**NASA DEVELOP National Program**

**2019 Summer Project Proposal**

**Alabama – Marshall**

**Kenya Agriculture & Food Security**

*Evaluating Drought Indices to Enhance Early Warning Systems in Kenya*

**Project Overview**

***Project Synopsis*:** Partnering with the Regional Centre for Mapping of Resources for Development (RCMRD) and the National Drought Management Authority (NDMA), this project aims to enhance drought monitoring in Kenya through the use of the Regional Hydrologic Extremes Assessment System (RHEAS). RHEAS will utilize a variety of indices, including the Water Requirement Satisfaction Index (WRSI) derived from a suite of Earth observations, including Terra & Aqua MODIS, Suomi NPP VIIRS, SMOS MIRAS, Aqua AMSR-E, and SMAP. These indices will be evaluated alongside the existing Early Warning Bulletins created and published by the NDMA to mitigate drought-related threats to Kenya’s agricultural practices. This project will contribute to early warning tools and provide valuable information to improve drought response applications through drought story maps and an indices analysis. These additions can improve the response to threatening droughts through the implementation of mitigation and adaptation strategies that provide farmers and cattlemen the resources necessary to prepare for and recover from severe drought.

***Community Concern:*** In East Africa, severe drought commonly plagues the countries of Ethiopia, Kenya, and Somalia, leaving over 10 million people hungry. With dependence on rain-fed agriculture in a highly variable climate, both crop and livestock production are extremely vulnerable to the impacts of drought. In Kenya, arid land comprises over 80% of the country and is home to 70% of its livestock. Between 2011 and 2012, a severe drought caused a food crisis in the region, resulting in the death of 10,000 people a day from starvation and threatening the livelihood of 9 million more. During the 2016 to 2017 drought in Kenya, over 3 million people experienced food insecurity related to drought conditions. To lessen the threat of drought-related crises, local authorities are working to establish regulations for the sustainable management of drought to prevent acute agro-pastoral loss.

***Source of Project Idea:*** Stakeholders, specifically in East Africa, have expressed the need for timely, actionable, and detailed early warning information on drought and its implication on crop productivity for decision making. Lee Ellenburg from NASA SERVIR and Lilian Ndungu from the RCMRD brought this project idea to the attention of the Alabama – Marshall Node leadership. The NDMA stated that the results of this project would provide valuable information that could enhance the organization’s decision-making processes.

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

***Study Location:*** Kenya

***Study Period:*** January 2016 – December 2018

***Advisors:*** Dr. Jeffrey Luvall (NASA Marshall Space Flight Center), Dr. Robert Griffin (The University of Alabama in Huntsville), Dr. Lee Ellenburg (NASA SERVIR Science Coordination Office)

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **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 (RCMRD)** | Lilian Ndungu, SERVIR Eastern and Southern Africa Agriculture & Food Security Thematic Lead | Collaborator | Yes |

***End-User Overview***

***End User’s Current Decision-Making Process:***The NDMA is mandated to ensure that drought does not lead to widespread famine and the impacts of changes in climate are sufficiently mitigated by establishing, institutionalizing, and coordinating structures for drought management. The NDMA manages a drought early warning system that provides timely and credible early warning information on drought risks. As a result, they communicate the current drought status via publishing monthly bulletins that farmers and other stakeholders use to plan for and mitigate the impacts of drought on agriculture and food security. The NDMA conducts a variety of projects to alleviate the impact of drought, including distributing feed for livestock, providing school lunches, and buying livestock in counties experiencing extreme drought. The NDMA also creates guidelines for the different thresholds of drought warning that a variety of stakeholders rely on.

***End User’s Capacity to Use NASA Earth Observations:***

*National Drought Management Authority (Kenya)* – Currently, the NDMA has the capacity to use Earth observations on both the county and national level. However, its analysis focuses on the use of the Normalized Difference Vegetation Index (NDVI) and Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) Rainfall data. The RHEAS modeling framework capitalizes on a widely used land surface model known as Variable Infiltration Capacity (VIC) and is dependent upon multiple remote sensing observations, such as rainfall, weather information, soil moisture, and etc. This model has the capability of estimating seasonal conditions and determining drought onset, severity, recovery, and duration with ground observations used for calibration. Through a RHEAS evaluation, the NDMA can build capacity by expanding its use of a variety of NASA Earth observations for drought monitoring processes.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*Regional Centre for Mapping of Resources for Development (RCMRD)* – RCMRD will provide scientific expertise and guidance in the creation of the RHEAS drought indices, examples of their assessment for usability, and adequate packaging methods for the dissemination of project results.

