**Northern & Central Brazil Agriculture**

*Measuring Soybean Yields in Northern Brazil During El Niño-Southern Oscillation Conditions to Evaluate Trends in Agricultural Production and Support Crop Forecasting, 1984 – 2023*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Brazil, one of the largest agricultural exporters in the world, plays a significant role in the world's food supply. Crop productivity in Brazil is heavily influenced by El Niño-Southern Oscillation (ENSO), which in northern and central Brazil is associated with drier than normal conditions and lower than normal rates of precipitation, that drives spatially heterogenous effects on growing conditions of crops. This project focused on understanding the relationship between ENSO conditions and soybean productivity from 1984 to 2023 in four states: Pará, Mato Grosso, Tocantins, and Bahia.

***Abstract:***

As one of the largest agricultural exporters in the world, Brazil’s crop productivity is highly influential to the world’s food supply. Crop productivity across Brazil is heavily influenced by climatic factors, such as the El Niño-Southern Oscillation (ENSO), which drives spatially heterogenous effects on growing conditions. To understand the relationship between ENSO conditions and staple crop productivity, the team used 1984 – 2023 climatic data and vegetation indices for four Brazilian states: Bahia, Mato Grosso, Pará, and Tocantins. The team focused on soybean growing areas in each state derived from annual land use/land cover classifications. Monthly mean normalized difference vegetation index (NDVI) per state were calculated using multispectral imagery from the Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imagery (OLI) sensors. In addition, crop production indices, ENSO anomalies, temperature, and precipitation data were used in this study. The team found that although monthly ENSO anomaly did have a positive relationship between temperature and a slight negative relationship with precipitation, ENSO and monthly soy NDVI were not significantly correlated. Results find no association between ENSO conditions and NDVI in the study area at the state level spatial resolution during the study period. Furthermore, the team found that there was no correlation between cumulative growing season soy NDVI and detrended soy production yield for this study region at the spatial and temporal scale of the analysis. Findings from this project will be used by the United States Department of Agriculture’s Foreign Agriculture Service to inform crop productivity forecasting.

***Key Terms:***

Remote sensing, Landsat, crop productivity, soybean production, Brazil, El Niño, NDVI

***Application Area:*** Agriculture, Climate

***Study Location:*** Northern and central Brazil: Pará (PA), Mato Grosso (MT), Tocantins (TO), and Bahia (BA)

***Study Period:*** 1984–2023

***Community Concerns:***

* Variable weather conditions due to climate change are impacting global agriculture production which is a growing issue that is threatening global food security.
* Brazil plays a crucial role in the global food supply as top exporter of agriculture products, serving over 200 countries and territories. Thus, a reduced agriculture production in Brazil has both local and global consequences.
* As Brazil expands agriculture production, climatic variability, including dry weather and extreme precipitation, threatens food production nationally as well as in countries that rely on Brazil’s food commodity exports.
* Domestically, the agriculture sector of Brazil composed 29% of Brazil's GDP in 2021 and serves as a source of employment for its citizens. Furthermore, reduced crop production detrimentally impacts the national economy and job security.

***Project Objectives:***

* Examine the relationship between soybean production yield, normalized difference vegetation index (NDVI), and precipitation, temperature, and ENSO conditions
* Produce a time series analysis from 1984 to 2023 comparing crop yield and environmental conditions during ENSO phases
* Conduct statistical analysis to examine relationships between soybean crop yield, NDVI, and temperature, precipitation, and ENSO conditions

**Partner Overview**

***Partner Organization(s):***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** | **Sector** |
| **USDA Foreign Agriculture Service, International Production Assessment Division** | Dr. Sunita Yadav-Pauletti, Crop Analyst for Brazil | End User | Federal Government |
| **USDA Office of the Chief Economist and World Agricultural Outlook Board** | Dr. Mark Brusberg, Chief Meteorologist | Collaborator | Federal Government |

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

The USDA FAS coordinates the USDA’s international activities to enhance export opportunities and global food security through trade policy, global market development, and the collection and analysis of statistics and market information. IPAD assesses global agricultural production outlook and conditions affecting food security internationally by estimating area, yield, and production of crops. Currently, IPAD collaborates with NASA to produce the Global Inventory Monitoring and Modeling Studies (GIMMS) Global Agriculture Monitoring (GLAM) system, which provides a global agricultural production outlook and monitors conditions affecting global food security using MODIS & VIIRS NDVI imagery. With the return of El Niño in 2023, IPAD is interested in assessing the impact of El Niño–Southern Oscillation on crop production in Brazil to inform estimates of agricultural production in the country.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 5 TM** | Normalized Difference Vegetation Index (NDVI\*) | Normalized difference vegetation index (NDVI) was calculated using at-surface reflectance data to measure crop yields at a 30m spatial resolution and 16-day spatial resolution. |
| **Landsat 7 ETM+** | Normalized Difference Vegetation Index (NDVI\*) | Normalized difference vegetation index (NDVI) was calculated using at-surface reflectance data to measure crop yields at a 30m spatial resolution and 16-day spatial resolution. |
| **Landsat 8 OLI/TIRS** | Normalized Difference Vegetation Index (NDVI\*) | Normalized difference vegetation index (NDVI) was calculated using at-surface reflectance data to measure crop yields at a 30m spatial resolution and 16-day spatial resolution. |

\* The team used the red bands (Band 3 in TM and EMT+, Band 4 in OLI) and the NIR bands (Band 4 in TM and EMT+, Band 5 in OLI) to calculate NDVI, as photosynthetically active vegetation is highly reflective of near-infrared (NIR) light and absorptive of red light.

