella, C. M., & Degioanni, A. J. (2015). Relationship between MODIS-NDVI data and

wheat yield: A case study in Northern Buenos Aires province, Argentina. *Information Processing in*  *Agriculture*, *2*(2), 73–84. https://doi.org/10.1016/j.inpa.2015.06.001

Mkhabela, M. S., Bullock, P., Raj, S., Wang, S., & Yang, Y. (2011). Crop yield forecasting on the Canadian

Prairies using MODIS NDVI data. *Agricultural and Forest Meteorology*, *151*(3), 385–

393. https://doi.org/10.1016/j.agrformet.2010.11.012

Sazib, N., Mladenova, I., & Bolten, J. (2018). Leveraging the Google Earth Engine for drought assessment

using global soil moisture data. *Remote Sensing*, *10*(8). https://doi.org/10.3390/rs10081265