Jet Propulsion Laboratory
California Institute of Technology

Introduction of the RHEAS Framework and Products

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Presentation Outline

- Overview and vision for the tool
- Introduction to the RHEAS Modeling Framework
- Terminologies used in the RHEAS Model & Simulation Approach
- RHEAS output products and their applications
- Stakeholders, their needs and explicit decision contexts
- East Africa work

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Acronyms and Terminologies Used

- NASA-JPL - National Aeronautics and Space Administration – Jet Propulsion Laboratory (NASA-JPL)
- RHEAS - Regional Hydrologic Extremes Assessment System
- VIC - Variable Infiltration Capacity – is a hydrologic model
- DSSAT - Decision Support System for Agro-Technology – is a crop yield model
- GIS - Geographic Information Systems
- PostGIS - is an open-source database that extends the well-known PostgresSQL object-relational database to include support for geographic objects.
- LAI – Leaf Area Index
- IPCC – Intergovernmental Panel on Climate Change

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RHEAS Software Vision

Need

Water resources management involves:

- tradeoffs between multiple objectives and
- coordination with a heterogeneous set of stakeholders.

Requiring:
Accurate information on water and energy conditions with as much lead time as possible.

Problem

Interaction between science organizations and end-users has improved, but…

Direct interaction and customization of the information producing system is needed to accelerate adoption of science information for management.

Solution

A software framework that:

- automates the ingestion of a diverse array of datasets,
- deploys a hydrologic model
- incorporates data assimilation and
- facilitates coupling with other earth science models.

Implementation

The system must be geared for relatively easy implementation and customization requiring minimal input.

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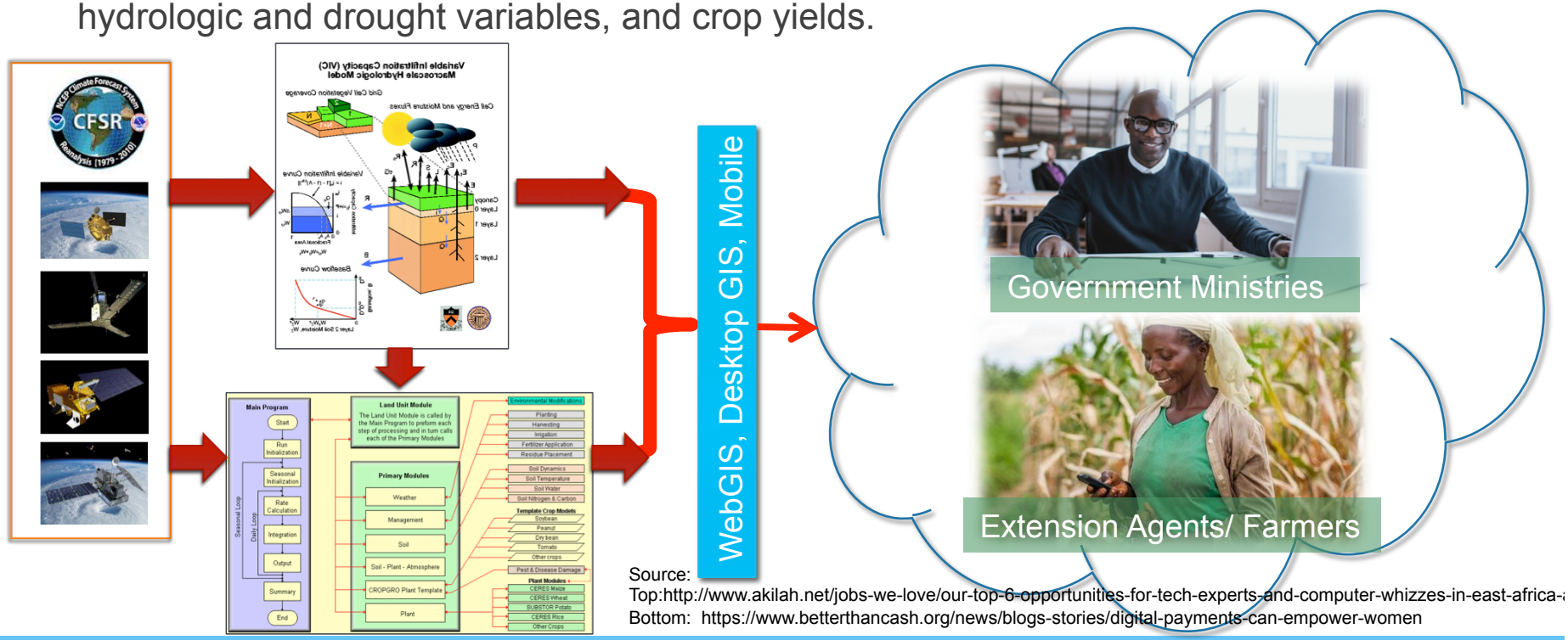
The Regional Hydrologic Extremes and Assessment System: A Modeling Framework

NASA-JPL has developed a software infrastructure that consists of:

1. a data ingestion framework; and
2. physical models: a hydrologic model and a crop model.

The infrastructure

1. takes advantage of data from a variety of sources including satellites, models, *in situ* and others; and
2. provides an interface to physical models that produce current and projected estimates of hydrologic and drought variables, and crop yields.



Source:
Top:http://www.akilah.net/jobs-we-love/our-top-6-opportunities-for-tech-experts-and-computer-whizzes-in-east-africa-
Bottom: https://www.betterthancash.org/news/blogs-stories/digital-payments-can-empower-women

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RHEAS

THE REGIONAL HYDROLOGICAL EXTREMES ASSESSMENT SYSTEM

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- Began as a project focused on California and the American West.
- Implemented for East Africa.
- Designed as a flexible modeling framework.
- Has a hydrologic model at its core – the widely used Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model (http://vic.readthedocs.org/en/master/)
- Uses best available data (including NASA Earth observations) as inputs for the model.

