Food and Agriculture Organization of the United Nations

International Network of Salt-Affected Soils

Introduction to Crop Modeling and DSSAT

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Global Food Systems Institute
University of Florida, Gainesville, FL, USA

Agriculture: Uncertainty and Risk

- Farming is a "risky" business
  - Weather variability
    - Day-to-day
    - Seasonal
    - Spatial
    - Extreme events
  - Pest outbreaks may occur
  - Costs are unknown (fertilizer prices!)
  - Grain prices are volatile
  - Governmental policies may change

Agriculture: Uncertainty and Risk

- Farming is a “risky” business
- Could **computer models** help with understanding the Genotype * Environment * Management Interactions?
- Could **computer model predictions** help reduce uncertainty and risk under climate variability and climate change?

Why Models?

- Traditional agronomic approach:
  - Experimental trial and error

Why Models?

- Traditional agronomic approach:
  - Experimental trial and error
- Systems Approach
  - Computer models
  - Experimental data
- Understand → Predict→ Control & Manage
  - (H. Nix, 1983)
- → Options for adaptive management, risk reduction, and short- and long-term economic and environmental sustainability

What is an agricultural model?

- Crop simulation models integrate the current state-of-the art scientific knowledge from many different disciplines, including crop physiology, plant breeding, agronomy, agrometeorology, soil physics, soil chemistry, soil fertility, plant pathology, entomology, economics and many others.

Models and Decision Support Systems

- To provide advisories, big data products, science-based models and decision support systems to managers for improving production and product quality, optimizing resource use and reducing environmental impact.

➢ Understand different management options

➢ Provide actionable information

The DSSAT
Crop Modeling Ecosystem

www.DSSAT.net

Some Historical Notes on DSSAT

- IBSNAT Project on Food Security
- Funded by USAID from 1982 to 1993
- DATA: Minimum Data Set Concept, 1983-1986
- Initial models included the CERES-Maize, CERES-Wheat and SOYGRO soybean models.
- Data standards for compatibility of models (1986, 1994)
- DSSAT v2.1 released in 1986
- DSSAT Version 3.5 released in 1998 (after project ended)
- DSSAT Cropping System Model, DSSAT v4 released in early 2004
- DSSAT v4.02 in 2006, v4.5 in 2012, v4.6 in 2015; v4.7 in 2017
- DSSAT v4.8 in 2021; v4.8.2 in 2023; *Version 4.8.5 in 2024*

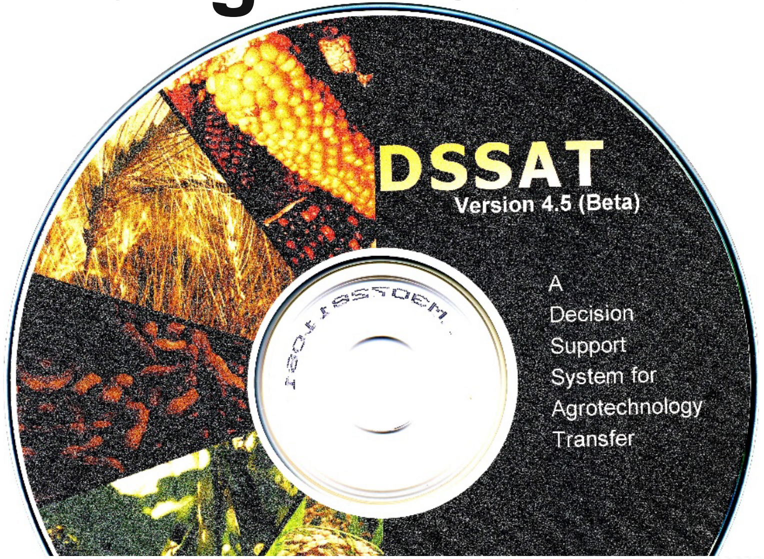
Original Software

Initial price: US $495 + shipping *costs*

Updated price: US $195 + shipping *costs*

Free download from DSSAT portal

Free download & Open Source 3-clause BSD license



Request DSSAT

DSSAT is *Free of charge*!

Request to download your own copy today!

- DSSAT Version 4.8.5 **(New)**
  - Released on December 1, 2024

Download DSSAT v4.8.5

- Click here to see release notes
- Click here to download older versions of DSSAT

DSSAT is not just a software program but an ***ecosystem*** of:

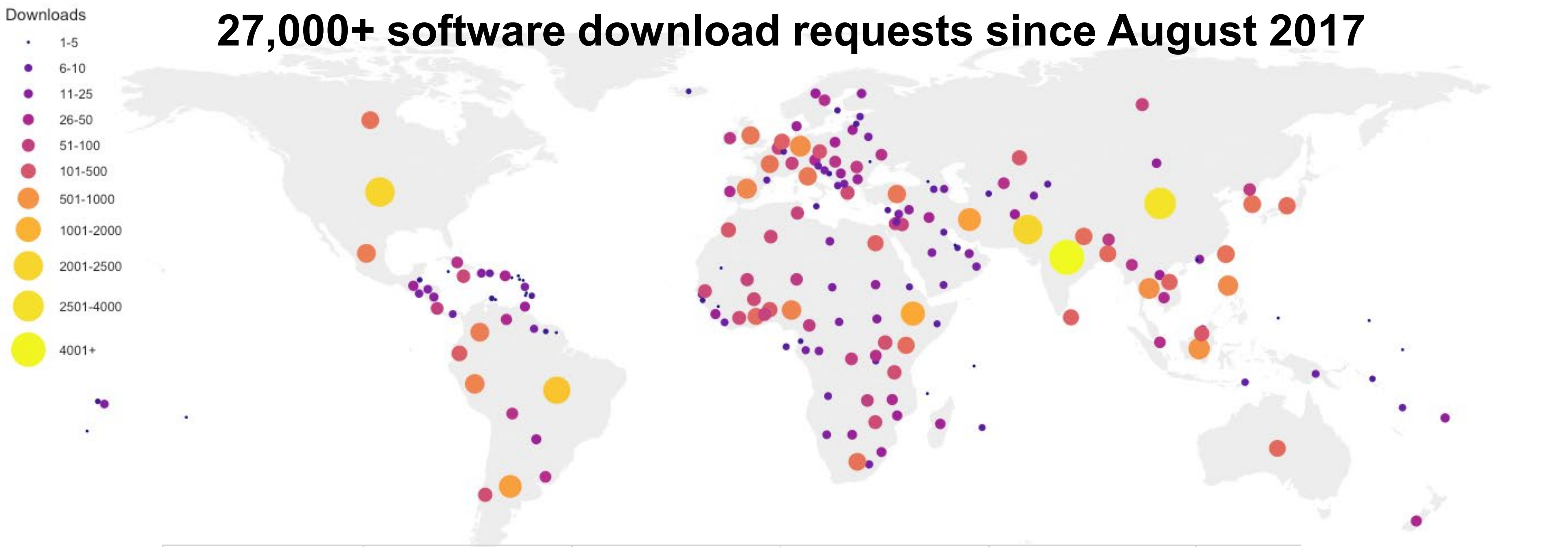
- Crop model users
- Crop model trainers
- Crop model developers

- Models for the most important food, feed, fiber, fuel, and vegetable crops (45+ crops)
- Tools and utilities for data preparation
- Minimum data for model calibration and evaluation
- ICASA Data standards

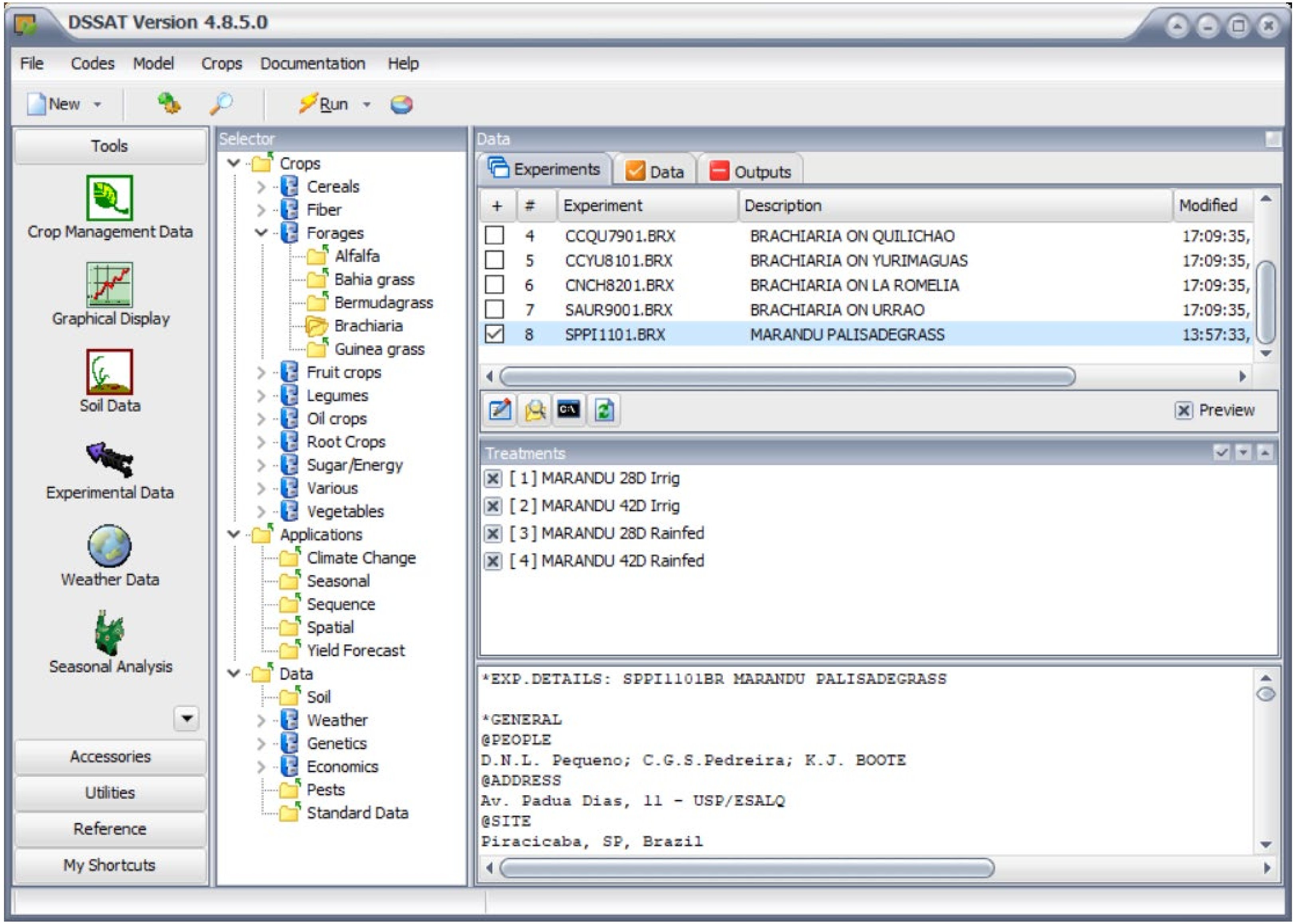
- Application programs for assessing real-world problems

