WWAO Annual Meeting 2024

Developing an integrated modeling framework for Rio Grande Basin Water Resource Management

Vikalp Mishra, Hatim M. Geli, W. Lee Ellenburg, J. Phillip King, Stacy Timmons, Christopher Hain

Image: AGU Chapman Conference 2022

Motivation

- The Rio Grande Basin is facing significant water resource management challenges due to a limited availability of alternate water sources other than the Rio Grande River.

- Appropriate allocation of the available water supply among its stakeholders spanning multiple states in the U.S. and Mexico is extremely critical.

- The RGB headwaters in Colorado are predominantly used for agriculture (80%), followed by domestic and industrial purposes.

- Rio Grande Basin needs assessment report identified current challenges and requirements for the basin including[1] :
  - **Need for a headwater hydrological model that can refine rainfall runoff predictions and can process future climate scenarios**
  - **Improved streamflow monitoring**
  - **Agricultural water conservation and improved basin wide planning and farm management among others**

[1]Rio Garnde Basin Needs Assessment Workshop Report, Prepared for NASA Western Water Applications Office, Pasadena, CA. 2022. (https://wwao.jpl.nasa.gov/documents/49/Water-Needs-Rio-Grande-Report-2022.pdf)

Goal

- This proposal aims to address two specific water resource management needs identified in the assessment:

  a) *Integrated Data/Information System and Modeling (4.1.2)*
  b) *Improved water supply forecasts to support planning and farm management (4.2.3)*

- We will use an integrated modeling framework that combines a hydrological and a cropping system model for a comprehensive outlook on the total water availability, agricultural water demand and drought assessments within a watershed.

- Moreover, the model outputs including runoff, streamflow, ET, drought conditions etc. will be leveraged to address and understand additional need identified:

  - *Identifying tipping point for irreversible change using satellite and model driven drought assessments (4.3.3).*

Project Team

End-User

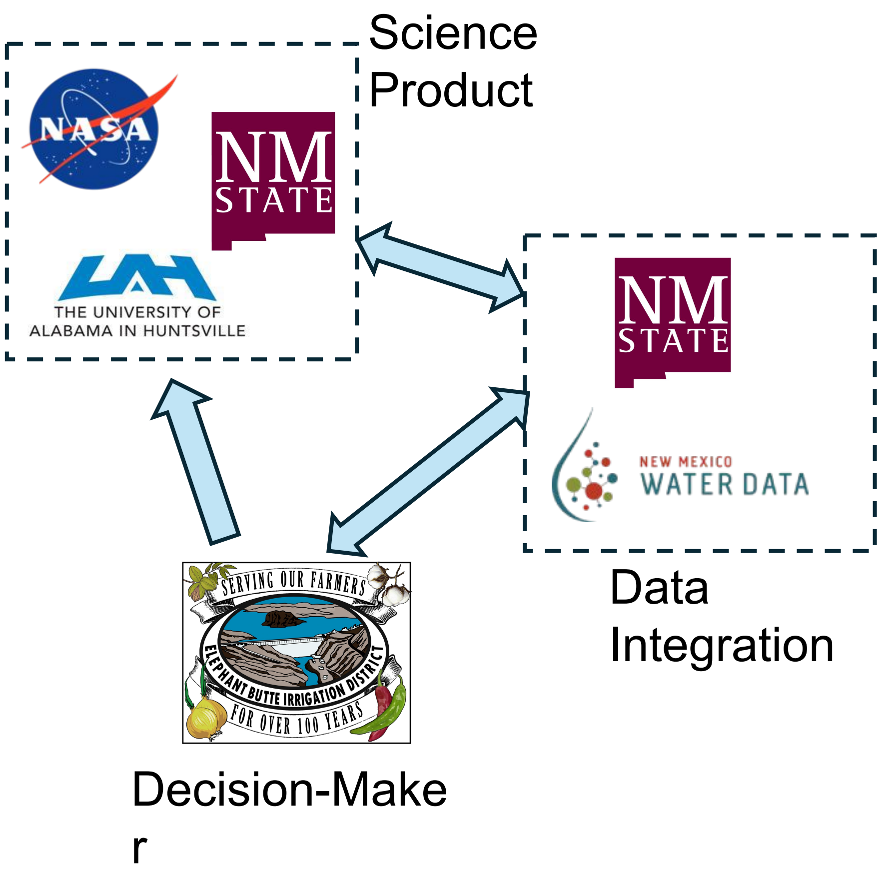
- J. Phillip King Elephant Butte Irrigation District

Integration and Data Dissemination Team

- Hatim Geli New Mexico State University
- Stacy Timmons New Mexico Water Data Institute