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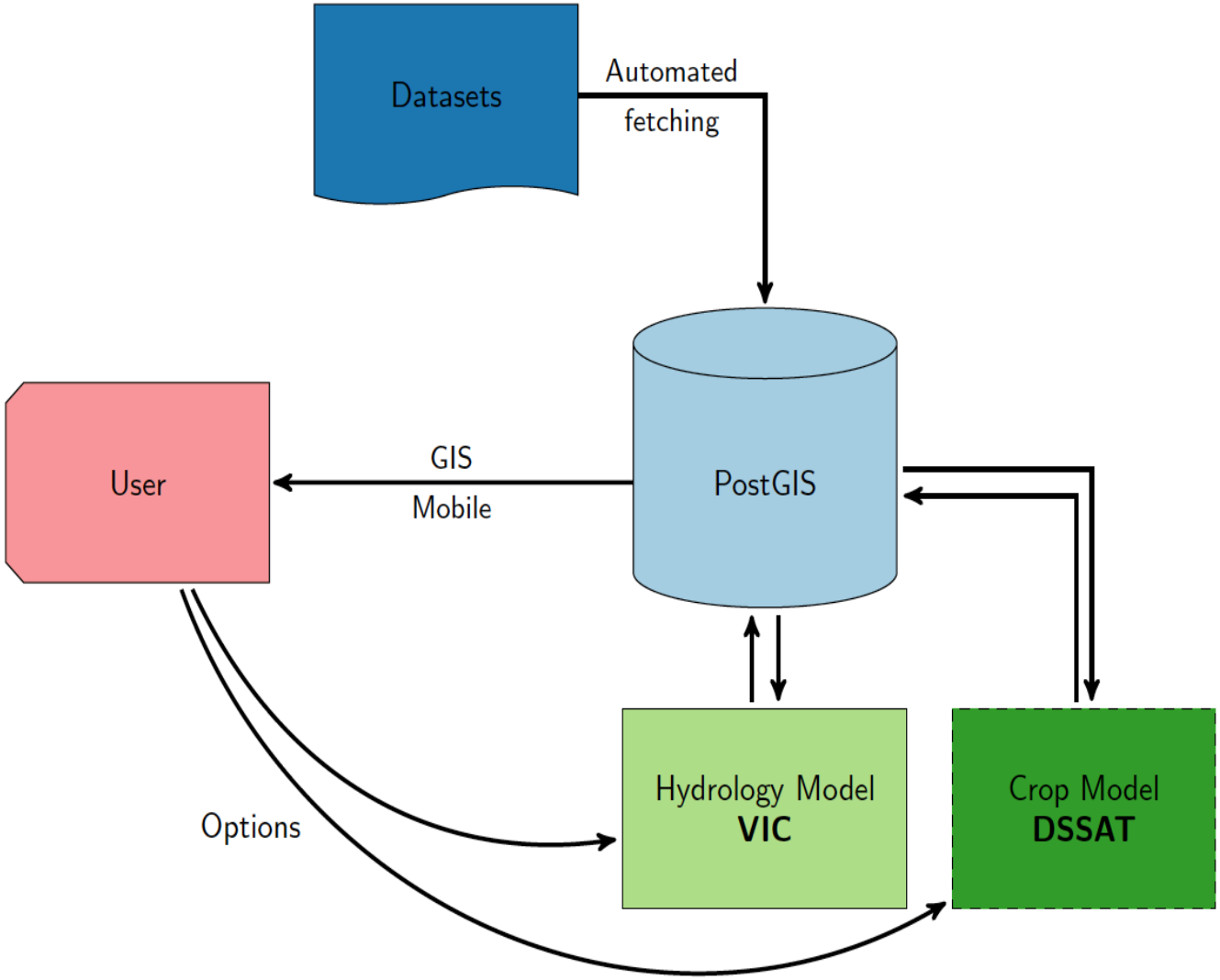
RHEAS Software Architecture



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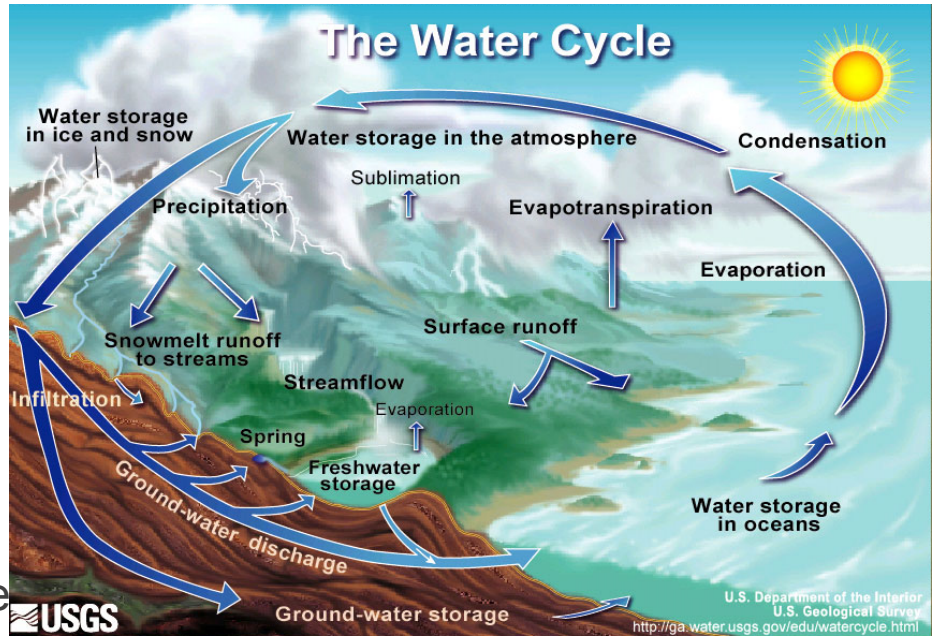
Hydrological Modeling