DSSAT User Community

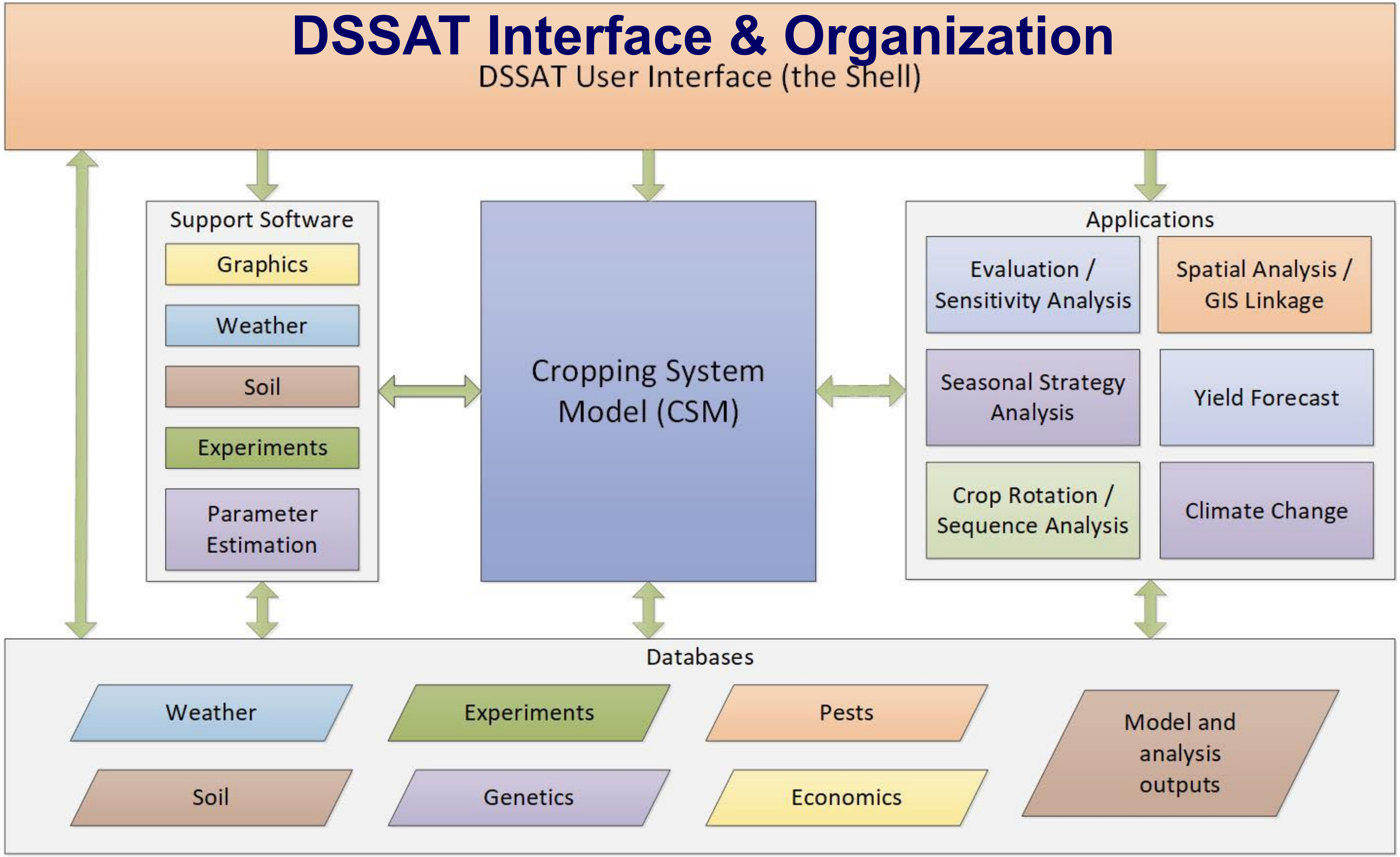
27,000+ software download requests since August 2017



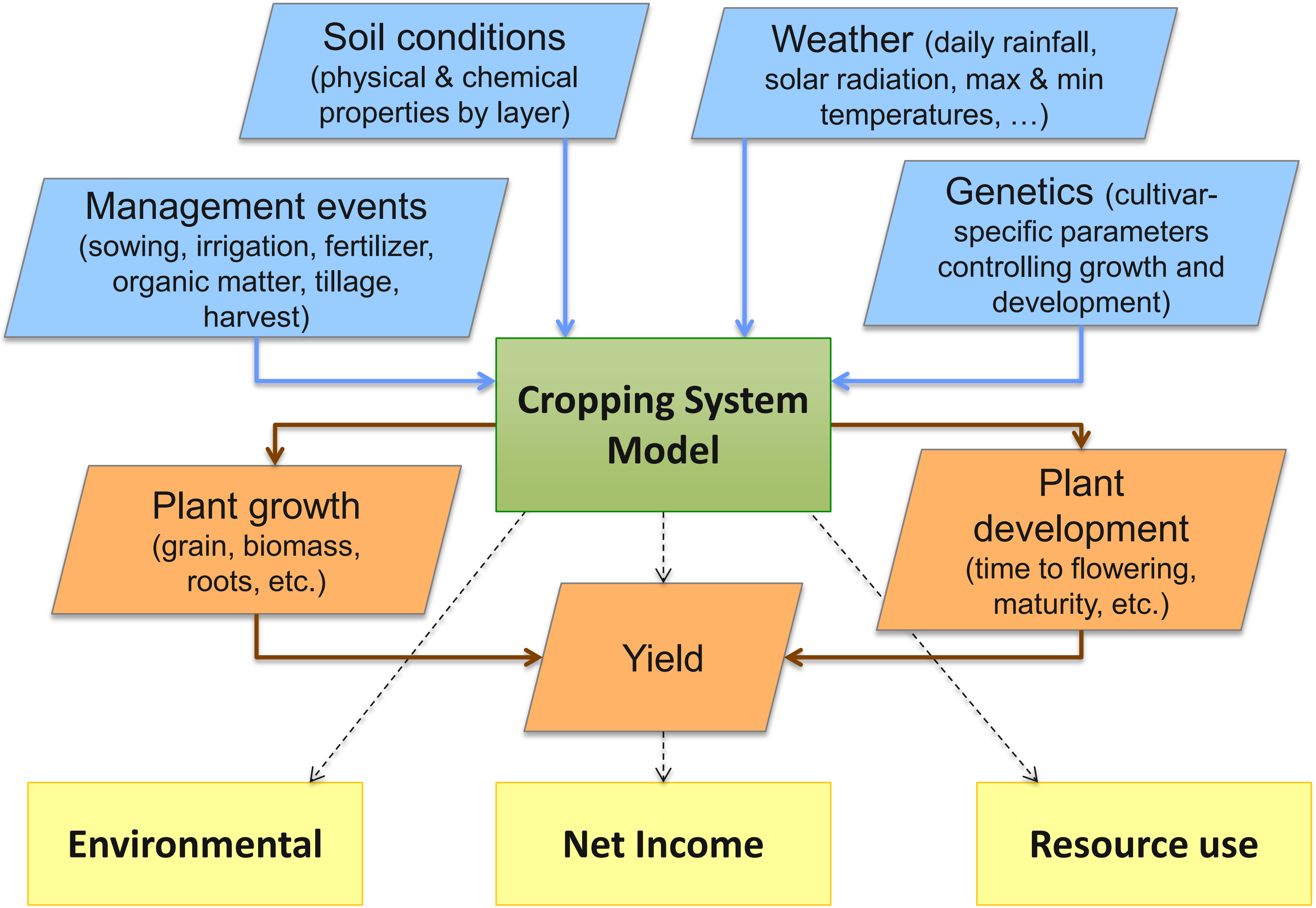
Country	Downloads	Country	Downloads	Country	Download
India	3527	Thailand	409	United Kingdom	211
China	2144	Germany	382	Italy	206
USA	1789	Spain	339	Canada	198
Pakistan	1768	Philippines	334	South Africa	195
Brazil	1224	Peru	312	France	180
Ethiopia	731	Nigeria	260	Taiwan	173
Iran	620	Mexico	244	South Korea	169
Argentina	590	Colombia	235	Australia	152
Indonesia	445	Turkey	233	Nepal	151
Countries	**194**	**Total**	**24958**		