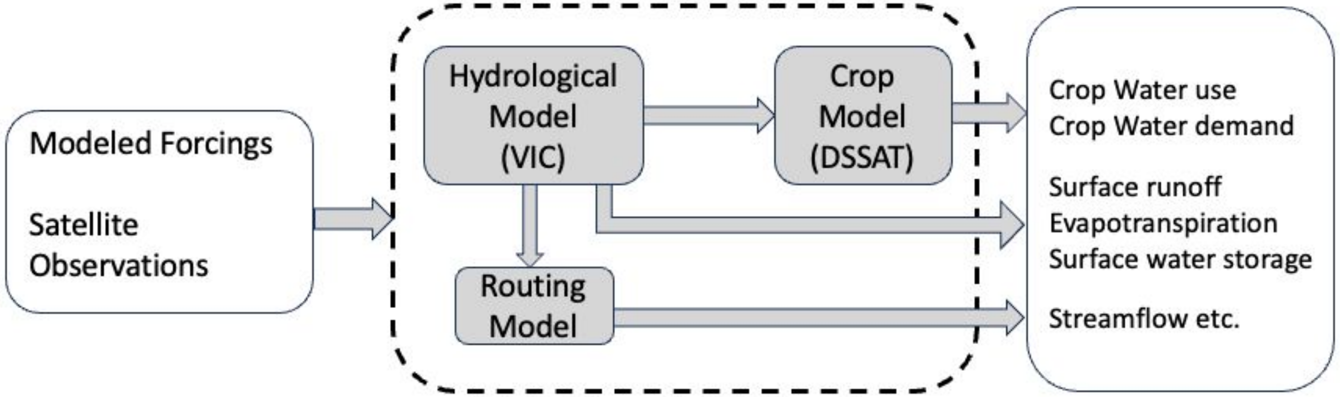
Technical Team

- Vikalp Mishra NASA SPoRT | University of Alabama in Huntsville
- W. Lee Ellenburg University of Alabama in Huntsville
- Modeler (TBD) University of Alabama in Huntsville
- GRA (TBD) New Mexico State University
- Christopher Hain NASA MSFC