- Hydrologic models are:
  - simplified, conceptual representations of a part of the hydrologic cycle.
  - used for hydrologic prediction and for understanding hydrologic processes.
- There are two major types of hydrologic models:
  - **Stochastic Models.** These models are black box system that use statistical approaches to link inputs (e.g., rainfall) to outputs (e.g., runoff).
  - **Process-Based Models**. These models try to represent the physical processes observed in the real world. They contain representations of surface runoff, subsurface flow, evapotranspiration and channel flow, but can be more complicated.
    - Called deterministic models



The Hydrologic cycle

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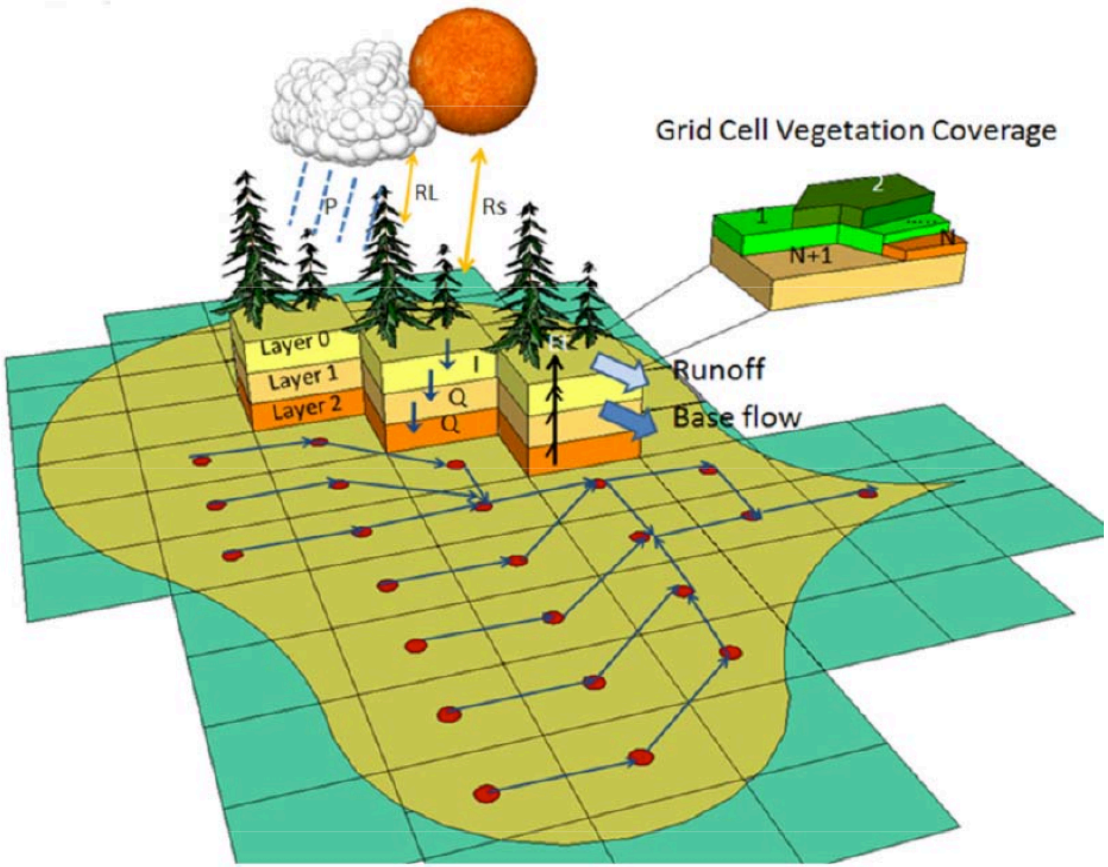
Variable Infiltration Capacity (VIC) Hydrology Model



Source: Carrasco and Hamlet, Final Report for the Columbia Basin Climate Change Scenarios Project, Chapter 6, 2010.

- Grid-based land surface representation.
- Simulates land surface-atmosphere exchanges of moisture and energy
- Developed for coupled simulations
  - Only recently used
- Off-line simulations for most uses:
  - Debugging, model improvement
  - Calibration
  - Module development

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Crop Simulation Modeling

- A **Crop Simulation Model** is a simulation model that helps estimate crop yield as a function of weather conditions, soil conditions, and choice of crop management practices.
- Crop simulation models have been classified into three broad categories:
  - **Statistical models:**
    - Rely on yield information for large areas (such as counties), and identify broad trends. .
    - Statistical models are a significant improvement over naive historical predictions, but are not suitable for fine-grained predictions.
  - **Mechanistic models:**
    - These attempt to use fundamental mechanisms of plant and soil processes to simulate specific outcomes.
    - These involve fairly detailed and computation-intensive simulations. .
  - **Functional models:**
    - These use simplified closed functional forms to simulate complex processes.
    - Computationally easier than mechanistic models, and
    - Can often give results that are of only somewhat worse accuracy.