DSSAT Version 4.8.5.0
File
Codes
Model
Crops
Documentation
Help
New
Run
Tools
Crop Management Data
Graphical Display
Soil Data
Experimental Data
Weather Data
Seasonal Analysis
Accessories
Utilities
Reference
My Shortcuts
Selector
Crops
Cereals
Fiber
Forages
Alfalfa
Bahia grass
Bermudagrass
Brachiaria
Guinea grass
Fruit crops
Legumes
Oil crops
Root Crops
Sugar/Energy
Various
Vegetables
Applications
Climate Change
Seasonal
Sequence
Spatial
Yield Forecast
Data
Soil
Weather
Genetics
Economics
Pests
Standard Data
Data
Experiments
Data
Outputs
+ # Experiment Description Modified
4 CCQU7901.BRX BRACHIARIA ON QUILICHAO 17:09:35,
5 CCYU8101.BRX BRACHIARIA ON YURIMAGUAS 17:09:35,
6 CNCH8201.BRX BRACHIARIA ON LA ROMELIA 17:09:35,
7 SAUR9001.BRX BRACHIARIA ON URRAO 17:09:35,
8 SPPI1101.BRX MARANDU PALISADEGRASS 13:57:33,
Preview
Treatments
[1] MARANDU 28D Irrig
[2] MARANDU 42D Irrig
[3] MARANDU 28D Rainfed
[4] MARANDU 42D Rainfed
*EXP.DETAILS: SPPI1101BR MARANDU PALISADEGRASS
*GENERAL
@PEOPLE
D.N.L. Pequeno; C.G.S.Pedreira; K.J. BOOTE
@ADDRESS
Av. Padua Dias, 11 - USP/ESALQ
@SITE
Piracicaba, SP, Brazil

DSSAT Interface & Organization



Cropping System Model (CSM)

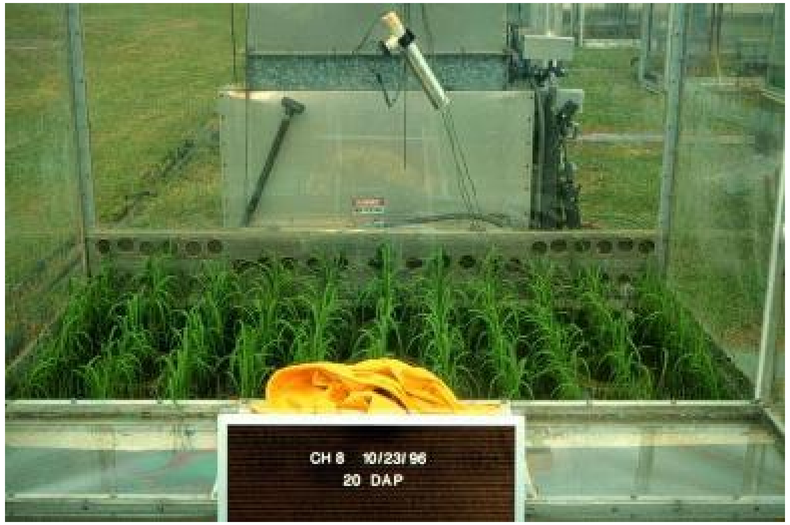


Implementation

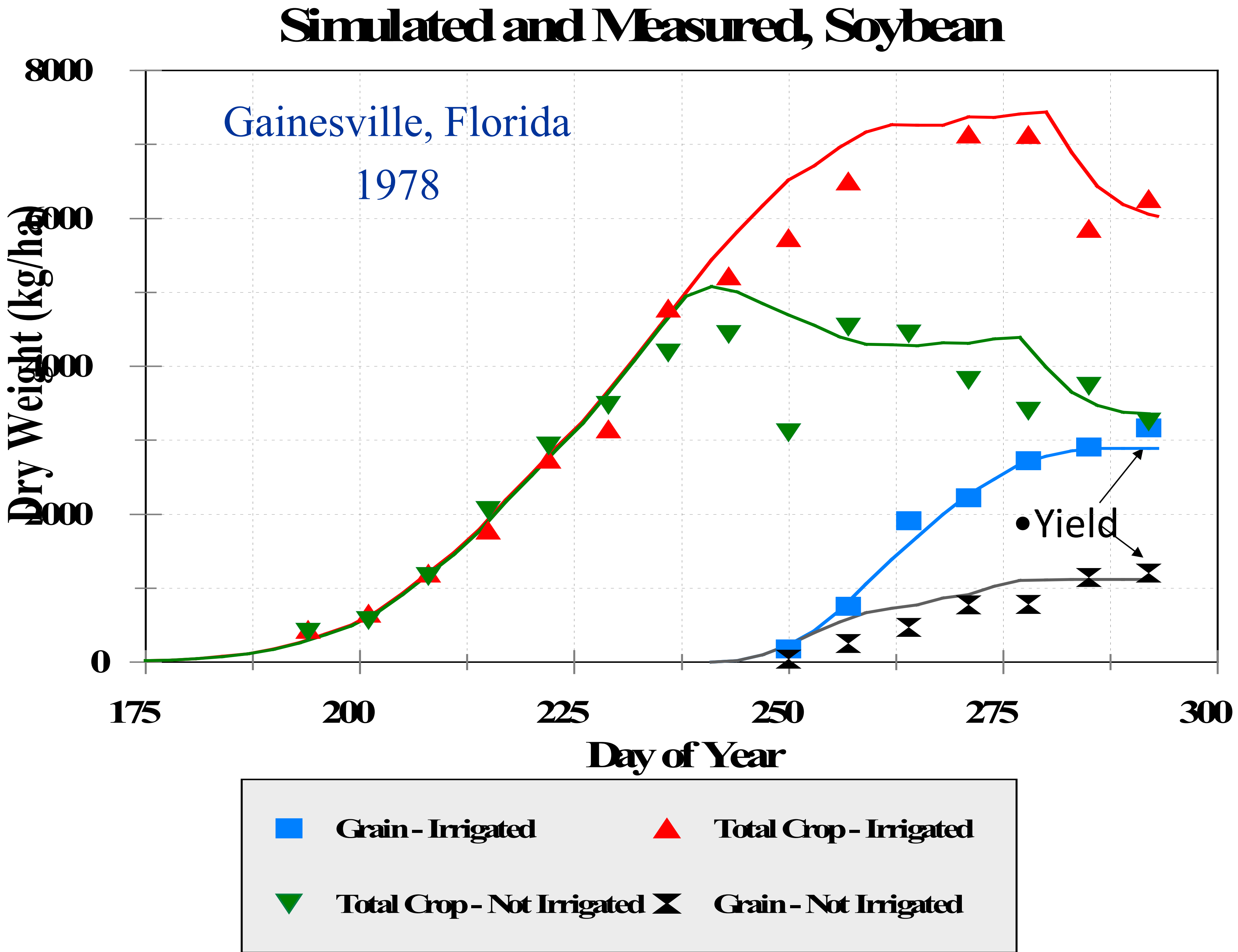
Crop Simulation Models

1. Require information (Inputs)
   - ✓Field and soil characteristics
   - ✓Weather (daily)
   - ✓Cultivar characteristics
   - ✓Management
2. Model calibration for local variety
3. Model evaluation with independent data set
4. Can be used to perform “what-if” experiments
5. Provide actionable information for Climate Smart Agriculture

Linkage between Data and Simulations



- Model credibility and evaluation
- Input data needs:
  - Weather and soil data
  - Crop Management
  - Specific crop and cultivar information
  - Economic data


Simulated and Measured, Soybean
Gainesville, Florida
1978
Dry Weight (kg/ha)
8000
6000
4000
2000
0
175
200
225
250
275
300
Day of Year
•Yield
Grain - Irrigated
Total Crop - Irrigated
Total Crop - Not Irrigated
Grain - Not Irrigated

Crop Model Applications

- Diagnose problems (Yield Gap Analysis)
- Precision agriculture
  - Diagnose factors causing yield variations
  - Prescribe spatially variable management
- Irrigation management
- Water use projection
- Soil fertility management
- Plant breeding and Genotype * Environment interactions
- Yield prediction for crop management

Crop Model Applications

- Adaptive management using climate forecasts
- Climate variability
- Climate change, adaptation and mitigation
- Soil carbon sequestration
- Environmental impact
- Land use change analysis
- Targeting aid (Early Warning)
- Biofuel production
- Risk insurance (rainfall)
- ➢ Salinity and land degradation

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Institute for Sustainable Food Systems

Meta analysis on the evaluation and application of DSSAT in South Asia and China
205 papers published from January 2010 – February 2022

Journal of Agrometeorology
ISSN : 0972-1665 (print), 2583-2980 (online)
Vol. No. 25 (2) : 185 - 204 (June- 2023)
DOI : https://doi.org/10.54386/jam.v25i2.2081
https://journal.agrimetassociation.org/index.php/jam

ASSOCIATION OF AGROMETEOROLOGISTS Estd : 1999

Invited Articles (Silver Jublee Publication)

Meta analysis on the evaluation and application of DSSAT in South Asia and China: Recent studies and the way forward

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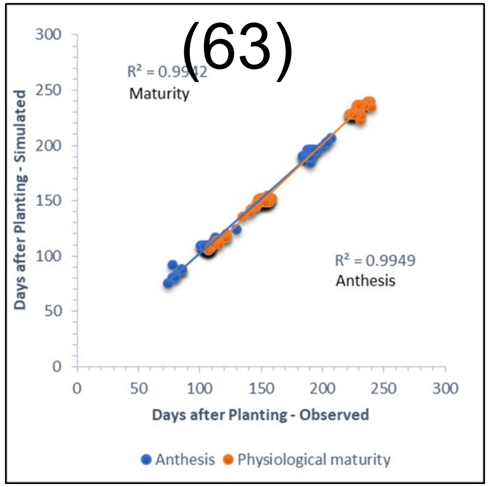
[2]*Krishi Vigyan Kendra, Ganderbal, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India-190025*
[3]*Global Food Systems Institute, University of Florida, Frazier Rogers Hall, Gainesville, FL 32611-0570, USA*
[4]*Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India-190025*
[*]*Corresponding author email: gerrit@ufl.edu*

