Enhancing and Extending Field Research with Modeling of Agricultural Systems --International Collaborations

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Need for Quantitative System Approaches in Agriculture

- Agriculture in the 21st century is much more complex due to: environmental concerns, limited water, climate change: droughts & uncertainty, global competition; bio-energy

- Integrated and quantitative system approaches are needed as planning & decision tools for optimal management, & to help research develop them. System models provide these approaches.

Integrating Field Research with System Models Helps Both

- Enhances understanding of the experimental results & complex interactions; cause & effect relations
- Enables their synthesis, quantification & extends results to longer time periods
- Helps transfer results, their optimal application to other soils/ climates, and aids management
- Identifies knowledge gaps to focus further research; reduces duplication
- Good field data help improve the models

THE GUIDING PRINCIPLE & VISION

CUTTING EDGE FIELD RESEARCH

SIMPLER DECISION SUPPORT SYSTEMS

for Farmers & Ranchers, Ag Consultants, and Action Agencies

PROCESS MODELS OF AGRICULTURAL SYSTEMS

Extend Research & Applications

The CGIAR Science Council (2005) Research Priorities:

- **“Modeling and the ability to combine data from different sources, …promises to revolutionize understanding of processes affecting management of natural resources.”**
- **“Thanks to strategic accumulation of data, tools, and modeling resources in the coming decade, one can expect the development of a more predictive approach to agriculture”.**
- **Policy to focus limited resources on a few comprehensive field studies and then use models to extend them to other locations and countries.**

Agricultural Systems Research Unit

Agricultural Research Service

USDA

Fort Collins, Colorado
U.S.A.

OUR UNIT'S RESEARCH MISSION

Develop whole-system approaches to help optimize resource management & evaluate/ develop sustainable agricultural systems:

- Synthesis of disciplinary knowledge to the whole system level and collaborative research to fill knowledge gaps.
- Computer models of agriculture systems to help research, site-specific management, and create simpler decision aids.
- Decision support technology packages for farmers, ranchers, ag consultants and action agencies for planning and management.
- Techniques for more efficient development & maintenance of models & decision tools

More Recent Major Team Products

- **The Root Zone Water Quality Model (RZWQM) to simulate management effects on water, water quality and crop production.**

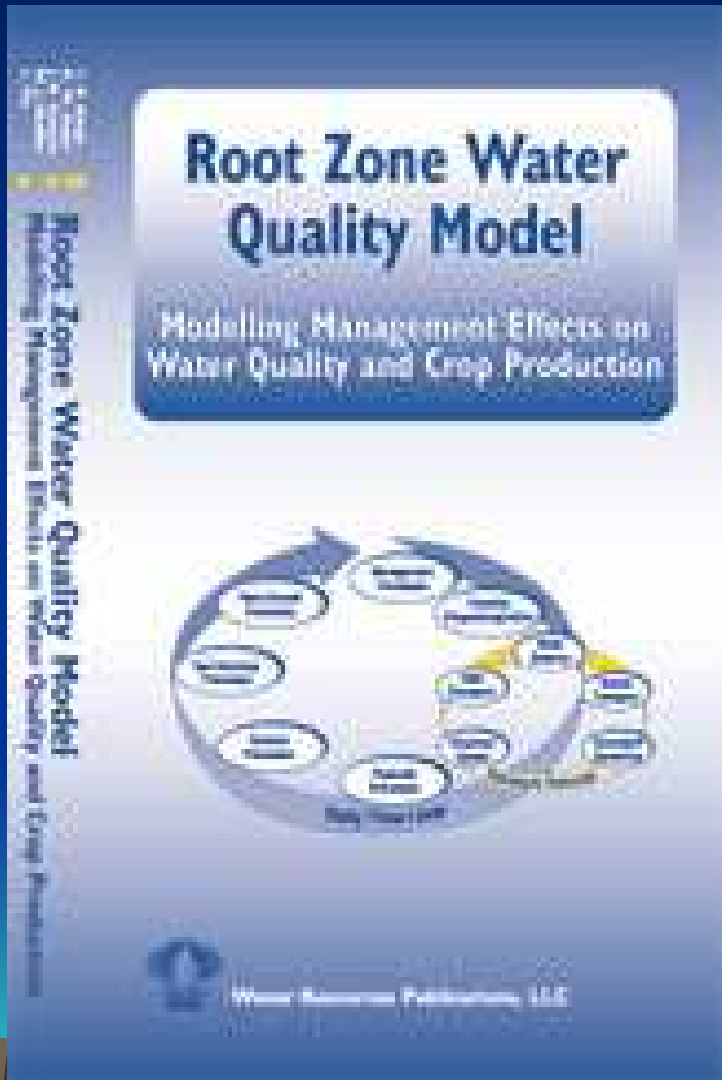
  Updated to RZWQM2-DSSAT & RZWQM2-GIS for precision spatial management & conservation effects assessment--CEAP .