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Decision Support system for AgroTechnology (DSSAT)

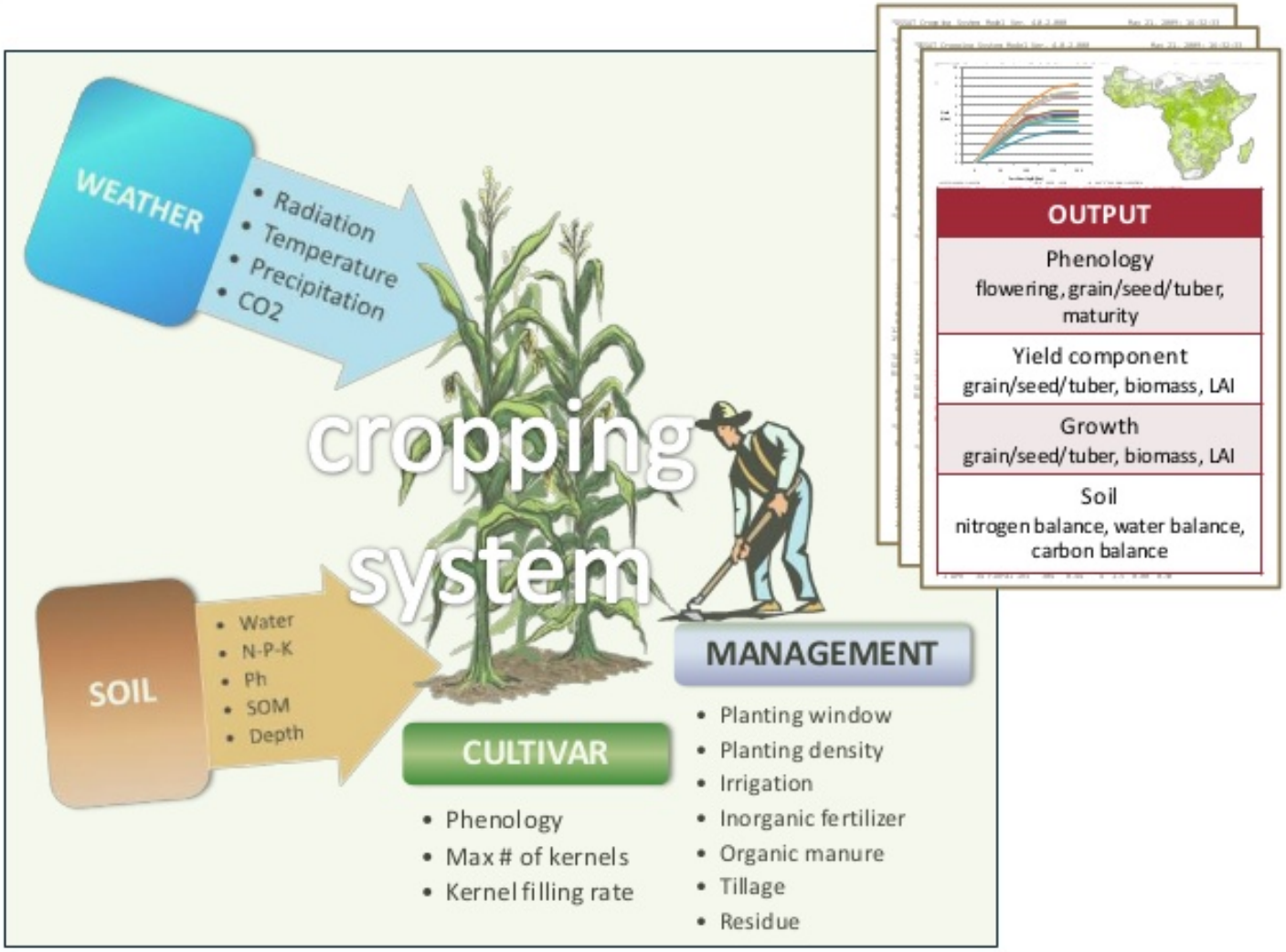

Image credit: Harvest Choice

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RHEAS East Africa Output Products
As nowcasts, seasonal outlooks and projections

Product	Decision-making activity	Who
Soil moisture, temperature, and precipitation	Determines the break of season, potential for growth, onset and duration of rapid growth.	ESA, Farmer, Ministry
Change in soil moisture with time	Quantify depletion rates and provide outlook on growth potential	ESA, Farmer, Ministry
Drought onset, recovery and duration	Dry conditions control timing of crops, food storage planning and security.	ESA, Farmer, Ministry
Drought severity	Can control how aggressive actions need to be to alleviate problems.	ESA, Farmer, Ministry
Greenness/vegetation health	Related to health of crops during the growing season.	ESA, Farmer, Ministry
Crop yield	Outlook on expected yield to support risk management.	Ministry

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Stakeholders: Needs

- Stakeholders
  - Our primary stakeholders are government ministries.
    - Agricultural, environmental, meteorological
  - Others: NGOs, commercial, farmers through agricultural extension services.
- Needs
  - Monitoring current hydrologic and drought conditions at country-scale using data of homogeneous quality.
    - Data poor regions rely on sparse networks of in situ sensors with data gaps and quality control issues.
  - Weekly estimates of yield during the growing season.
  - Sub-seasonal to seasonal forecasts of conditions and yield
  - Projections of future conditions at decadal scales to assess suitability for crops.

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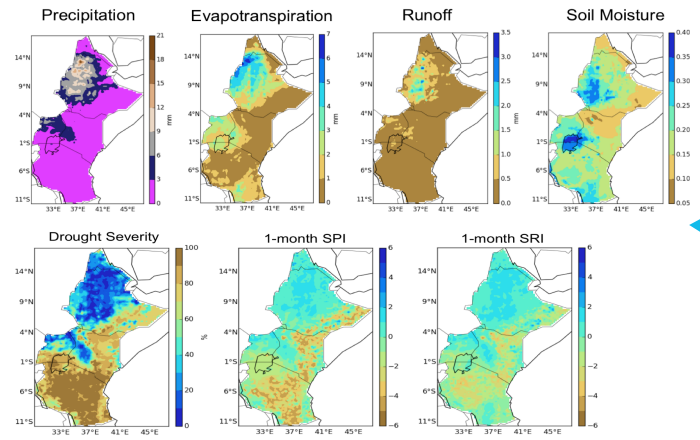
Decision Context