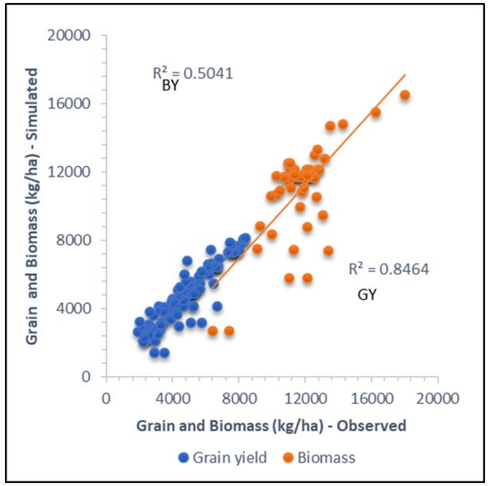
ABSTRACT

The Decision Support System for Agrotechnology transfer (DSSAT) is a global modelling platform that encompasses crop models for more than 40 different crops. The models have been used extensively throughout the world, including South Asia and China. From the web of science database, we reviewed 205 papers that were published from January 2010 to February 2022 containing examples of the evaluation and application of the DSSAT crop simulation models. In South Asia and China, more than 50 traits and variables were analyzed for various experiments and environmental conditions during this period. The performance of the models was evaluated by comparing the simulated data with the observed data through different statistical parameters. Over the years and across different locations, the DSSAT crop models simulated phenology, growth, yield, and input efficiencies reasonably well with a high coefficient of determination (R^2), and Willmott d-index, together with a low root mean square error (RMSE), normalized RMSE (RMSEn), mean error (ME) or percentage error difference. The CERES models for rice, wheat and maize were the most used models, followed by the CROPGRO models for cotton and soybean. Grain yield, anthesis and maturity dates, above ground biomass, and leaf area index were the variables that were evaluated most frequently for the different crop models. The meta-analysis of the data of the most common simulated variables (Anthesis, maturity, leaf area index, grain yield and above ground biomass) for the four com-

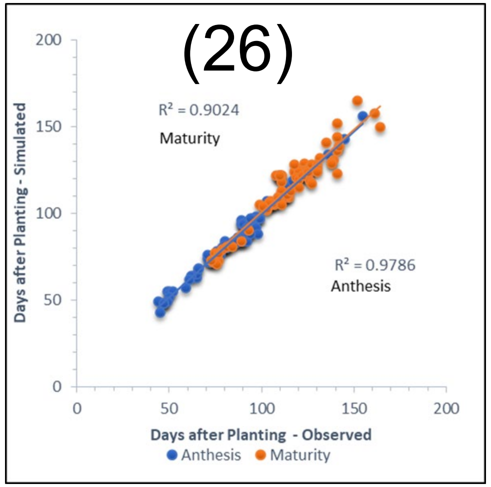
Meta analysis on the evaluation and application of DSSAT in South Asia and China: Recent studies 2010-2022

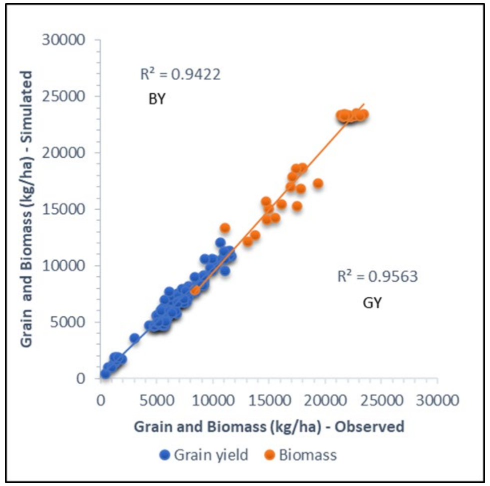
Ceres-Wheat (63)



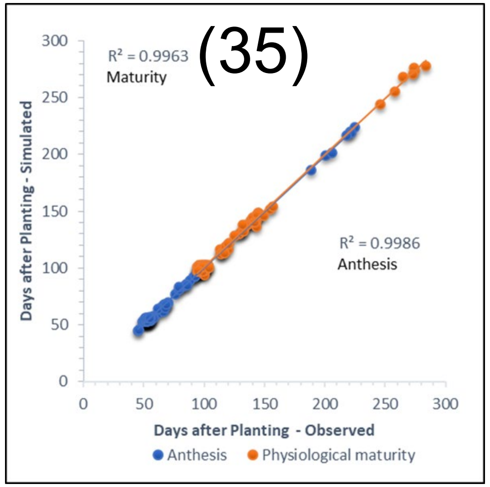


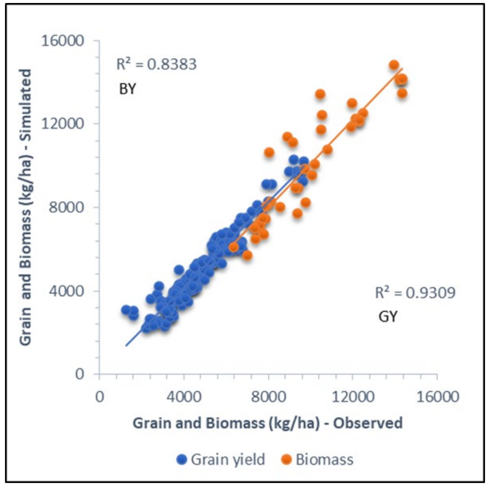
Ceres-Rice (26)



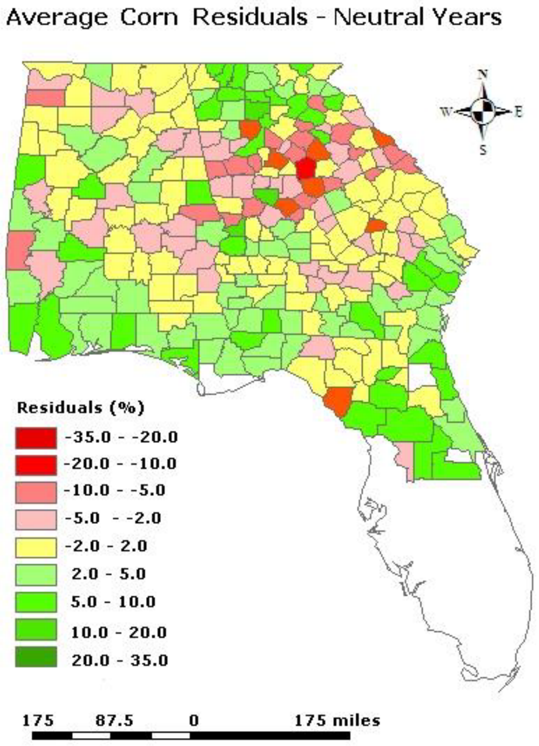


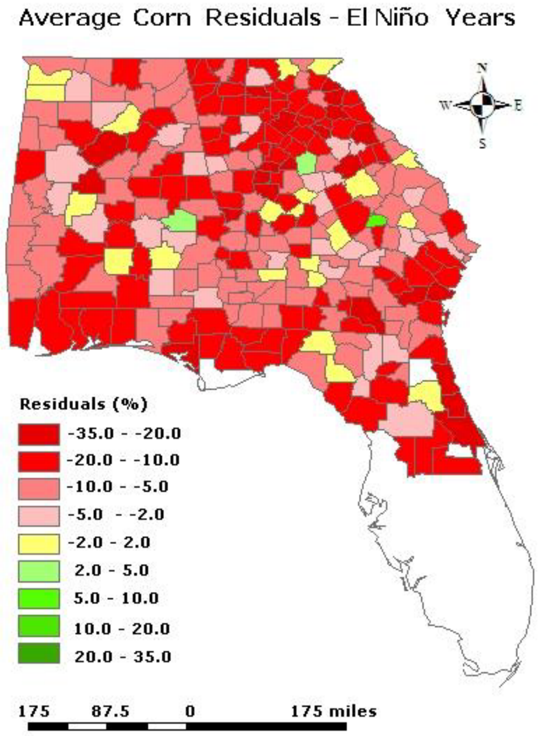
Ceres-Maize (35)

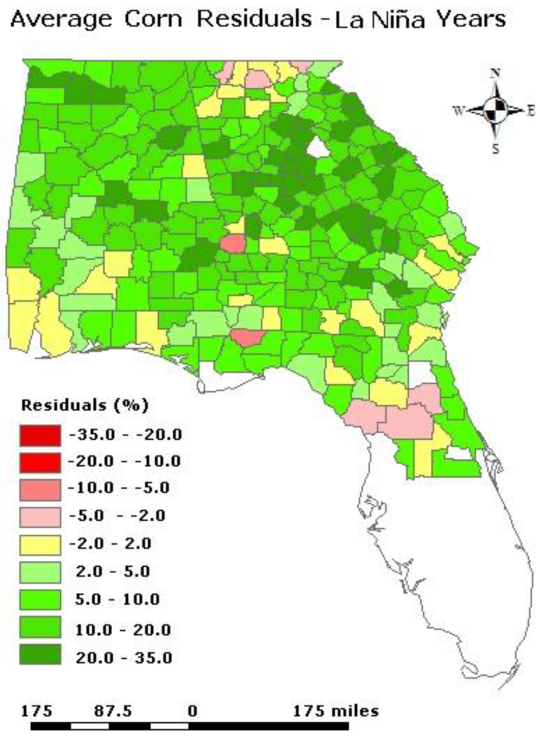




Climate in the southeastern USA
Why should farmers care?