***Dissemination by Boundary Organizations*:**

*National Drought Management Authority* *(Kenya)* – The NDMA disseminates drought-related information on the national, county, and community levels through its monthly Early Warning Bulletins, its website, and other networks. As head of the Food Security Technical Working Group, the NDMA has established relationships across agencies and sectors for the improvement of drought monitoring and preparedness. Its guidelines for preparedness at different levels of drought warning are accessed widely by other governmental departments across the region. The results of this project will be accessible across NDMA’s current networks.

*Regional Centre for Mapping of Resources for Development (RCMRD)* – The RCMRD hosts the Rangelands Decision Support Tool. This online tool displays NDVI, NDVI anomalies, and Vegetation Condition Index data in near real-time in order to allow for monitoring of rangeland productivity. The RCMRD aims to disseminate results from this project through this tool.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** Communication between the DEVELOP team and the project partners will take place biweekly via teleconference or in-person meetings. Lines of communication will remain open if issues arise, but these meetings will primarily involve project updates and high-level results. The Center Lead will coordinate an initial project meeting within the first two weeks of the term and will transition this responsibility to the Project Lead. Initial communications will be collaborative, involving all partners to determine key project goals.

***Transition Plan*:** All end products and deliverables will be provided to the project partners via NASA Large File Transfer (LFT) after approval from export control at the end of the term. The RHEAS model will be run on Socrates (the SERVIR computer cluster). RCMRD and NDMA will have access to outputs hosted on the server. The team will conduct a handoff presentation via web conference, using either Google Hangouts or WebEx. During this meeting, the team will present the project results to the partners and field any questions the partners may have.

***Letters of Support*:** Lilian Ndungu, SERVIR Eastern and Southern Africa Agriculture & Food Security Thematic Lead, Regional Centre for Mapping of Resources for Development. Nelson Mutanda, Drought Early Warning Officer, National Drought Management Authority.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **SMAP L-band Radar** | Soil moisture | This dataset will be assimilated into the RHEAS model to evaluate soil conditions impacting agriculture through the Water Requirement Satisfaction Index (WRSI). |
| **SMOS MIRAS** | Soil moisture | This dataset will be assimilated into the RHEAS model to evaluate soil conditions impacting agriculture through the WRSI. |
| **Suomi NPP VIIRS** | Land surface temperature | This dataset will be assimilated into the RHEAS system to determine land surface temperature in drought-prone areas of Kenya. |
| **Aqua MODIS** | Land surface temperature | This dataset will be assimilated into the RHEAS system to determine land surface temperature in drought-prone areas of Kenya. |
| **Terra MODIS** | Land surface temperature | This dataset will be assimilated into the RHEAS system to determine land surface temperature in drought-prone areas of Kenya. |
| **Aqua AMSR-E** | Precipitation, surface wetness | This dataset will be assimilated into the RHEAS system to analyze evapotranspiration through the  Standardized Precipitation Evapotranspiration Index (SPEI) and the Potential Evapotranspiration (PET) Index. |

***Ancillary Datasets:***

National Drought Management Authority Drought Early Warning Bulletins – contextualize RHEAS drought indices

Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) Precipitation Data – assimilate into RHEAS for analysis of the SPEI and the PET Index

***Modeling:***

Regional Hydrologic Extremes Assessment System (RHEAS) (POC: Lee Ellenburg, NASA SERVIR)