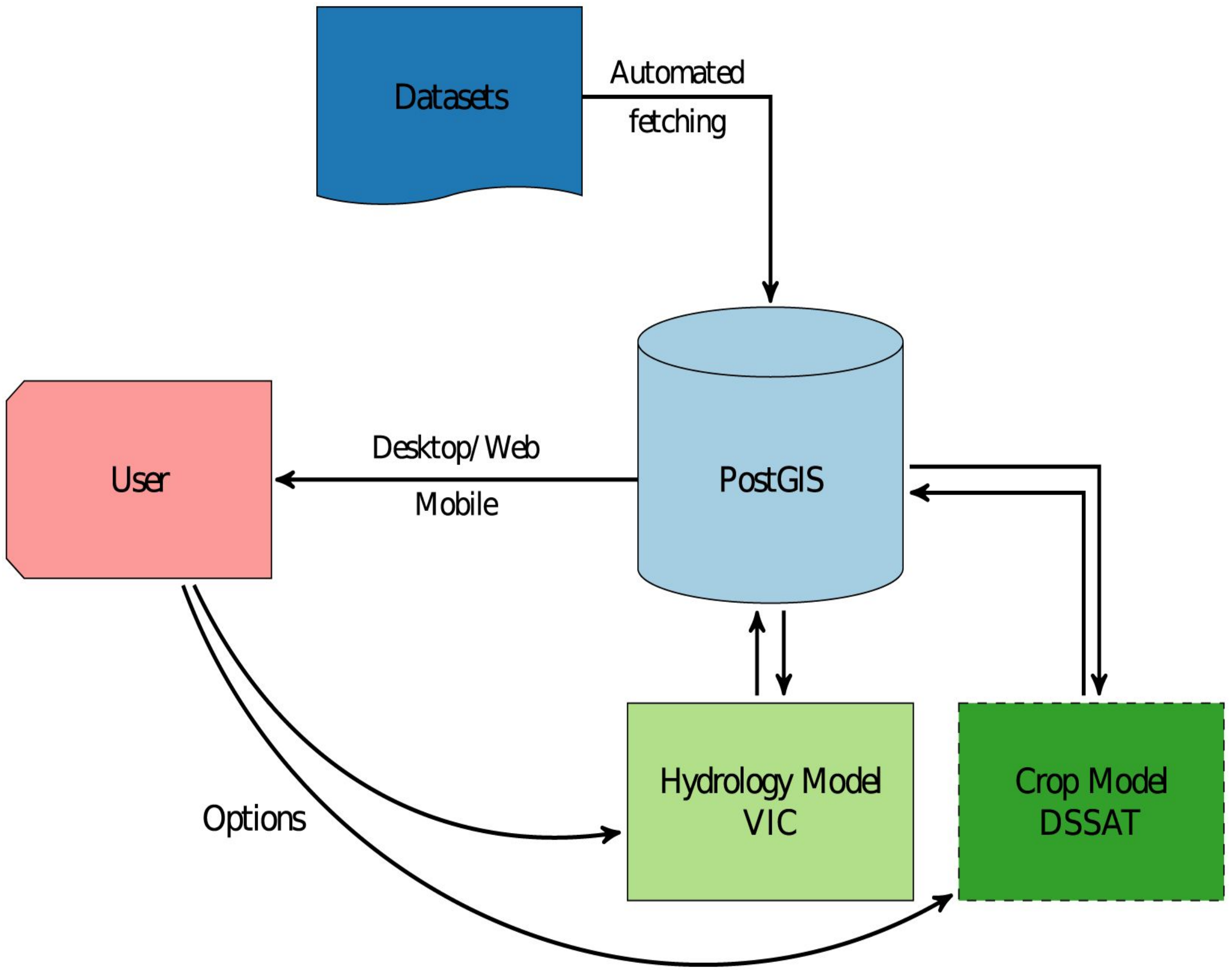
Modeling Tool

Regional Hydrological Extremes Assessment - RHEAS



- Automatic ingest of Earth observations, forecasts, in situ, and climate projections
- Assimilation of remote sensing and model data from multiple sources.
- Object-oriented software design allows for modularity and extensibility.
- Linked hydrologic and crop models
  - Variable Infiltration Capacity (VIC: X. Liang, 1994)
  - Decision Support System for Agro-technology (DSSAT: Jones, 2003)
- PostGIS database enables efficient storage and access to input data and model outputs.
- Runs in both nowcast and forecast modes.

RHEAS Model Structure



1. **Automated Ingest**
   - Automatic Search
   - Download
   - Resolution and projection Match
   - Store
2. **Data Management**
   - Spatially enabled PostgreSQL database
   - Data Format Agnostic
   - Parallel processing
3. **Model Implementation**
   - Hydrological Model –VIC
   - Crop Model - DSSAT
4. **Coupling/Assimilation**
   - DA capabilities
   - One-way coupling
5. **Output**
   - Hydrological Model outputs (raster)
   - Crop Model Output (Vector)

