**Kenya Food Security & Agriculture II**

*Utilizing NASA Earth Observations to Enhance Drought Warning Systems and Develop Capacity to Use the RHEAS Model in Kenya*

**Project Team**

***Project Team:***

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***Past or Other Contributors:***

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**Project Overview**

***Project Synopsis:*** Drought in Kenya is an ongoing cause of economic hardship and mortality. The team’s work addressed this challenge by developing an effective Combined Drought Indicator (CDI) to strengthen drought-warning systems led by the Kenya National Drought Management Authority (NDMA). Through collaboration with the Regional Centre for Mapping of Resources for Development (RCMRD) and NASA SERVIR, the team incorporated high resolution outputs from the Regional Hydrologic Extremes Assessment System (RHEAS) model as input into the CDI calculation. The project’s findings and CDI will be implemented in Kenya by NASA SERVIR and the RCMRD.

***Abstract:***

Twenty-three counties in Kenya experience frequent drought, which damages agricultural productivity and threatens the health and wellbeing of millions. NASA DEVELOP partnered with NASA SERVIR, the Regional Centre for Mapping of Resources for Development (RCMRD) and Kenya’s National Drought Management Authority (NDMA) to enhance drought-detection capacity using NASA Earth observations. Currently, the NDMA publishes monthly Early Warning Bulletins with drought conditions for each arid or semi-arid county in Kenya. These bulletins utilize the Vegetation Condition Index (VCI) from the Moderate Resolution Imaging Spectroradiometer (MODIS) as well as a variety of biophysical, social and economic drought indicators, but do not allow for advanced forecasting. To improve drought-monitoring capabilities, the team created a Combined Drought Indicator (CDI) using the Regional Hydrologic Extremes Assessment System (RHEAS) model and data from Aqua and Terra MODIS and the National Centers for Environmental Prediction.  The CDI combined precipitation anomalies, soil moisture anomalies, evaporative stress, and VCI according to weights determined by principal component analysis. To evaluate the performance of the CDI across Kenya, the team compiled a dataset of drought events from historical reports and the NDMA’s records. Results suggested that the CDI detected drought earlier than VCI alone. However, more validation is needed to ensure that the CDI accurately and consistently detects drought earlier than current warning systems. In order to better understand the behavior of individual indices and the potential for earlier drought detection, the team also conducted a time-lag analysis. The team found that VCI responds to drought, on average, one month later than most other indices included in the CDI, suggesting that incorporating additional indices could improve early drought warning systems in Kenya.

***Keywords:***

RHEAS, remote sensing, drought, SMAP, CHIRPS, Aqua, Terra, CDI

***National Application Area Addressed:*** Food Security & Agriculture

***Study Location:*** Kenya

***Study Period:*** January 1990 to December 2019

***Community Concerns:***

* Agriculture and livestock production yields approximately a quarter of the gross domestic product of Kenya, while 80% of the country is considered arid or semi-arid and experiences regular drought
* Extreme drought in 2016-2017 resulted in food shortages that necessitated food aid for three million people and resulted in tens of thousands of deaths
* The NDMA is working on establishing guidelines for improved resource distribution to prevent acute agro-pastoral loss and reduce drought-related crises

***Project Objectives:***

* Validate RHEAS model outputs at a 5km spatial resolution
* Develop a new combined drought indicator that outperforms existing RHEAS predictions
* Validate the combined drought indicator using a dataset of historical drought events

***Previous Term:*** 2019 Summer (MSFC) – Kenya Agriculture & Food Security

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC**  | **Partner Type** | **Boundary Org?** |
| **National Drought Management Authority (Kenya)** | Nelson Mutanda, Drought Early Warning Officer | End User | Yes |
| **Regional Centre for Mapping of Resources for Development** | Lilian Ndungu, SERVIR Eastern and Southern Africa Agriculture & Food Security Thematic Lead | Collaborator | Yes |
| **NASA SERVIR Science Coordination Office** | Dr. Lee Ellenburg, Food Security & Agriculture Thematic Service Area Lead | Collaborator | No |

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

Following the 2016-2017 drought in Kenya that led to extensive food shortages, the Kenyan government established the NDMA to ensure that future drought events did not result in widespread crisis. The NDMA coordinates drought risk management between the government and stakeholders, implements programs to strengthen drought resilience in affected areas, and serves as the main source of drought related information and forecasts. Drought is classified by evaluating a series of biophysical, social, and economic indicators (rainfall, livestock production, crop production, access to water, terms of trade and health and nutrition), as well as Vegetation Condition Index (VCI) data from Moderate Resolution Imaging Spectroradiometer (MODIS) indices. While these indicators can effectively communicate the severity of current drought events, they are limited in their ability to forecast drought. The drought classification system currently in place uses five drought classes: Normal, Alert, Alarm, Emergency, and Recovery. Based on this classification system, the NDMA directs social programs to avoid widespread social and economic damage in counties experiencing drought.