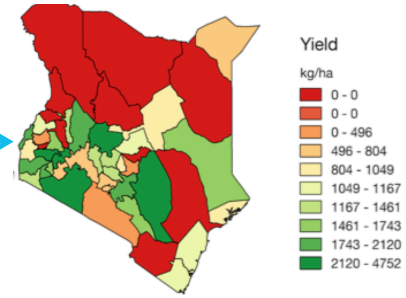
- Premise
  - Linked drought and crop productivity nowcasts and forecasts -> Improve management/ planning (establishing priorities, strategies) -> Reduces uncertainty and risk.
- Use of RHEAS information about current and forecast drought conditions used to:
  - Plan for and mitigate drought impacts on agriculture
  - Inform food security/economic decisions at the ministry level
- Data and maps of drought characteristics (e.g., soil moisture) and derived measures (drought severity) tied to agricultural yield used to:
  - Adjust the timing of crops.
- Data and maps of projected hydrological, and yield conditions used to:
  - Assess future suitability of region for growing specific crops

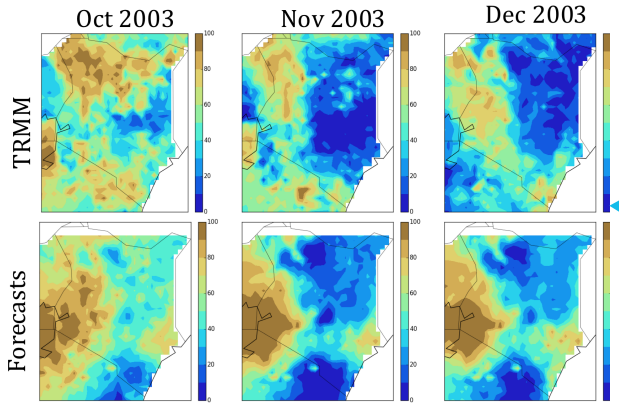
Information Product Examples



Nowcasts of hydrologic variables

Nowcast of Maize yield





RHEAS drought severity forecasts.

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East Africa Drought and Agricultural Productivity Assessment and Prediction

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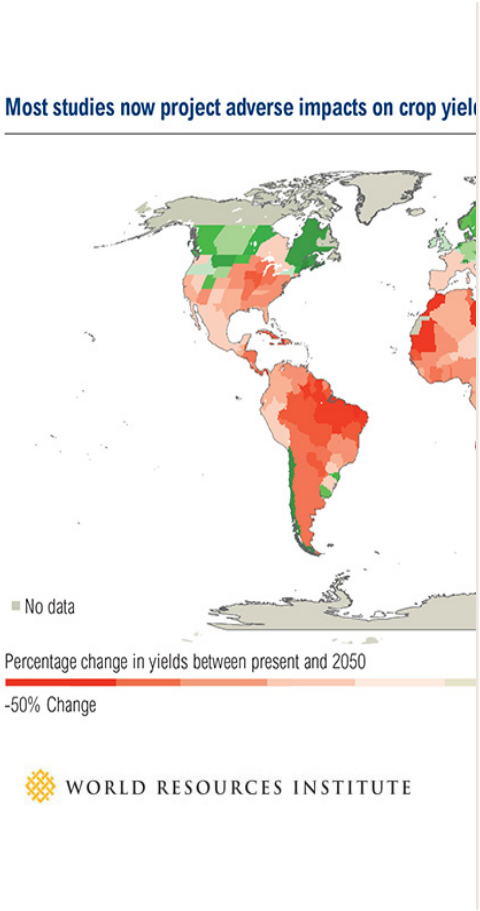
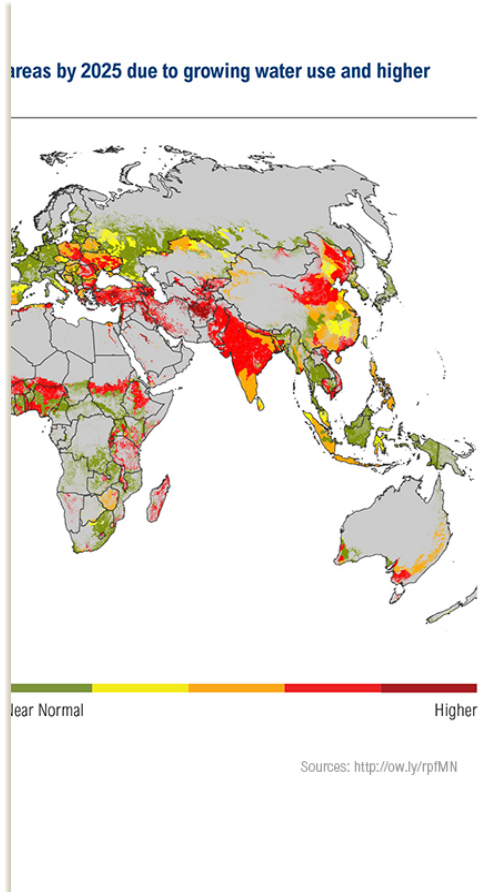
SERVIR RCMRD ICIMOD CATHALAC USAID NASA

A Cross-cutting Challenge: Water, Agriculture and Climate Change





A key conclusion of the IPCC Working Group II authors is that climate change will increase the risk of reduced crop productivity associated with heat and drought stress.