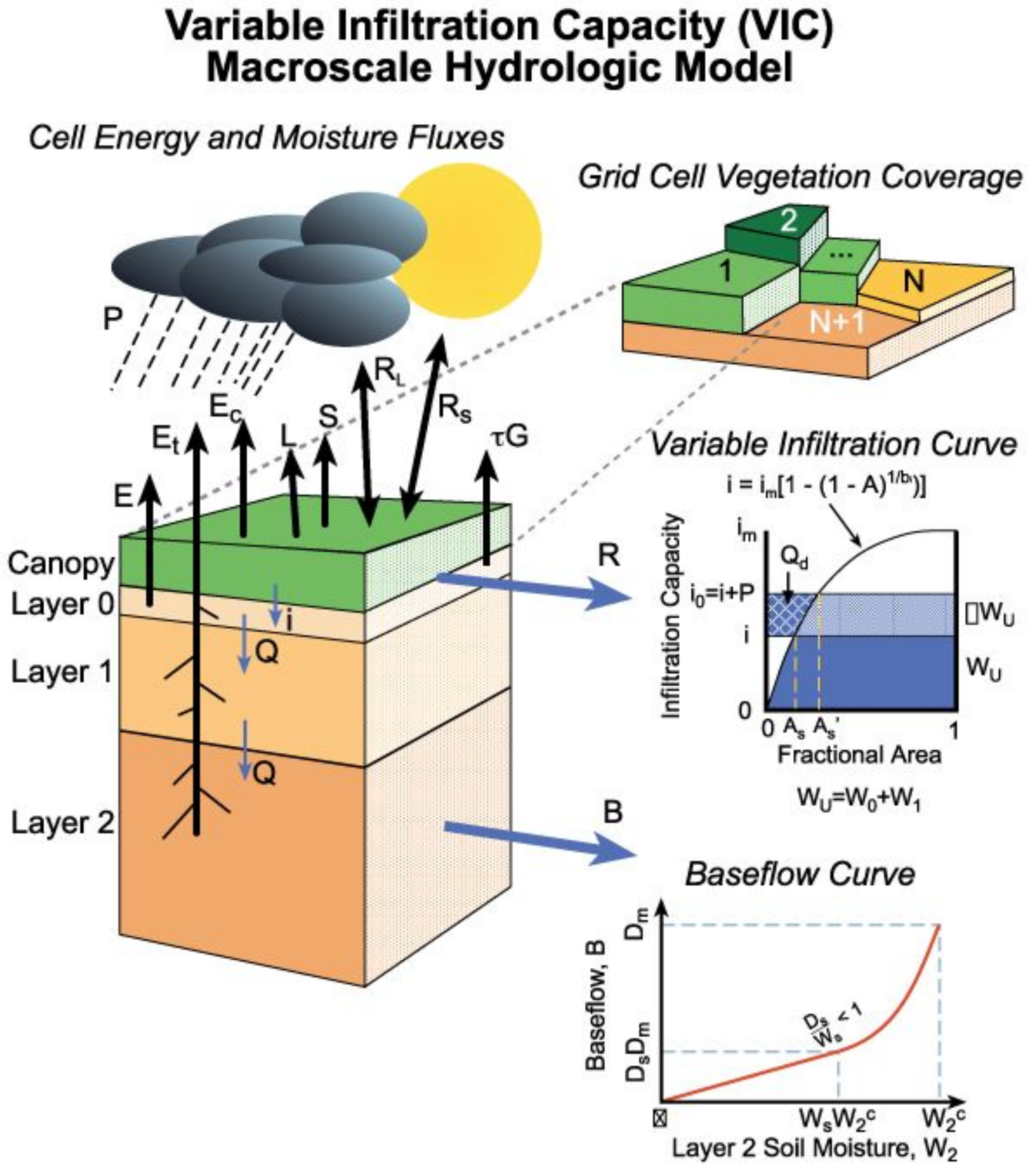
RHEAS – Hydrological Model

Variable Infiltration Capacity Model

- Large-scale hydrologic model (Liang et al, 1994)
- Simulates water & energy storage and fluxes
- Sub-grid variability (vegetation, elevation, infiltration) handled with statistical distribution
- Inputs: meteorological drivers
    - Precipitation
    - Air temperature
    - Wind speed
- Widely applied across a range of hydro-climatic environments and has also been used to simulate global soil moisture and drought severity

RHEAS VIC

- Globally calibrated
- Globally preprocessed parameter files (snow bands, vegetation etc.)

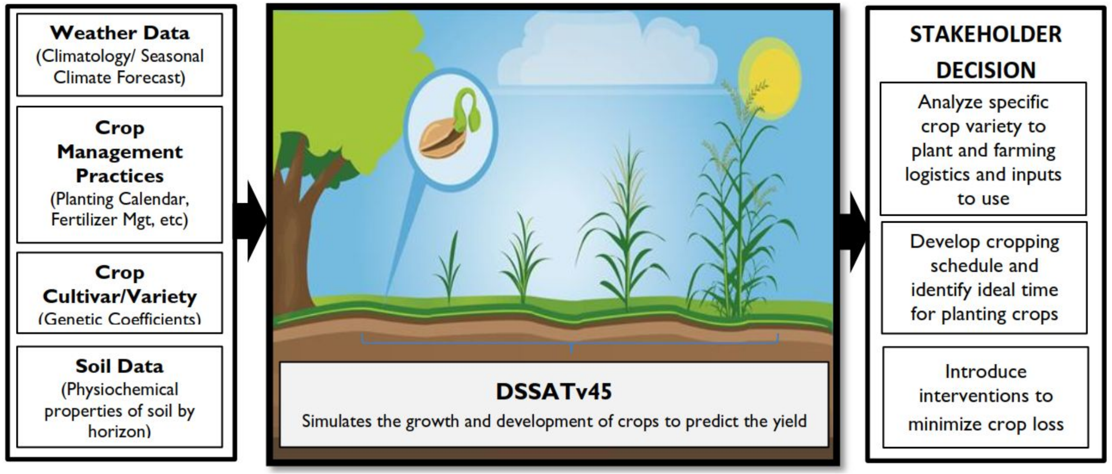


Source: https://vic.readthedocs.io/en/master/Overview/ModelOverview/

RHEAS – Crop Model

<u>Decision Support System for Agrotechnology Transfer (DSSAT)</u>

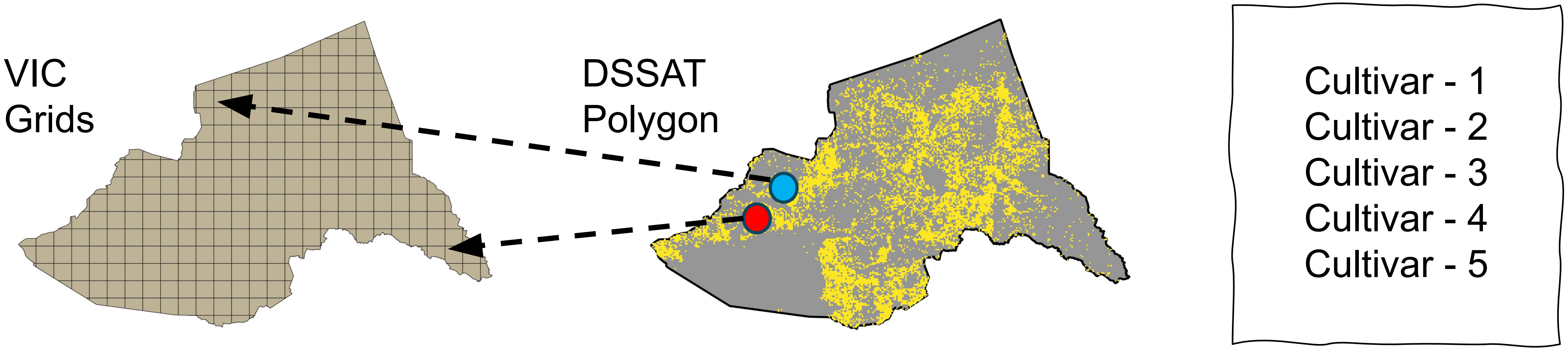
- Model that simulates the crop development and growth based on various factors including:
  - Weather
  - Plant characteristics (genetics: cultivar type)
  - Soil physical and chemical properties
  - Management options (planting and harvest dates, irrigation/fertilization type, amount, timing etc.)
- Modular 1-D (point) Crop modeling system
- Mature – More than 30 years of history
- Modules to simulate more than 28 crops