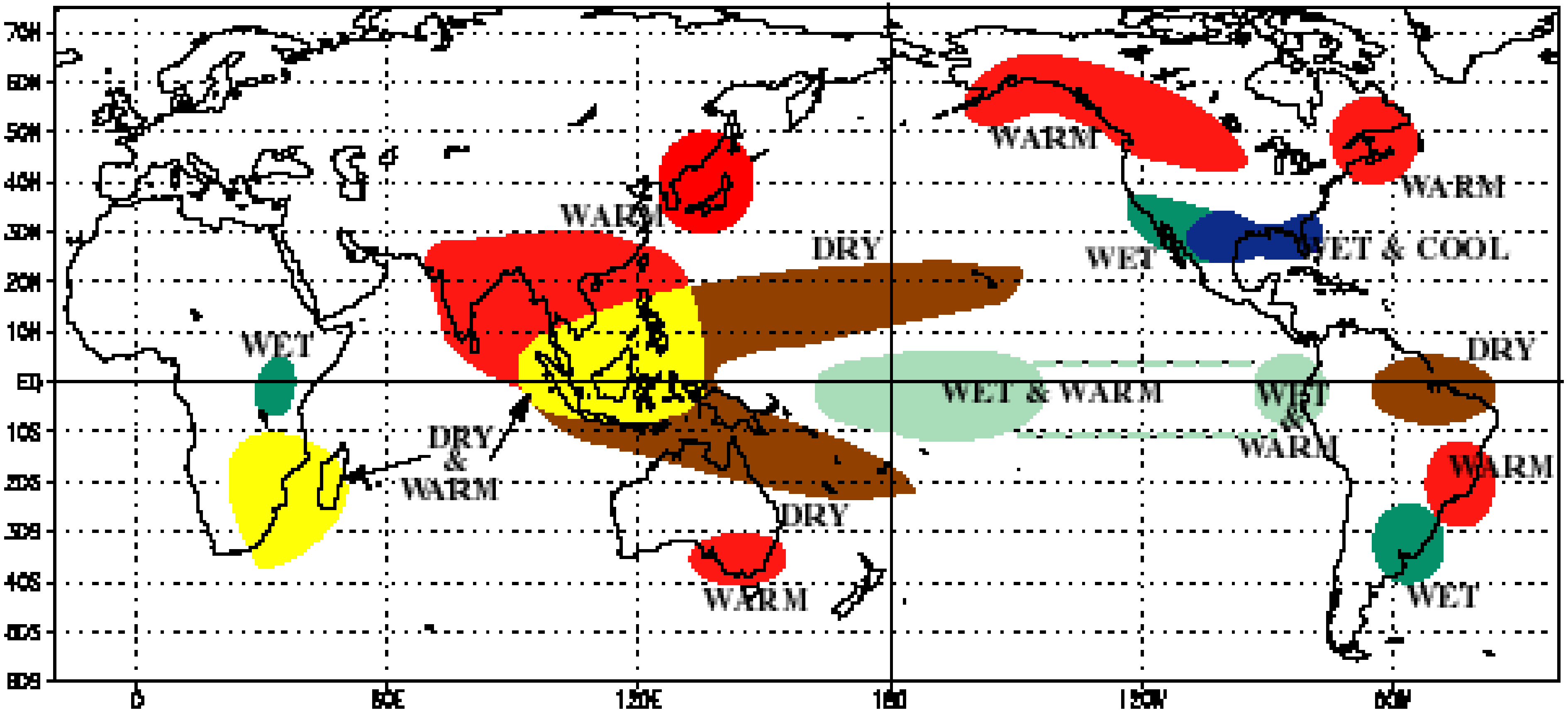






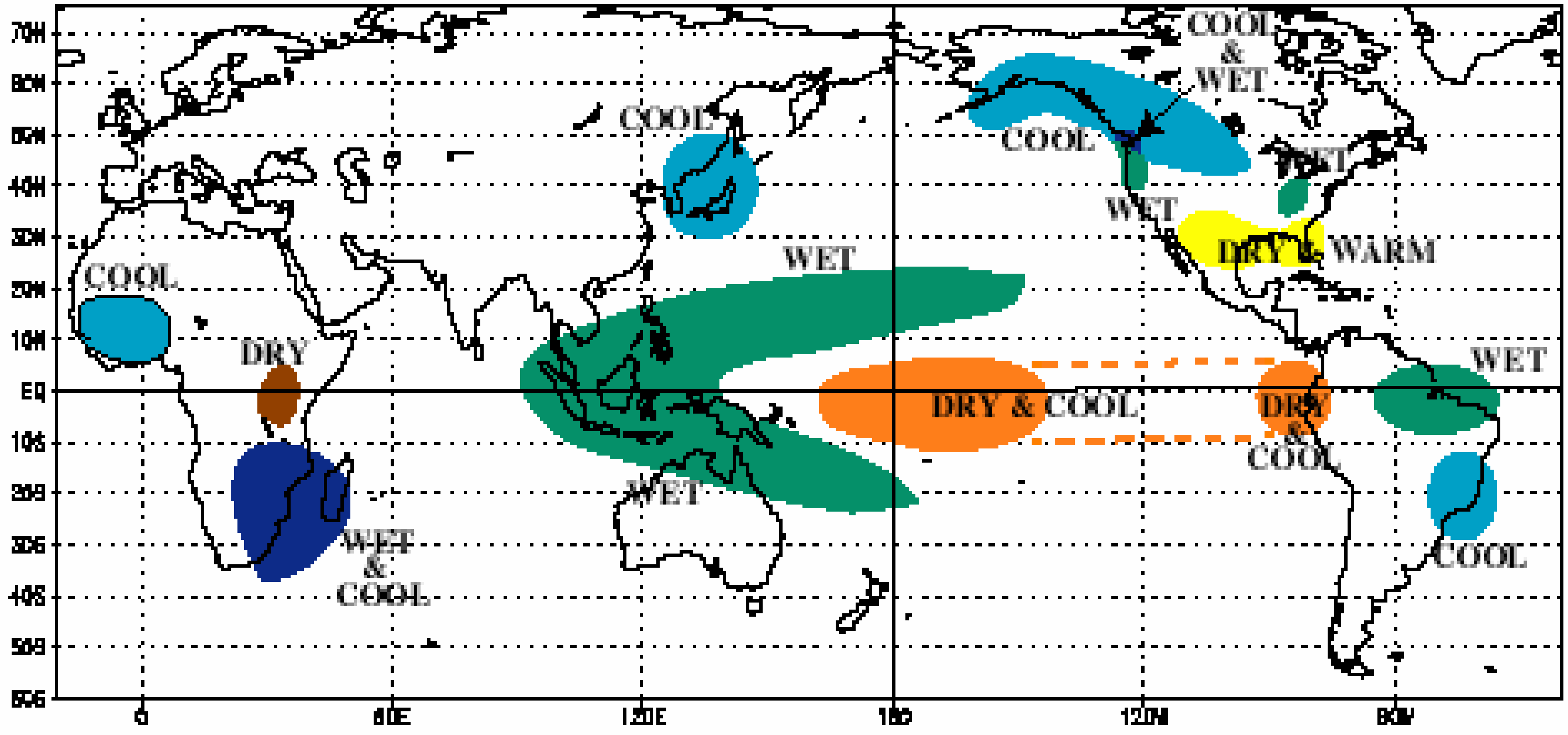
Why are El Niño and La Niña important?

Effects of El Niño



Why are El Niño and La Niña important?

Effects of La Niña



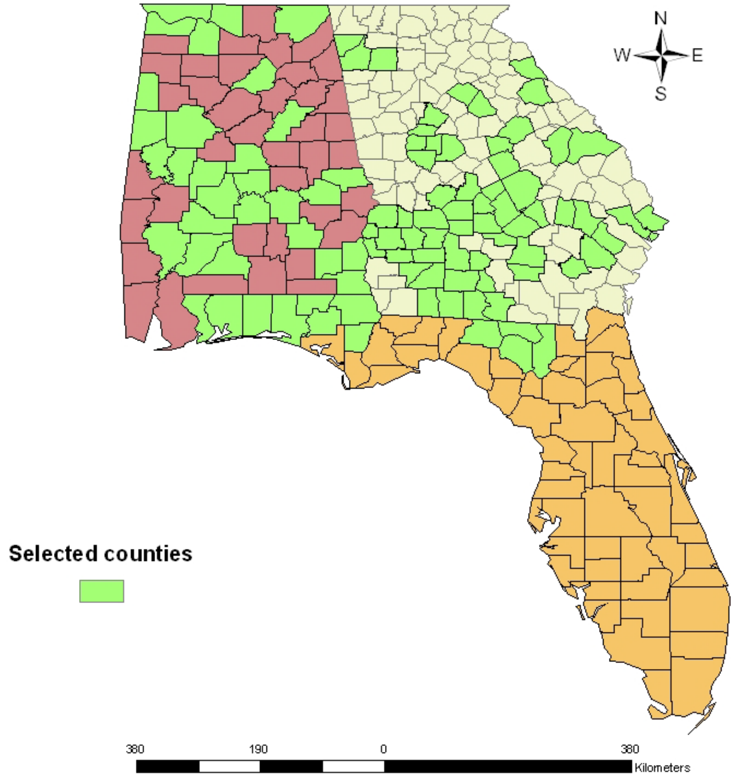
DSSAT Simulations

Peanut variety “Georgia Green”