- **GPFARM, a simpler whole farm/ranch decision support system for strategic planning.**

- **Object Modeling System: Create models from library of stand-alone modules**

Root Zone Water Quality Model

Modeling Management Effects on Water, Water Quality and Crop production



Water Resources Publications, LLC

Distinguishing Features of RZWQM

- Agricultural management practices and their integrated effects on water, crop production, and environmental quality (tillage, irrigation, fertilization, manure application, tile drainage, pesticide application, and crop rotation).
- Macropore/preferential flow.
- Water table fluctuation and tile flow.
- Chemical transport in runoff/percolation water.

Distinguishing Features of RZWQM

- Detailed carbon/nitrogen dynamics with consideration of microbial populations.
- Multiple year simulation for crop rotations with capability of answering “what-if” scenarios
- Detailed crop-specific models from DSSAT package

RZWQM-RZWQM2 Applications

- Extensively used in U.S & other countries to evaluate water quality/quantity impacts of ag management & develop sustainable systems.
- Adopted by EPA and used by pesticide industry for pesticide registration
- Used by USGS for NAWQA program
- China: water & N could be reduced by 50% w/o reducing corn yield
- Continues to play an important role in our new research projects.

GPFARM: A Farm Level DSS

A whole-farm decision support system for strategic planning: evaluation of alternate cropping system, range-livestock systems, and integrated farming options for production,

economics, and environmental impacts

<u>End Users</u>: Farmers and Ranchers, Consultants, Action Agencies, Extension, and Scientists

GPFARM Applications

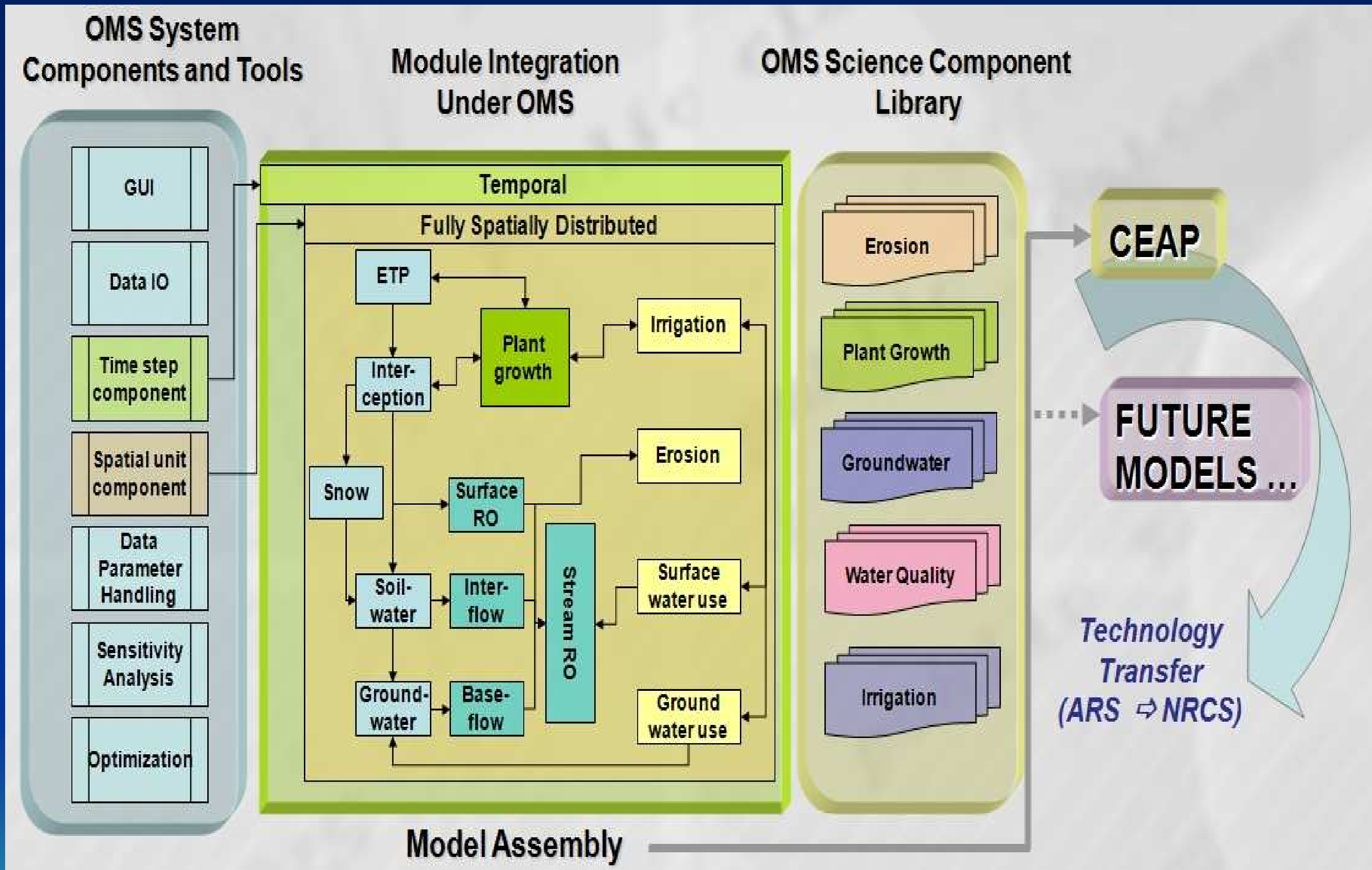
- Several invited presentations to Colorado Conservation Tillage Association & farmers
- MOU with CAWG: GPFARM distributed to 600 members; trained 150 members
- GPFARM-Range model has been extensively used for synthesizing research data from three range research stations in the Great Plains