***Project Benefit to End User:***

The NDMA has the capacity to use Earth observations at the county and national scale. However, the NDMA’s current analysis focuses on the use of NDVI, VCI, and Climate Hazards Center InfraRed Precipitation with Station data (CHIRPS) data. By implementing outputs from RHEAS, NDMA can capitalize on the use of the land surface model known as Variable Infiltration Capacity (VIC) which depends on remote sensing observations such as rainfall, meteorological conditions, and soil moisture. The RHEAS model has the capacity to estimate seasonal conditions and determine drought severity, recovery, and duration with the use of ground observations for calibration. Using validated data produced by the RHEAS model to create a combined drought indicator (CDI) will increase the NDMA’s ability to forecast drought and effectively prepare resource distribution to mitigate drought-related crises.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Aqua MODIS** | Land Surface Temperature (LST), Leaf Area Index (LAI), Normalized Difference Vegetation Index (NDVI) | Aqua MODIS derived LST and LAI were used to create Evaporative Stress Index (ESI). The team used Aqua MODIS derived NDVI to calculate VCI. |
| **Terra MODIS** | LST, LAI, NDVI | Terra MODIS LST and LAI were used to create ESI. The team used Terra MODIS derived NDVI to calculate VCI. |
| **Suomi-NPP VIIRS** | LST, LAI | Suomi-NPP VIIRS derived LST and LAI were used to create ESI.  |

***Ancillary Datasets:***

* Kenya National Drought Management Authority Drought Early Warning Bulletins – *in situ* data used to evaluate Combined Drought Indicator (CDI) performance by comparing how often CDI’s drought predictions matched actual instances of drought
* Climate Hazards Center InfraRed Precipitation with Station data (CHIRPS) – rainfall dataset ingested into the RHEAS model
* National Centers for Environmental Prediction (NCEP) model data – temperature and wind data ingested into the RHEAS model

***Modeling:***

* Regional Hydrologic Extremes Assessment System (RHEAS) (POC: Dr. Lee Ellenburg, NASA SERVIR) – NASA hydrologic model with forecasting and nowcasting capabilities

***Software & Scripting:***

* Esri ArcMap 10.5 – Spatial analysis and mapping
* Python 2.7.12 – Analysis of RHEAS outputs and development of CDI

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **CDI** | Aqua MODISTerra MODISSuomi-NPP VIIRS | The CDI will incorporate various indices to produce an accurate drought indicator. The NDMA can implement this CDI to allow an earlier indication of drought and produce earlier drought warnings.  | II |
| **Time-Lag Analysis of Drought Indices** | Aqua MODISTerra MODISSuomi-NPP VIIRS | The time-lag analysis indicates the delay in response time of some indices relative to others. The RCMRD and NDMA can look at specific indices that detect drought faster than others.  | II |
| **CDI Safari: Utilizing NASA Earth Observations to Enhance Drought Monitoring in Kenya – ArcGIS StoryMap** | Aqua MODISTerra MODISSuomi-NPP VIIRS | The StoryMap will describe the creation of a CDI to monitor drought in Kenya. The StoryMap can be used as an outreach tool to provide background about drought in Kenya and the tools being used to forecast and manage drought.  | II |

**Project Handoff Package**

***Transition Plan:*** During week 10 of the project, the team conducted a partner handoff via web conference to explain results and end products. End products were sent to end users and collaborators through NASA Large File Transfer.

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***Handoff Package:***

* Combined Drought Indicator (CDI)
* Time-Lag Analysis of Drought Indices
* Validation of RHEAS Drought Indices
* CDI Safari: Utilizing NASA Earth Observations to Enhance Drought Monitoring in Kenya – ArcGIS Story Map
* Poster
* Presentation
* Technical Paper

**References**

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