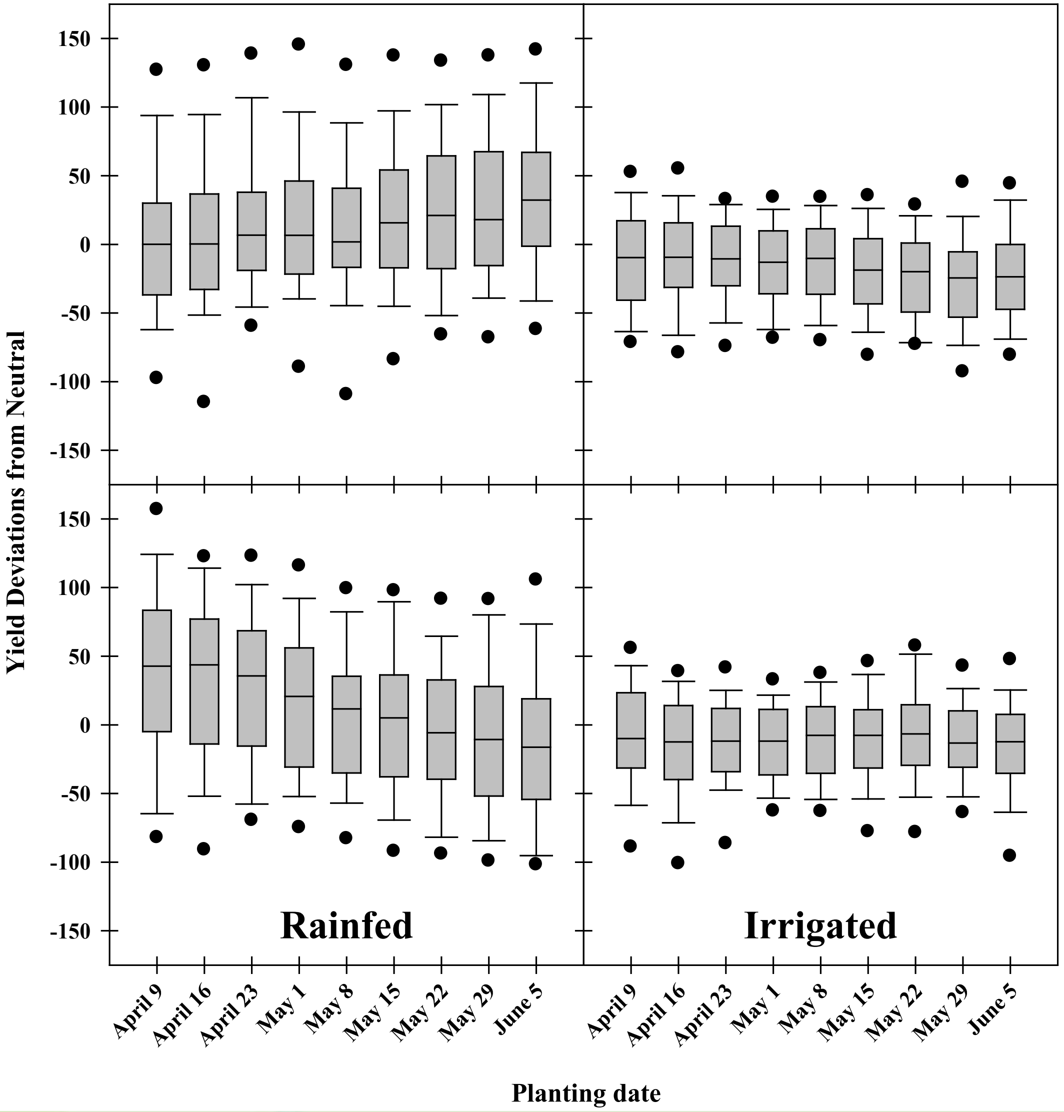
9 planting dates, rainfed vs irrigated

38 – 107 years of daily historical weather data

3 soil representative soil profiles per county



Impact of Planting Date on Peanut Yield Climate Variability



El Niño

La Niña

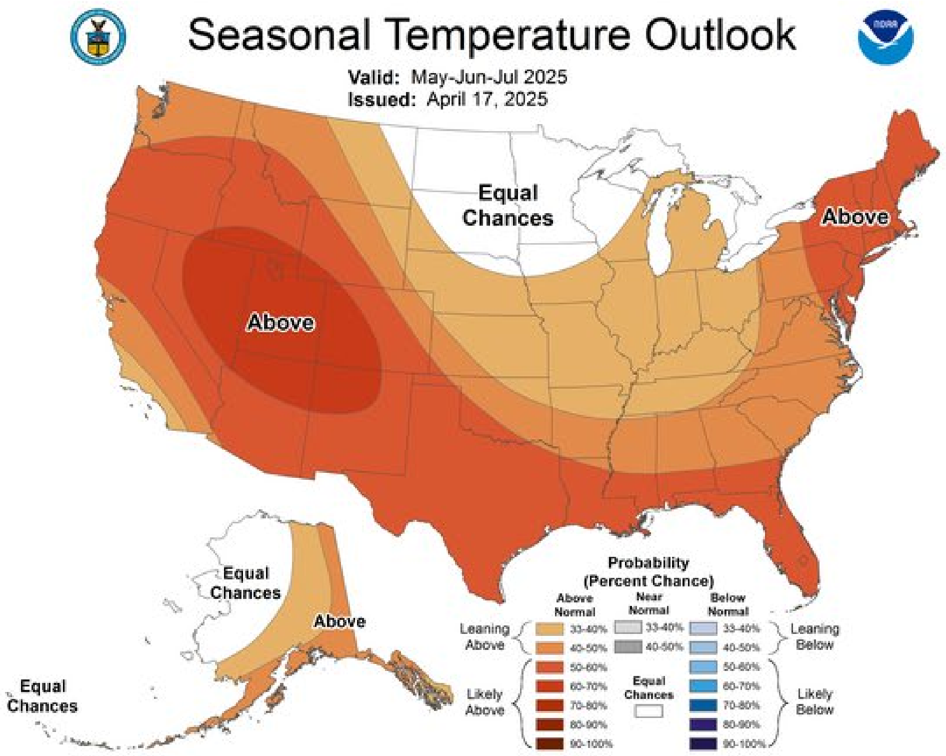
Southeast ClimateConsortium

UF

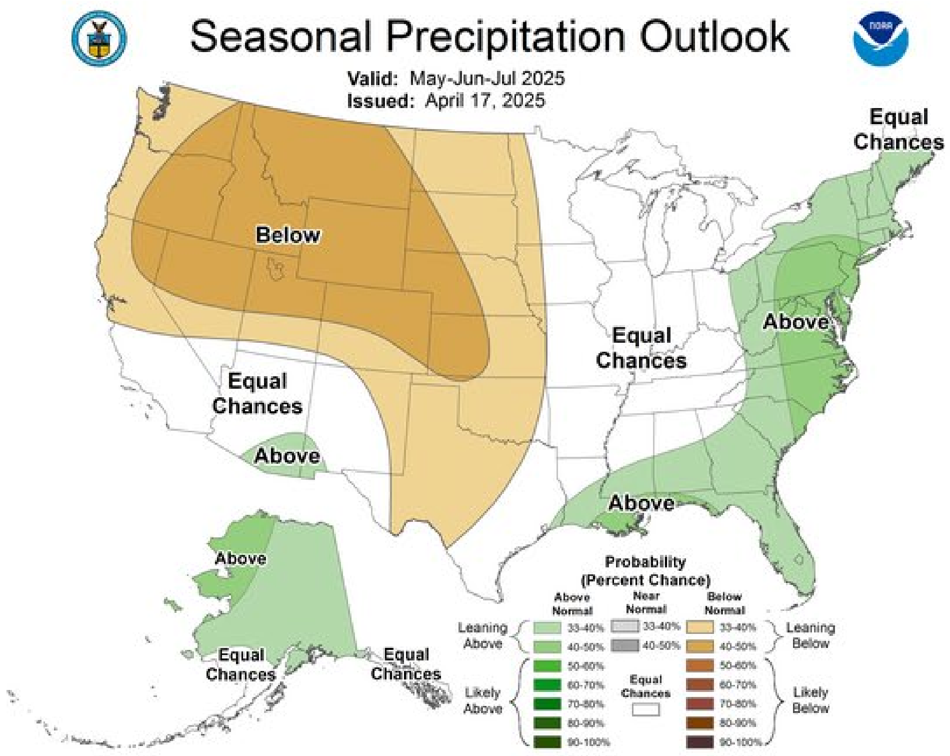
WWW.AGROCLIMATE.ORG

Pacific sea surface temperature (SST) anomalies

Temperature

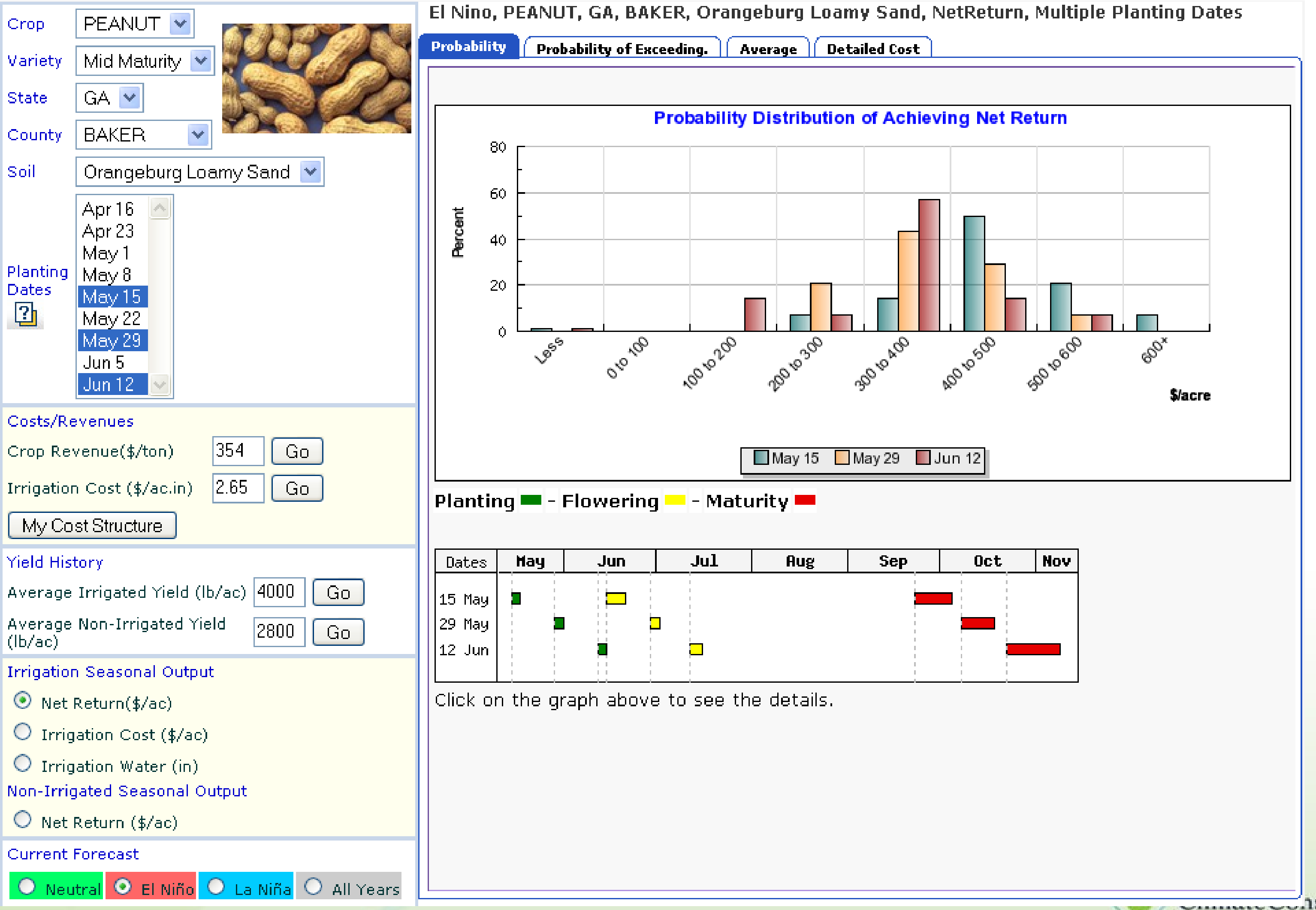


Precipitation



Crop Simulations: AgroClimate

Extension, Producers and Consultants



African Cassava Agronomy Initiative (ACAI) project

Project funded by the Bill and Melinda Gates Foundation

Modeling cassava as part of the agronomic decision support service for smallholder growers in Africa

---

IITA Transforming African Agriculture

ACAI

AKILIMO we know cassava

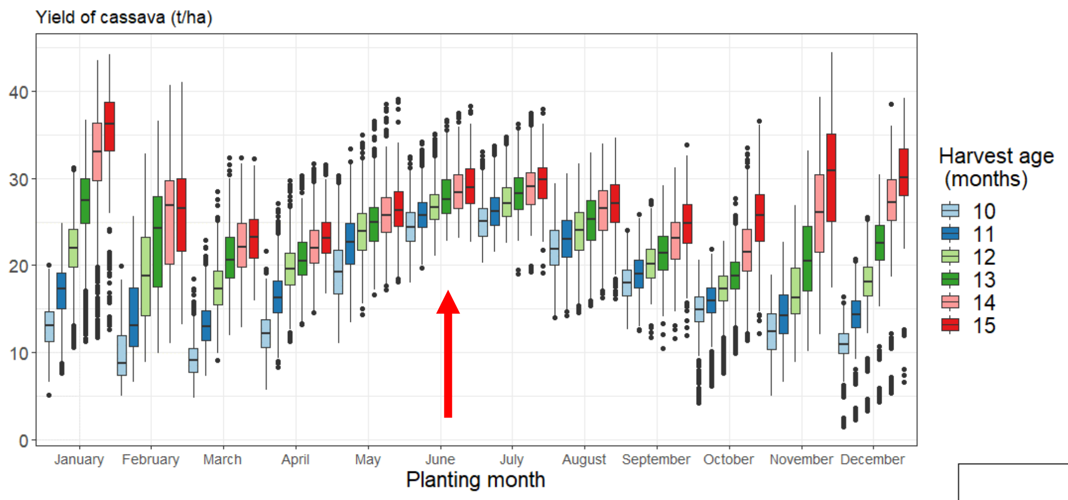
EiA Excellence in Agronomy 2030

Agricultural & Biological Engineering

UF IFAS University of Florida

Alliance Bioversity International CIAT