<u>RHEAS DSSAT – Regional Crop Modeling System</u>

- Currently supports three crop types:
  - Corn (Maize)
  - Wheat
  - Rice
- Uses global planting season calendar
- Default soils characteristics derived using – 250 m ISRIC soil database
- Randomized ensemble model implementation over a polygon

RHEAS – Crop Model



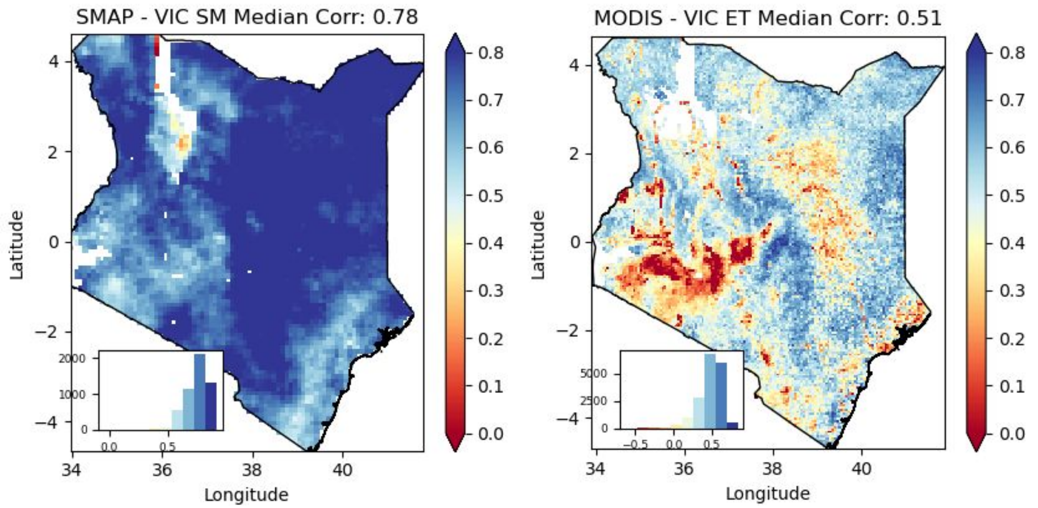
1. Check to see if at least 10% of cropland exists within polygon
2. Randomly select ‘n’ soils from cropland mask [n = ensemble size]
3. For each selected soils, select weather information from any of the grid randomly chosen.
4. Similarly, if there are 5 different cultivars are being used in this polygon then each of the ensemble member will select any of those 5 cultivar at random

Example:

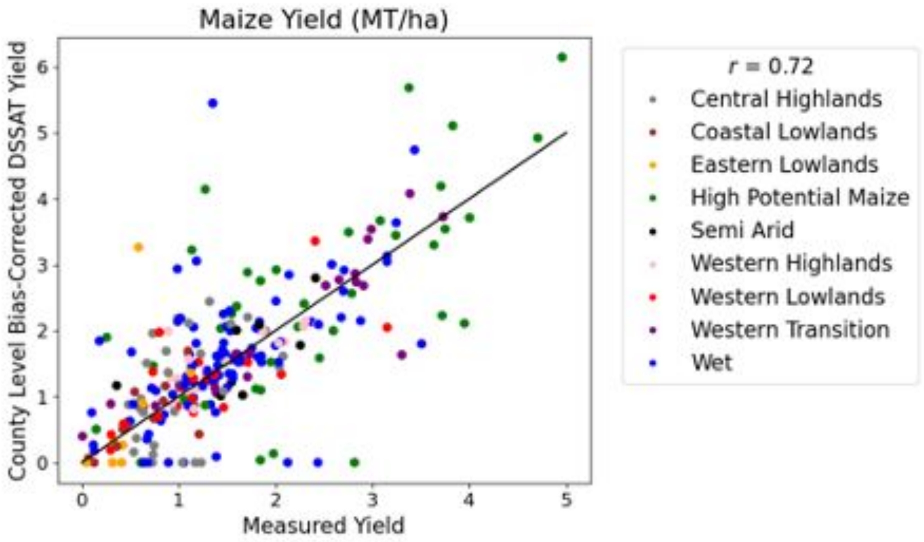
\# of ensemble (n) = 50
\# of grids = 200
\# of Cultivars = 5
\# soil types = 40