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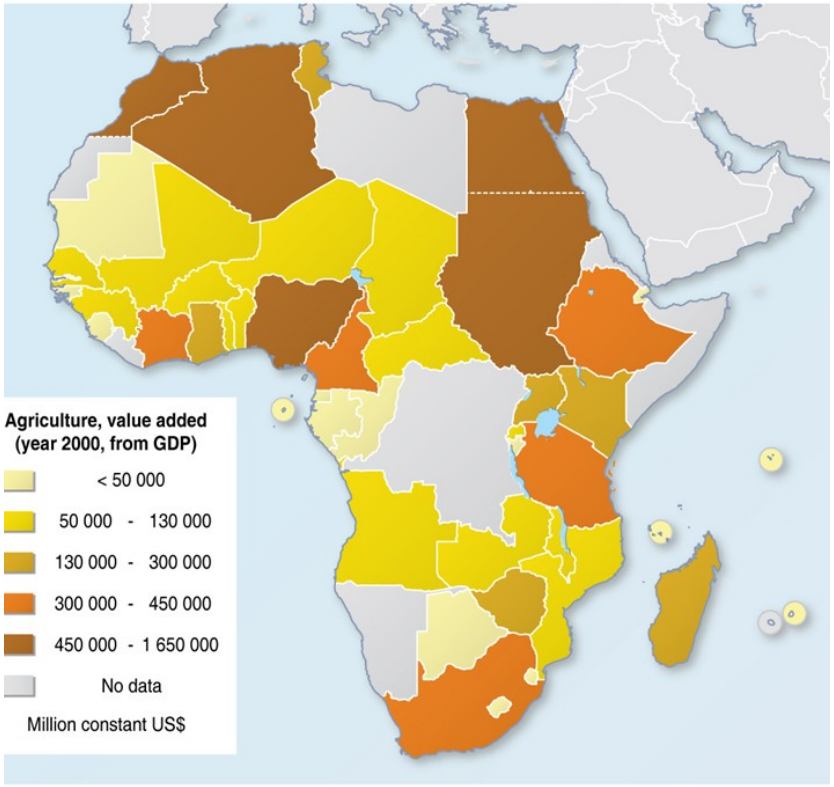
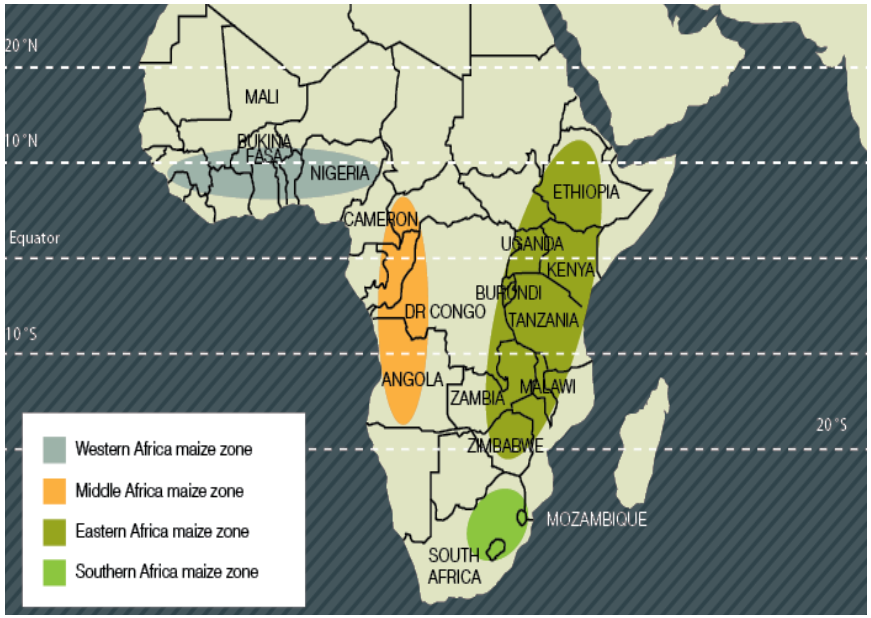
Agriculture in Eastern and Southern Africa



Source: World Bank, World Development Indicators, through UNEP DEWA/Geneva Data
http://geodata.grid.unep.ch/ Accessed January 2006

Credit: Hugo Ahlenius, UNEP/GRID-Arendal
Source: http://www.grida.no/graphicslib/detail/agriculture-in-africa-value-added-out-of-gdp_10e3#



Credit: Australian Center for International Agricultural Research
Source: /http://aciar.gov.au/files/mn-158/s5_4-maize-sub-saharan-africa.html

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Why this Project?

- **Agriculture** is the **economic engine** of eastern and southern Africa and as **96%** of agriculture is **rain-fed** agriculture, it is **severely impacted by climatic shifts** and **extreme events**.
- There is a **critical** need for **consistent, reliable and quantitative** drought and crop yield information at regional, national and local scales.
- **Advances** in **remote sensing** technology and tools enable the collection and analysis of hydrologic and agriculture data over large geographic regions…
  - Yet the use of satellite-based systems for **forecasting hydrological** variables and **agricultural** output is **rare** in Sub-Saharan Africa (SSA).

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Objectives

- **Implement the RHEAS modeling framework** to provide drought and crop yield information to agricultural communities of SERVIR-Africa.
  - Current conditions
  - Short to mid-term forecasts of drought characteristics tied directly to measures of crop productivity
  - Climate-scale projections (experimental)
- **Engage appropriate stakeholders** to ensure information we're producing is the right information and that it's useful.
- **Ensure information is useable and accessible** via GIS-friendly formats and online access, and disseminate information through a prototype mobile application.