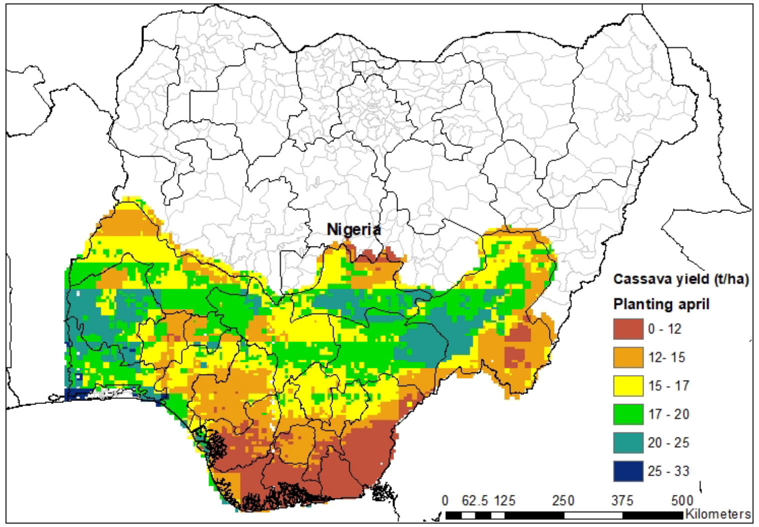
African Cassava Agronomy Initiative (ACAI) project



DSSAT*

Estimated cassava yield (t/ha) under different planting and harvesting months in Nigeria.

Spatial layer of estimated cassava yield (t/ha) for April planting with harvesting age of 10 months.

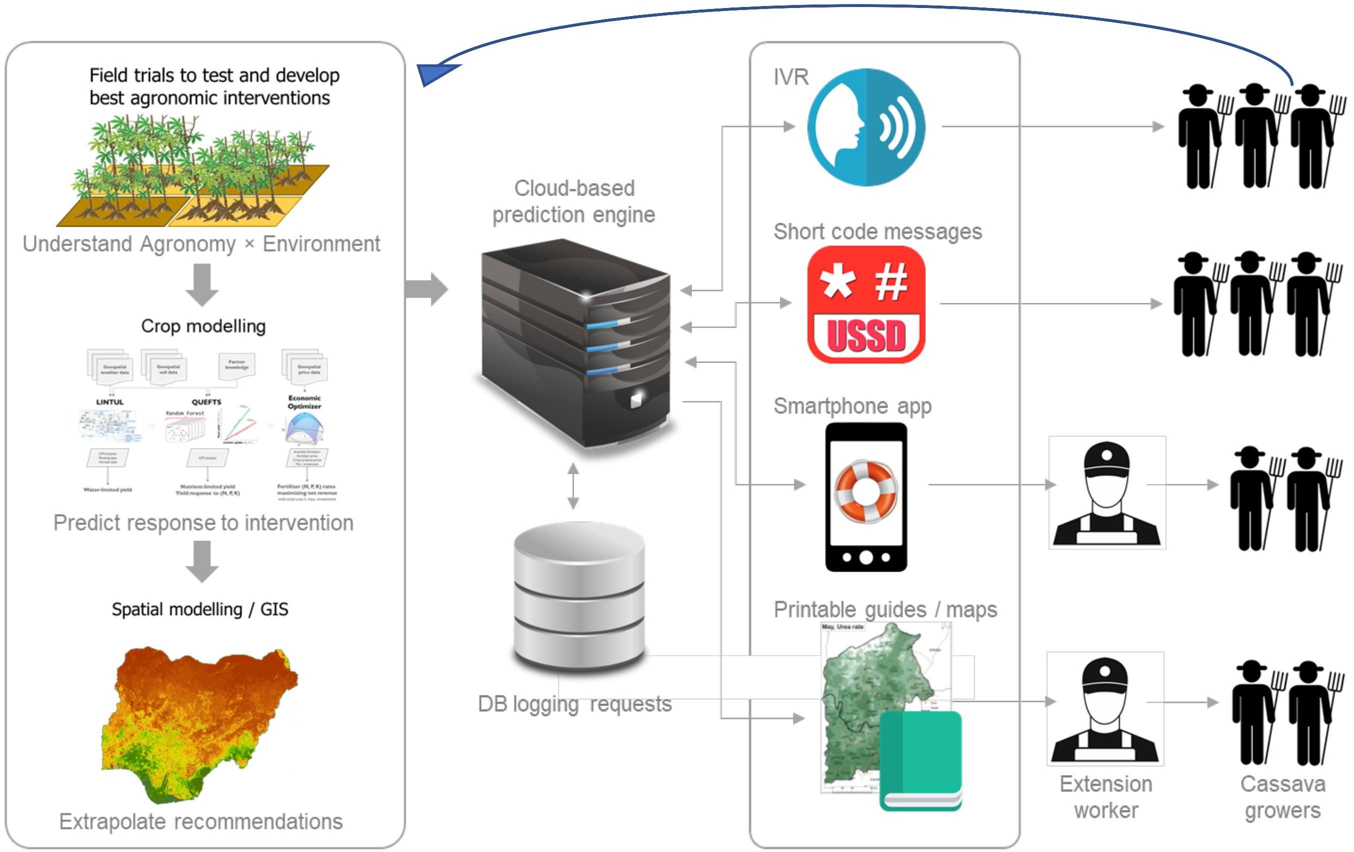


*Decision Support System for Agrotechnology Transfer (DSSAT)

African Cassava Agronomy Initiative (ACAI) project

Akili→ smart *Kilimo*→ agriculture

developing and delivering tailored agronomy recommendations to cassava growers



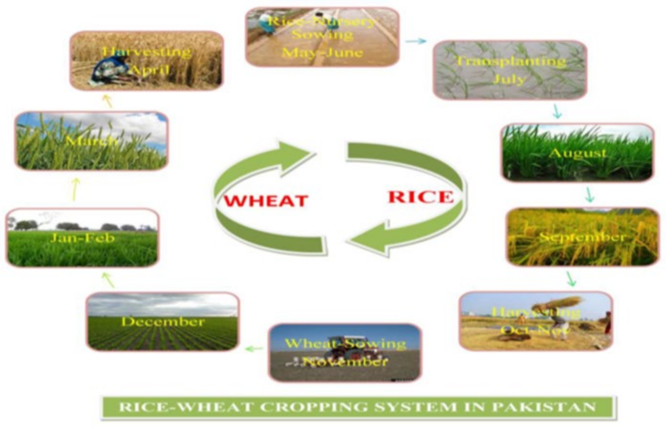
www.iita.org | www.cgiar.org | www.acai-project.org

Climate Change Impact Assessment, Adaptation, and Resilience

1. Incorporate state-of-the-art climate, crop, and agricultural economic model improvements into coordinated regional and global assessments of current and future climate impacts.
2. Perform multi-model integrated regional and global assessments of technology and policy options for increasing food security and adapting to current and future climate risks.