***Ancillary Datasets:***

* [Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) Daily Precipitation](https://app.climateengine.org/climateEngine) – Evaluate precipitation trends across the study period
* [Niño 3.4](https://www.ncei.noaa.gov/pub/data/cmb/ersst/v5/index/) – Determine onset and termination El Niño of conditions during the duration of the study period
* [European Centre for Medium-Range Weather Forecasts – Copernicus Climate Change Service Climate Data Store (CDS) ERA 5 Dataset](https://climate.copernicus.eu/) – Determine monthly aggregated total precipitation and mean air temperature data
* [Companhia Nacional de Abastecimento (CONAB) Crop Yield Data](https://www.conab.gov.br/info-agro/safras/serie-historica-das-safras#gr%C3%A3os-2) – Annual, state-level, corn and soy crop yield data will be used to measure and map variations in crop yields across the study area
* [MapBiomas Agricultural Lands](https://plataforma.brasil.mapbiomas.org/cobertura?activeBaseMap=9&layersOpacity=100&activeModule=coverage&activeModuleContent=coverage%3Acoverage_main&activeYear=2022&mapPosition=-15.072124%2C-51.416016%2C4&timelineLimitsRange=1985%2C2022&baseParams%5bterritoryType%5d=1&baseParams%5bterritories%5d=1%3BBrasil%3B1%3BCountry%3B0%3B0%3B0%3B0&baseParams%5bactiveClassTreeOptionValue%5d=default&baseParams%5bactiveClassTreeNodeIds%5d=1%2C7%2C8%2C9%2C10%2C11%2C2%2C12%2C13%2C14%2C15%2C16%2C17%2C3%2C18%2C19%2C28%2C30%2C31%2C32%2C33%2C34%2C29%2C35%2C36%2C37%2C38%2C20%2C21%2C4%2C22%2C23%2C24%2C25%2C5%2C26%2C27%2C6&baseParams%5bactiveSubmodule%5d=coverage_main&baseParams%5byearRange%5d=1985-2022) – Locations of soy production will be used to mask non-agricultural lands from analysis

***Software & Coding Languages:***

* Google Earth Engine API – Acquire and process Landsat 5, 7, and 8 NDVI data
* Excel (Version 16.80) – Clean and compile datasets
* RStudio (Version 2023.12.0+369) – Analyze and visualize results

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

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| **End Product(s)** | **Earth Observations Used**  | **Partner Benefit & Use** |
| **Time Series Trend Analysis of Crop Yield and Environmental Conditions** | Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI were used to calculate NDVI in soybean production areas.  | Time series analysis of soybean production, NDVI, temperature and precipitation rates during ENSO phases will be used to assess trends in crop production during ENSO conditions. |
| **Crop Yield & El Niño Correlation and Principal Component Analysis** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI | Crop yield data was compiled to evaluate the impact of ENSO conditions on soybean crop production. These results will be used by partners to inform crop production outlooks during ENSO years and determine the climatic factors which influence crop production.  |
| **Soy NDVI and Cropland Layer** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI | Raster layers depicting NDVI during El Niño conditions and annual soy crop lands will be used by project partners to evaluate the impact of ENSO on crop production at the state level between 1984–2023. |

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

Our results indicate that NDVI is not correlated with ENSO as there were challenges in using ENSO conditions to forecast soybean crop productivity. Nevertheless, the methodology developed in this project may be useful for examining the impact of temperature and precipitation on crop productivity. Furthermore, a combination of temperature and precipitation data is viable to ascertain relationships between NDVI, seasonality, and progression over time. Moreover, correlation analyses producing time series and NDVI or crop yield maps provide a means of obtaining accurate trends and determining which factors affect crop production yield. Findings from this analysis benefit project partners by developing methods and testing the feasibility of using ENSO conditions as a predictor of NDVI and soybean production. Furthermore, project partners can refine the methodology and can conduct an analysis using a multivariate index for SST and ENSO conditions to assess the impact of ENSO conditions on additional crops produced in Brazil. In addition, it will be beneficial for partners apply the methods developed in this analysis to a smaller study area, such as the sub-state level, as there can be significant climatic variation which can impact crop production within states. In sum, the methods in this study provide a preliminary overview of how to examine associations between ENSO conditions and crop productivity and can continued to be refined in the future.

**References**

Arvor, D., Dubreuil, V., Simões, M., & Bégué, A. (2013). Mapping and spatial analysis of the soybean agricultural frontier in Mato Grosso, Brazil, using remote sensing data. *GeoJournal*, *78*, 833-850.

Cirino, P. H., Féres, J. G., Braga, M. J., & Reis, E. (2015). Assessing the Impacts of ENSO-related Weather Effects on the Brazilian Agriculture. Procedia Economics and Finance, 24, 146–155.

Júnior, R. D. S. N., & Sentelhas, P. C. (2019). Soybean-maize off-season double crop system in Brazil as affected by El Niño Southern Oscillation phases. *Agricultural Systems*, *173*, 254-267

Reis, L., Santos e Silva, C. M., Bezerra, B., Mutti, P., Spyrides, M. H., Silva, P., ... & Andrade, L. (2020). Influence of climate variability on soybean yield in MATOPIBA, Brazil. Atmosphere, 11(10), 1130.

Valdes, C. (2022). Brazil’s Momentum as a Global Agricultural Supplier Faces Headwinds. United States Department of Agriculture Economic Research Services. <https://www.ers.usda.gov/amber-waves/2022/september/brazil-s-momentum-as-a-global-agricultural-supplier-faces-headwinds/>