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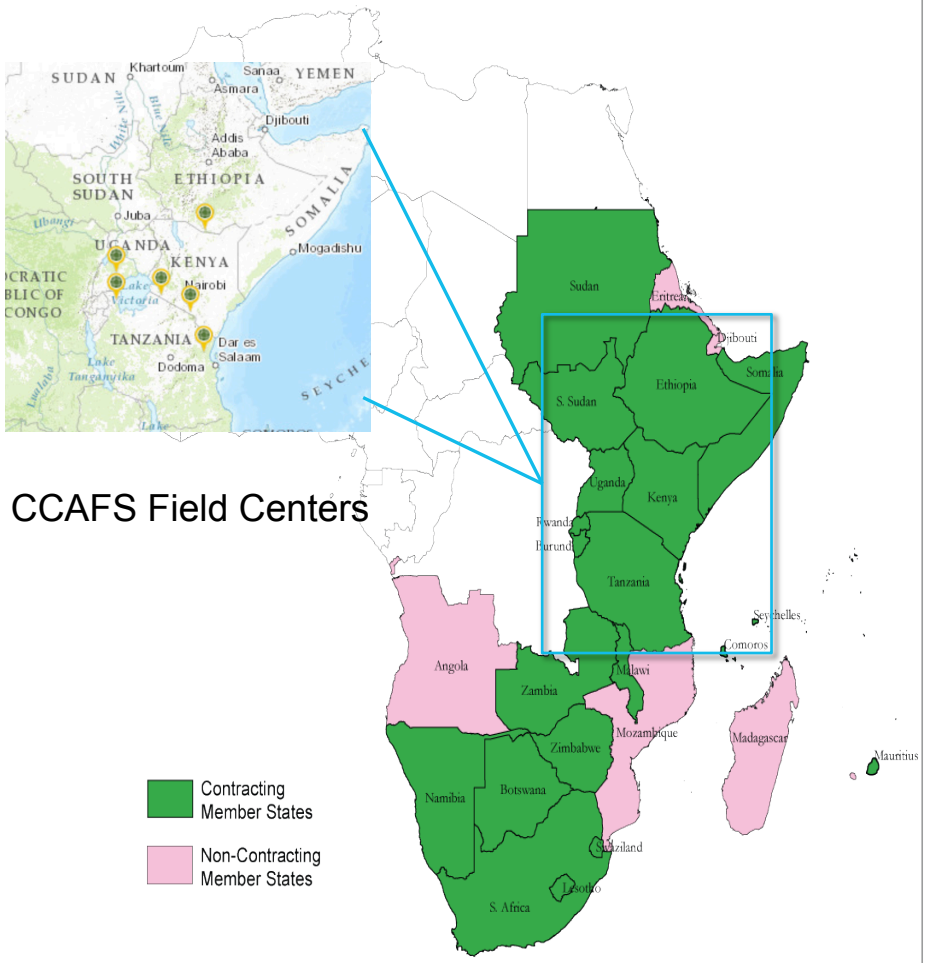
Regional Focus

Focus on six RCMRD member countries

- CCAFS established field centers in Ethiopia, Kenya, Tanzania, Uganda
- RCMRD received requests to expand to Malawi and Zambia.



CCAFS Field Centers

RCMRD members Countries, Source: RCMRD

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Partners and End Users

Project Partners and Collaborators

Regional Centre for Mapping of Resources for Development
RCMRD

The International Research Institute for Climate and Society

MICHIGAN STATE UNIVERSITY

CGIAR

RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security

CCAFS

Project End Users

HARAMBEE

Jamhuri ya Muungano wa Tanzania

UNITY AND FREEDOM

One Zambia One Nation 1964 2014

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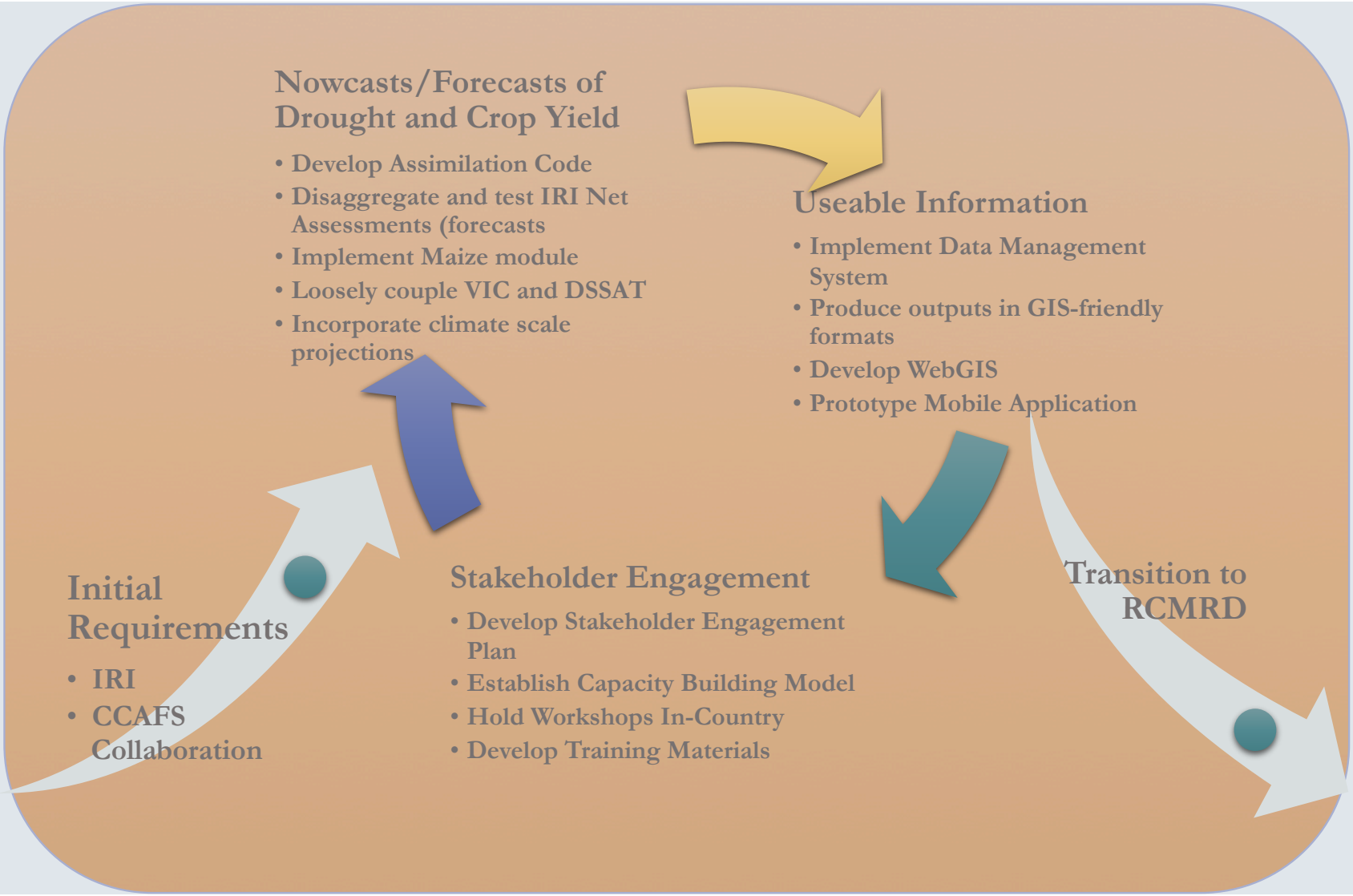
Approach/Project Activities