Punjab, Pakistan

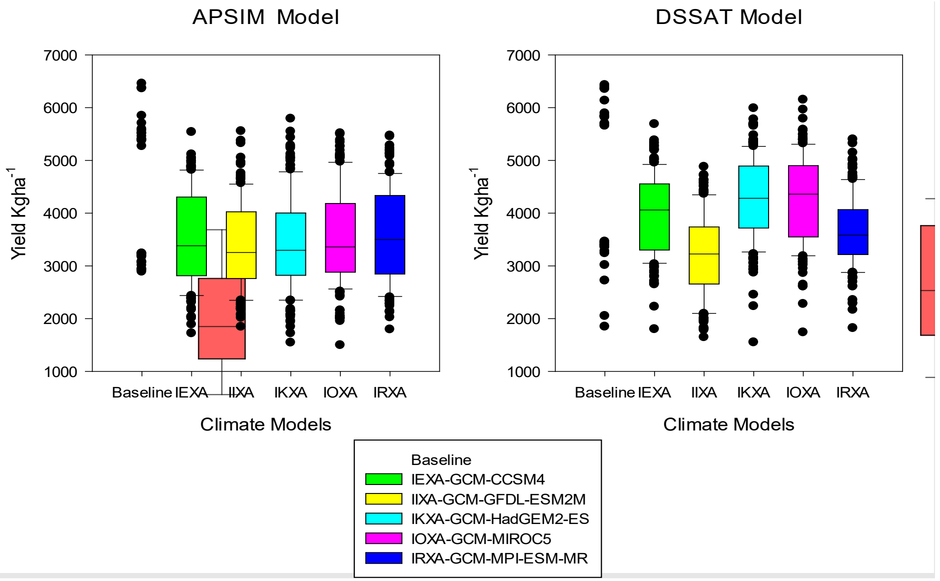
- The Rice-Wheat cropping system is the breadbasket of Punjab, Pakistan and Punjab, India
- The Punjab is the largest agricultural production system in South Asia, covering 13.5 m ha
- 20% of the world population depends on its agricultural production



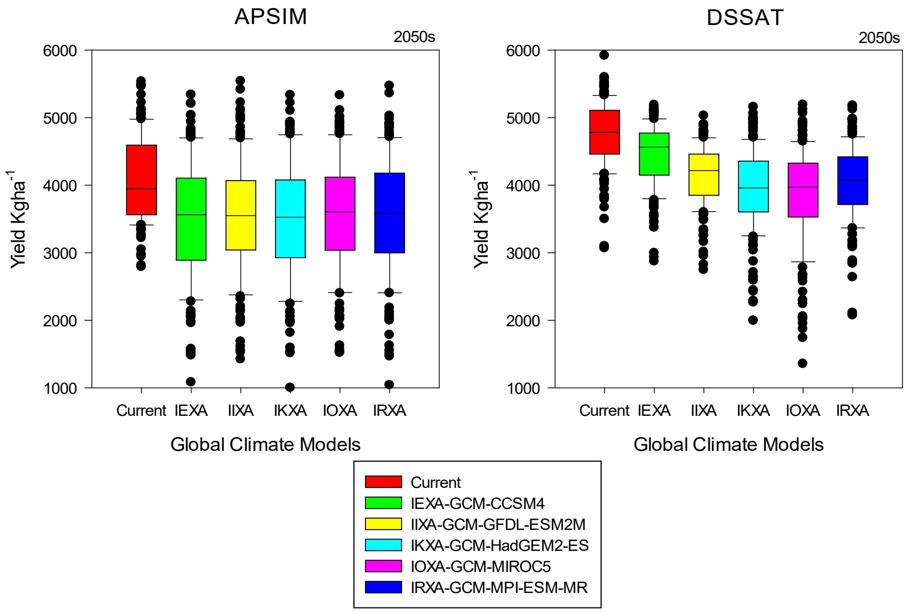
Climate Change Impact on Rice & Wheat Production

5 Climate Models (GCMs), *2* Crop Models and *1* Economic Model

Rice



Wheat



Government Policy Brief

Food Security in Punjab, Pakistan

Adapting rice-wheat farming to climate change

Harvesting rice in Pakistan.

AgMIP The Agricultural Model Intercomparison and Improvement Project

Policy Brief
June 2014

Key Messages Punjab, Pakistan

Adaptations using different crop varieties and management practices can help reduce projected losses and poverty rates caused by increases in temperature and greater rainfall extremes.

CLIMATE

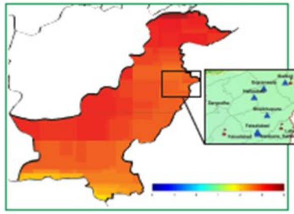
- **Climate change in the Pakistan Punjab** region is already occurring with **temperature increases of up to 1°C,** record-breaking floods, and drought.
- Temperatures are **projected to increase an average of 2°C** by 2050.
- **Heavy rainfall** and **increasing flooding** may occur during the wet seasons; **dry seasons could get drier.**

IMPACTS

- **Major losses of irrigation water** for the Punjab area could result from Himalayan glacier melt.
- **Yields** trends of rice, wheat, and cotton **have recently plateaued,** partly due to changes in climate.
- **Rice yield losses** could range from **8-30%** and **wheat yield losses** could range from **6-19%** by 2050.
- Poverty might increase by about 6% due to climate change in the Punjab by 2050.

ADAPTATIONS

- The **adaptation package** evaluated consisted of new varieties, earlier sowing dates, increase in fertilizer, and higher sowing density.
- The models predict that the **majority of farmers** would likely **adopt** the simulated adaptation packages.
- **Additional adaptations could be tested** to understand how to mitigate the negative impacts of climate change.



Adaptations Tested

The adaptation package included improved cultivars, changes in cropping patterns, improved farming practices, water management, fertilizer subsidies, diversification, and irrigation policies.

Impacts to Livelihood

Poverty could possibly be reduced from about 35% to about 13% through use of the adaptation package under climate change conditions by the 2050s.

RESULTS

By the 2050s, average annual temperature in Punjab, Pakistan is likely to **increase by about 2°C.** Increased dryness in the dry season, coupled with a higher number of heavy rain events in the wet season may result in more flooding. Overall the region is expected to become slightly wetter than at present.

Without changes to the current production system, **70-80% of small-holders could suffer losses** and the **poverty rate* could increase by 4-8%.**

Adaptations that greatly improved simulated outcomes for farmers in the 2050s included:

Sowing improved cultivars

Increasing sowing density - up to 30% for wheat and up to 15% for rice

Shifting sowing date earlier - about 15 days for wheat and 5 days for rice

Increasing fertilizer - up to 25% for wheat and 15% for rice.

RECOMMENDATIONS

Utilize the integrated assessment methodology to demonstrate how stakeholders and researchers can work together to address variable and changing climate.

Prioritize current adaptation strategies for testing of longer-term sustainability and effectiveness.

Explore adaptations that improve overall food security across diverse communities – design and test adaptations for at-risk farm systems, but also for successful farm systems.

*Poverty Line = US $1.25/person/day.

CLIMATE CHANGE IMPACTS on farms in Punjab, Pakistan

What is the sensitivity of CURRENT agricultural production systems to CLIMATE CHANGE*?

74% of farms could be **negatively affected** due to climate change†

What is the impact of CLIMATE CHANGE on FUTURE* agricultural production systems?

66% of farms could be **negatively affected** due to climate change†

What are the benefits of FUTURE ADAPTATIONS* to CLIMATE CHANGE?

93% of farms could **benefit** from **adaptation** to climate change†

*Climate change was simulated for RCP 8.5 with 5 GCMs.
†Mean of 69-83% - projections from 5 GCMs and 2 crop models.

*Future development changes by 2050s consisted of trends in number of people in household, non-agricultural income, yield, price of outputs, and production costs.
†Mean of 57-78% - projections from 5 GCMs and 2 crop models.

*Adaptation package tested included improved cultivars, changes in cropping patterns, improved farming practices, water management, fertilizer subsidies, diversification, and irrigation policies.
Adaptation benefits for some farms are not cost-effective.
†Mean of 92-94% - projections from 5 GCMs and 2 crop models.

Climate Change for Punjab Pakistan by 2050s

- Temperature projected to rise everywhere.
- Heavy rainfall is projected during the wet seasons, increasing the chances of flood.
- Dry seasons could get drier.

Participating Institutions: University of Agriculture, Faisalabad – Pakistan, Washington State University, USA, Pakistan Meteorological Department, Islamabad - Pakistan, Baha-ud-Din University, Multan - Pakistan, COMSATS University, Vehari – Pakistan

AgMIP receives major support from the UK Department for International Development's UKaid, in partnership with the US Department of Agriculture Agricultural Research Service

UKaid from the British people

Opportunities

Crop Modeling – Fact or fiction?

Environment * Management * Genotype

Economics

- Computer simulation model:
  - "A mathematical representation of a real-world system"
- Requires careful evaluation for local conditions
- Requires "accurate" input data

Opportunities

Crop Modeling – Fact or fiction?

Environment * Management * Genotype

Economics

- Prediction:
  - Yield
  - Resource use
  - Environmental impact
  - Economic returns
- Management decisions and explore “what-if” type questions
- Research design and analysis
- Teaching tool
- Policy and planning

Modeling Limitations?

Agricultural Production

- Potential production
- Water-limited production
- Nitrogen-limited production
- Nutrient-limited production
- Pest-limited production
- Other factors
  - ***SALINITY***
  - Intercropping
  - Economics
  - Food quality
  - Human decisions