Total possible combination for each ensemble = 200 x 5 x 40 = 40,000

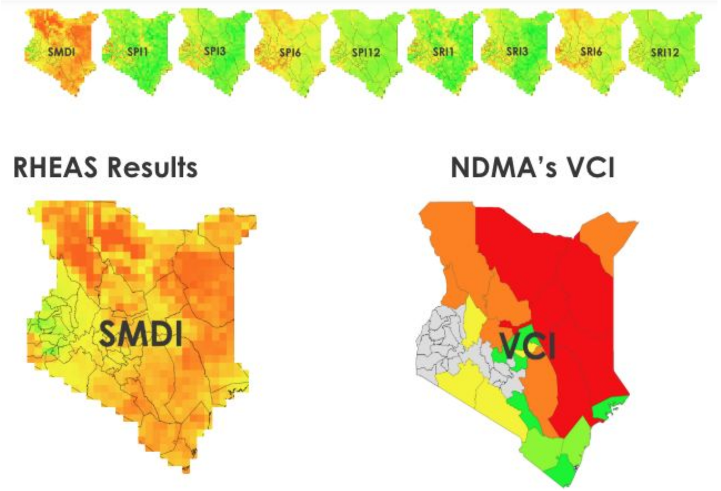
Results : Kenya



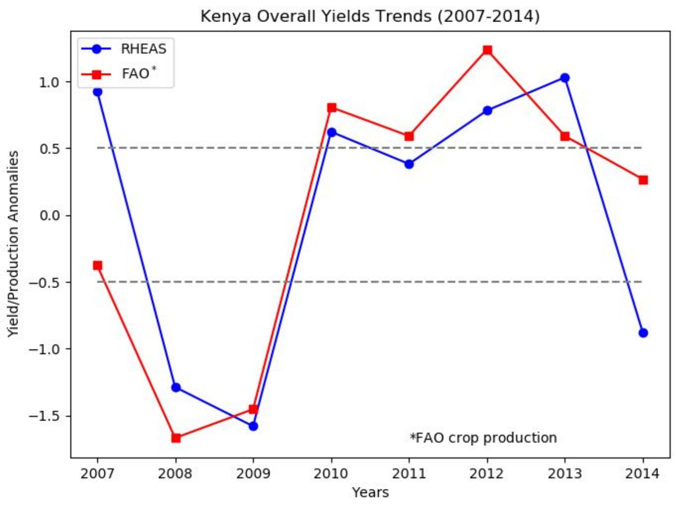
RHEAS VIC comparison against satellite observation over Kenya (2015-2019).
(*Ellenburg et al., 2014)*

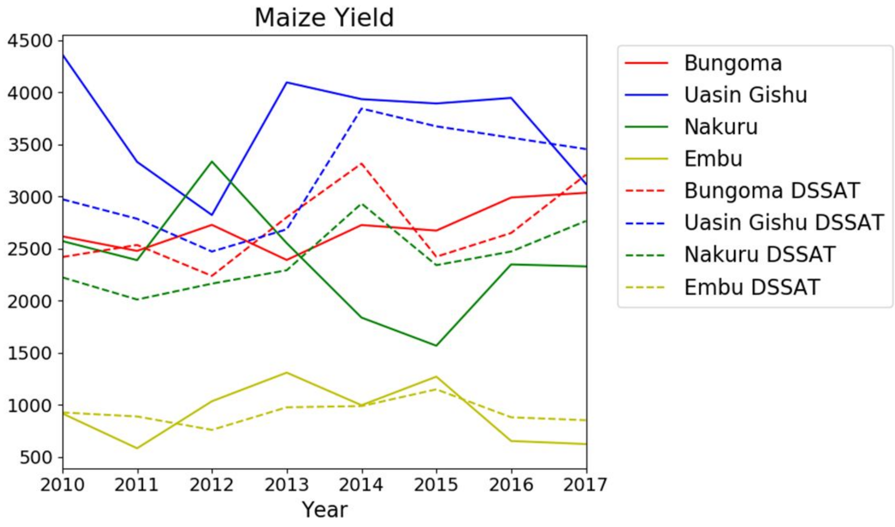


RHEAS maize yields for all major maize producing counties in Kenya compared to county scale Ministry of Ag. Data (2015-2020)