***Software & Scripting:***

Esri ArcMap – data analysis and map creation

PostGIS – database where RHEAS inputs and outputs are stored and executed

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **RHEAS Drought Indices** | The end user will use the RHEAS Drought Indices to enhance the Early Warning Bulletins that they currently produce. In turn, this will improve efforts focused on drought response and recovery in the region. | SMAP, Suomi NPP VIIRS, Aqua and Terra MODIS, Aqua AMSR-E, and SMOS MIRAS data will be incorporated into the RHEAS model that relies on VIC to identify key drought indices in Kenya. | N/A |
| **Drought Time Series** | The end user will use this time series to visualize the spatial and temporal distribution of drought to enhance their identification of counties with potential chronic food security issues. | These time series maps will be created in ArcMap using the output of potential drought areas from the RHEAS model that incorporates Earth observation data from SMAP, Suomi NPP VIIRS, Aqua and Terra MODIS, Aqua AMSR-E, and SMOS MIRAS. | N/A |
| **Evaluation of RHEAS Drought Indices in Kenya** | The end user will use this evaluation to guide their incorporation of RHEAS drought indices into their Early Warning Bulletins to better assist stakeholders in implementing drought mitigation and adaptation measures. | RHEAS-produced indices (from SMAP, Suomi NPP VIIRS, Aqua and Terra MODIS, Aqua AMSR-E, and SMOS MIRAS data) will be compared to the indices used in Early Warning Bulletins created and used by the NDMA. | N/A |
| **Drought in Kenya Story Map** | The end user will use this end product to inform the general public about the issue of drought in Kenya, its impact on agriculture, and the utility of the RHEAS drought indices when used in conjunction with Early Warning Bulletins for improved drought monitoring. | The story map will incorporate the Drought Time Series, the Evaluation of RHEAS Drought Indices in Kenya, and data from SMAP, Suomi NPP VIIRS, Aqua and Terra MODIS, Aqua AMSR-E, and SMOS MIRAS. | N/A |

***End-User Benefit*:** Currently, the Famine Early Warning Systems Network (FEWS NET) and the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM) provide similar products for drought monitoring. However, these systems can only be adapted for a limited number of variables. In contrast, RHEAS utilizes a land surface model that allows for unlimited variables and can easily be customized and interfaced for use with the partners’ current systems. The integration of Early Warning Bulletins with this new information will improve agro-pastoral management practices through the assimilation of additional Earth observations. The story map will be used as an outreach tool to inform the general public about drought and food security in Kenya.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2019 Summer to 2019 Fall

***Multi-Term Objectives:***

* **Term 1:** 2019 Summer (Alabama – Marshall) - Agriculture & Food Security
  + Term 1 will complete initial runs of the RHEAS model and analyze the outputs created. The team will create an assimilation framework based on the initial outputs to meet the needs of the project partners. The primary goal of the first term is to generate results. The team will systematically record all details of the framework so the Kenya Agriculture & Food Security II team can immediately begin validation. The initial results will be presented to the partners for their feedback so the model can be fine-tuned for the second term. A hand-off will provide the partners with an update on the status of the model.
* **Term 2 (Proposed Term):** 2019 Fall (Alabama – Marshall) – Kenya Agriculture & Food Security II
  + The second term of this project seeks to validate the results of the first term and also complete a detailed transfer of knowledge to the partners through comprehensive webinars or tutorials. The team, with the support of the SERVIR Coordination Office, will conduct half-day webinars with project partners to share framework and methodologies with project partners as well as address any concerns. Partner interaction will remain constant and culminate in the interactive hand-off.

***Related DEVELOP Work:***

2017 Spring (NC) – Missouri River Climate II: Utilizing NASA Earth Observations and NOAA Data Records to Produce Climate Indicators of Wildland Fire

2017 Spring (JPL) – Santa Monica Mountains Climate: Using NASA Earth Observations to Determine the Extent of Drought-Related Dieback in Oak Woodlands within the Santa Monica Mountains

**Notes & References:**

***Notes:*** Direct communication with the partners has been fantastic thus far. Both Nelson (NDMA) and Lilian (RCMRD) have provided extensive feedback on the project proposal, met via Skype, and have responded quickly and comprehensively to emails, even after the project was delayed. There has been no reason to think this relationship would not continue.

NDMA has been using MODIS indices in its drought assessments. However, the indices are not sufficient, especially in assessing the trajectory of drought and in assessing the status of drought in semi-arid areas where precipitation is not the only contributing factor to vegetation vigor. By introducing additional indices utilized in RHEAS, a more comprehensive evaluation can be conducted.

In the previous NPO edits, a question was raised about whether RHEAS would produce indices. To elaborate, the RHEAS modeling framework capitalizes on a widely used land surface model known as Variable Infiltration Capacity (VIC) and is dependent upon multiple remote sensing observations, such as rainfall, weather information, soil moisture, and etc. This model has the capability of estimating seasonal conditions and determining drought onset, severity, recovery, and duration with ground observations used for calibration. VIC is already used by the partners. Many of the NASA products will be assimilated into the model, and the outputs (soil moisture, evapotranspiration, temperature, etc.) will be used to create a suite of drought indices. These indices will be compared to the indices already used by the partner to determine their utility.

Lee Ellenburg is currently running this model alongside a user group in the SERVIR offices at MSFC. The support of the SERVIR team is crucial to the success of this project. The DEVELOP team will have an entire user group for advising throughout this project, as this is one component of a much larger project conducted by SERVIR.

***References:***

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