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Workshops and Technical Capacity Building

2014-2015: Inception workshops and technical capacity building in Kenya, Tanzania, Zambia. Malawi, and Ethiopia.

2016: Technical capacity building for RCMRD personnel in Nairobi, Kenya

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Challenges

Technical	Data	Structural/Organizational
Inadequate staff capacity and work overload: affecting application of modern technologies.	Lack of standardized and harmonized data collection, analysis and management guidelines	Limited networking and collaboration amongst relevant stakeholders and agencies.
Limited technical knowledge owing to poor training in data/statistics, remote sensing data, analysis, and data management.	Low appreciation of quality data at the ministry level and inadequate budgets for data collection and management.	Weak extension service.
Low use of modern technology: ITC, mobile phones.		Several and often conflicting sources of data within a limited regulatory framework.

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Best Practices

Technical	Data	Structural
Follow existing frameworks whenever possible for use of new tools.	Work directly with gov't ministries to improve data collection and access.	Focus on decision making for risk management (risk reduction) rather than increasing crop yield.
Use software solutions that connect with tools already familiar or already in use by stakeholders.	Follow data collection and management guidelines, understand and use common protocols.	Sustainability of NASA Earth science remote sensing products is a concern.
Co-authorship of academic papers, conference proceedings, reports		Ensure buy-in through close collaboration with stakeholder personnel at all levels.
Co-development of tools, data dissemination strategies.		

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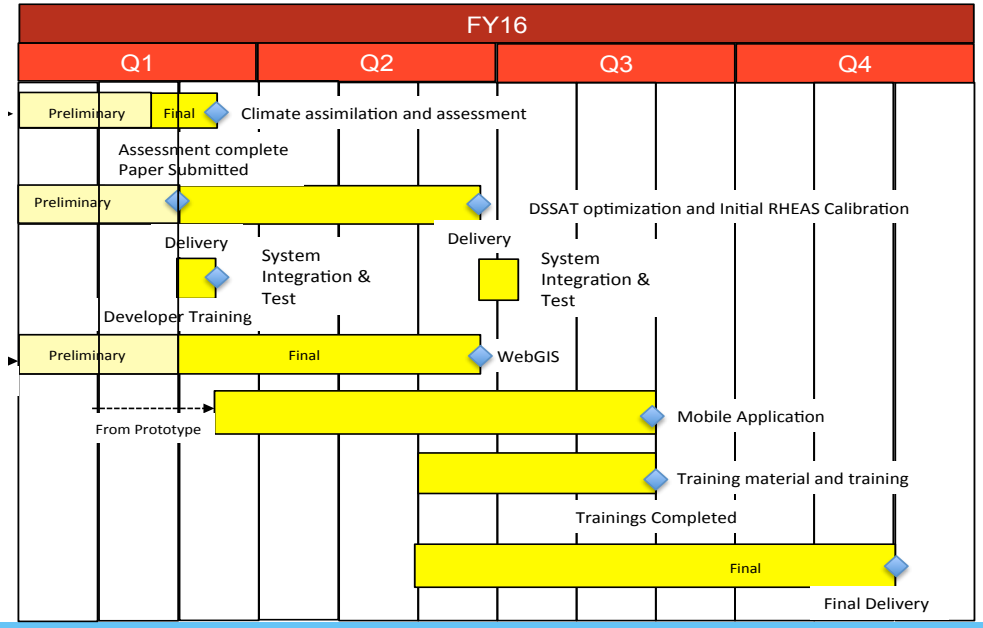
Accomplishments and Activities

RHEAS	Assimilation code is complete	Hydrologic model run in hindcast, nowcast and forecast modes (using IRI Net Assessments)	VIC and DSSAT models loosely coupled	Maize module completed (cultivar data acquired for Kenya, Tanzania, Ethiopia)
Stakeholder Engagement	Adapted capacity building model from public health sector	Developed training materials	Held National Workshops in 5 countries	
Accessible Information	OpenGeo database implemented (PostGIS)	Prototype WebGIS using OpenGeo Suite	Outputs in GeoTiff and as Web Map Services	



Major Accomplishments:

- RHEAS assimilation framework complete and tested.
- Loosely coupled the VIC and DSSAT models.
- Completed hydrologic forecasts.
- Generated documentation and instructions for installation of the system.
- Build a PostGIS database with search and subset functions optimized for future mobile applications.
- Developed the methodology to publish RHEAS outputs as web map services
- Supported National workshops in 5 countries
- Produced peer reviewed papers
- Delivered the RHEAS system to RCMRD

Plans for the coming year:

- Continue to work with stakeholders –2 workshops with RCMRD.
- Large-scale calibration of the modeling framework.
- Optimization of crop model
- Integration of climate projections from Robertson et al into the system.
- Complete web-based GIS and prototype mobile ap.
- Three deliveries of the system to RCMRD

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The End

Thank you!

Questions?

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