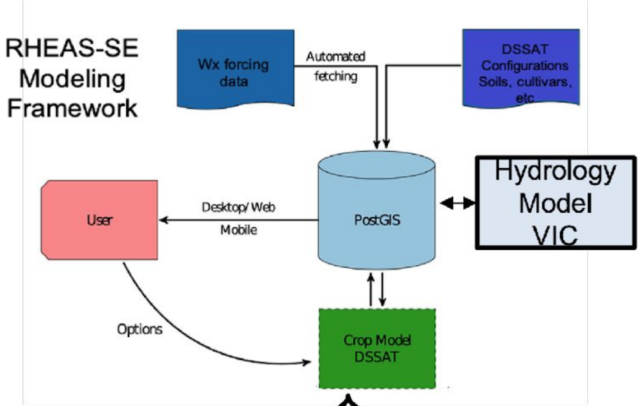
RHEAS outputs for drought assessment



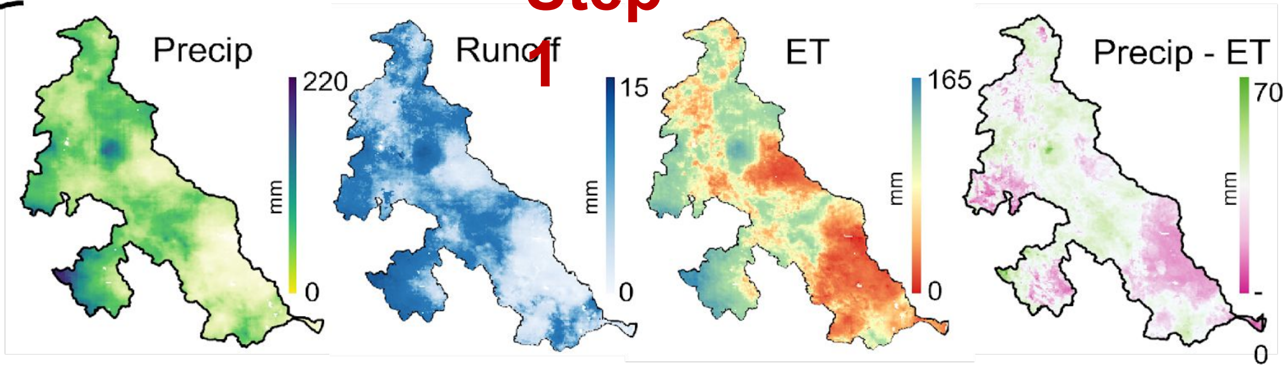


Crop yield comparisons between the FAO and RHEAS at country–level and over 4 counties in Kenya (2010-2017)

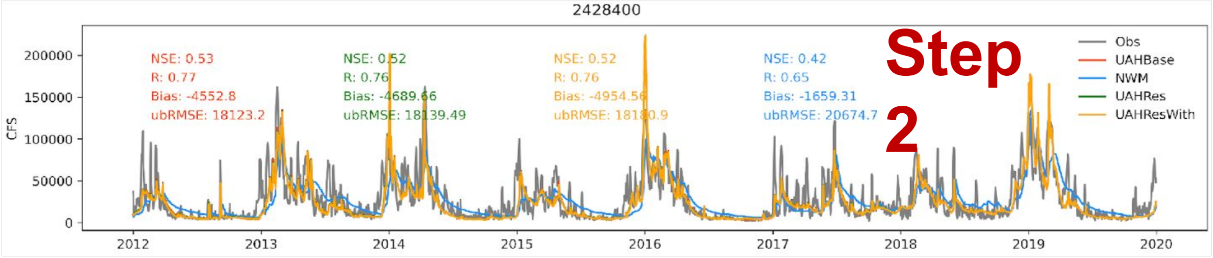
Proposed RHEAS Implementation for RGB



Step 1



Step 2



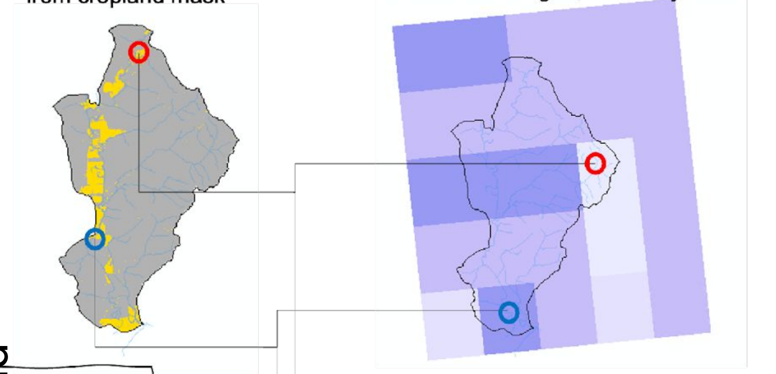
Surface Water Availability

Step 3

The DSSAT Crop model is run stochastically over an AOI (HUC-12), sampling n times (# of ensembles chosen) over **weather** inputs, **soil,** and **cultivars** randomized over the area

1. Randomly select soils from cropland mask

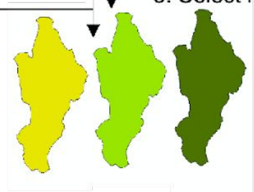
2. For each selected soils, select weather information from the grid, randomly chosen.



Irrigation water Demand

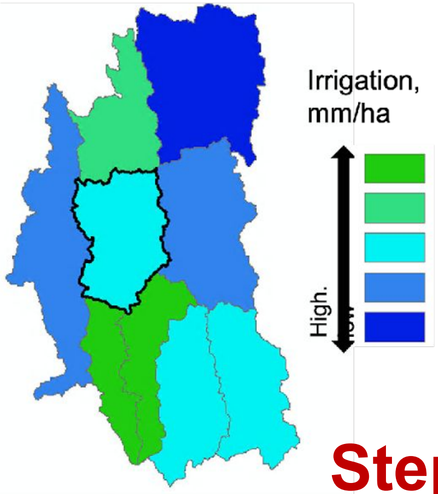
Cultivar - 1
Cultivar - 2
Cultivar - 3
...

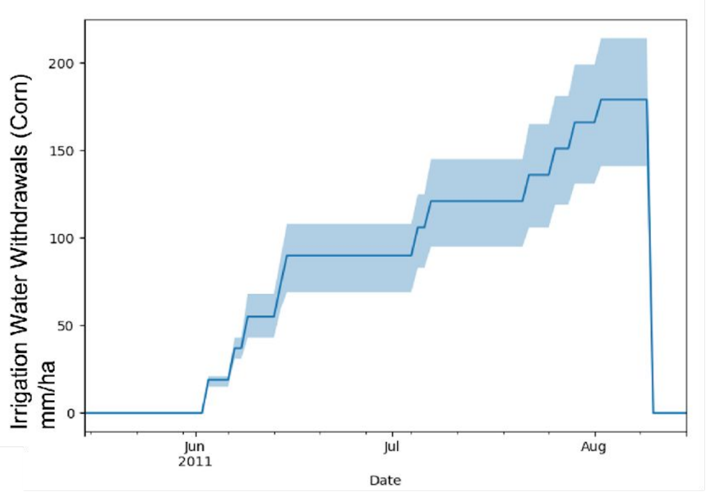
3. Select random cultivar from a curated list



OUTPUT: n number of simulations (and associated stats) of yield, irrigation demand, etc.

Irrigation Demand Statistics @ HUC 12

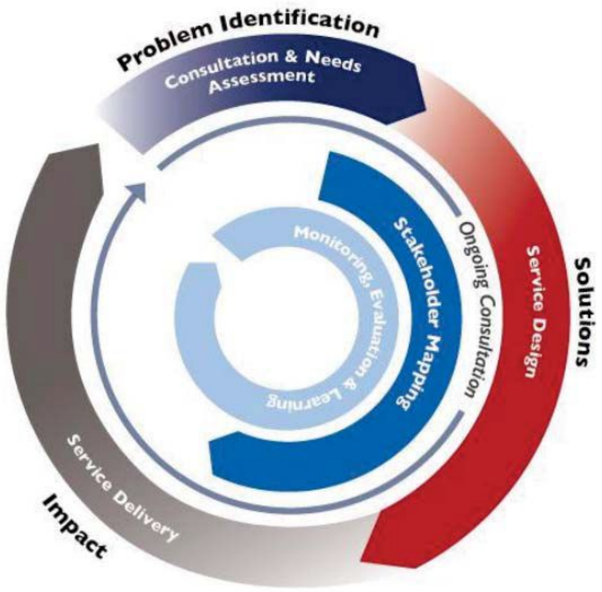




Step

Transition Plan

We will adopt a service planning framework that facilitates a need-driven, co-development system with an end goal of increasing the capacity of the end-user.



1. *Consultation and Need Assessment*
   - Problem identification and expectation management
   - Current gaps and opportunities
   - Current technical capabilities and gaps
   - Understand the decision-making context
2. *Service Design and Development*
   - Build consensus on technical approach and capacity building
   - Build a co-development technical team consisting of technical experts from science, integration and decision-making teams
   - Model setup, calibration and validation (re-evaluation)
3. *Service Delivery*
   - Monitoring, evaluation and learning
   - Model operationalization and output communication, error characterization
   - Technology transfer and integration into their decision-making framework through workshops

Expected Outcome

- The model will be regionally calibrated with the inputs from the partners to refine hydrological predictions and process future scenarios. We will co-develop the model calibration and validation strategy after the consultations with the stakeholders.

- The end-user and implementing partners will be trained on the modeling setup and result interpretations.

- The outputs of the model and visualization platform will be deployed at the NMWDI

- Making sure that the model outputs align with the end-user (EBID) needs and gets integrated into their decision-making framework.