The Object Modeling System (OMS)

- An Object Modeling System consists of a library of modules which facilitates the assembly of a modeling package, tailored to the problem, data constraints, and scale of application.
- Collaborators: ARS, NRCS, USGS, Friedrich-Schiller University, Jena, Germany
- Has been adopted by NRCS as a uniform system to deliver conservation technology and is being used to develop a new field to watershed scale model.

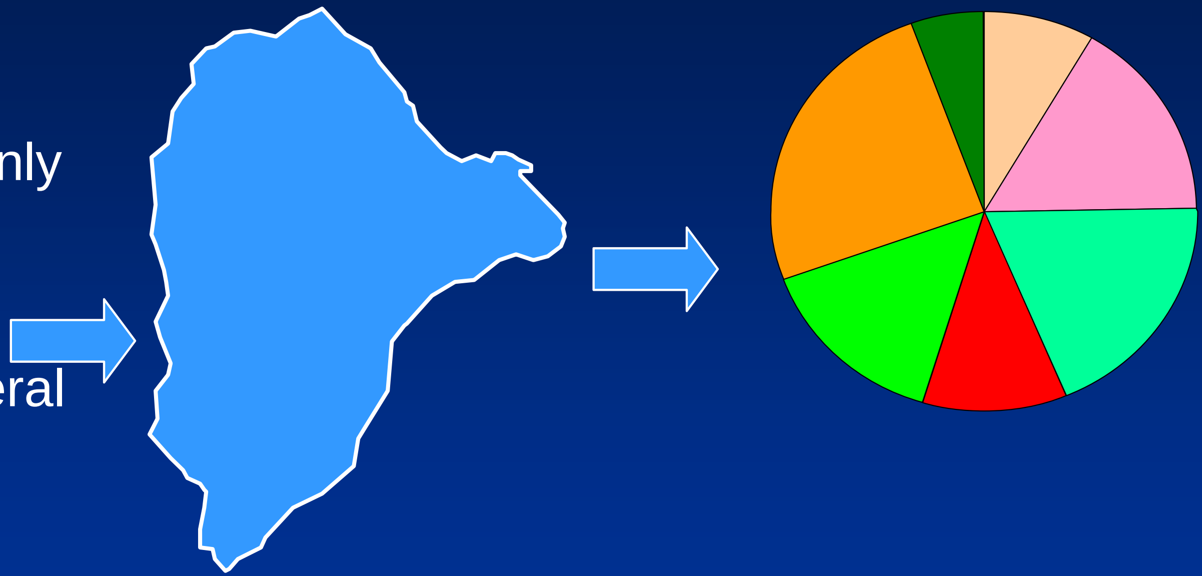
Model and Field Research a Precursor to Dcision Support Tools

The Object Modeling System (OMS) facilitates the development of component-based models which benefits decision support tool development.

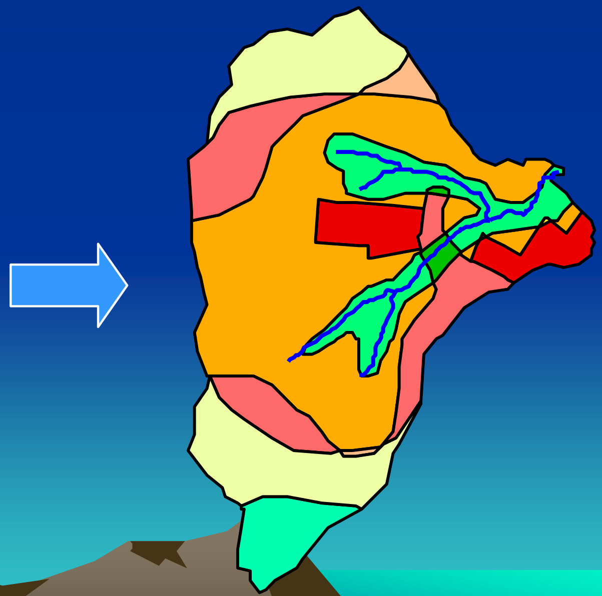


CEAP Watershed Compared to SWAT

- The semi-distributed SWAT concept considers distributed information within a sub-basin only statistically but not in terms of location.
- Important processes, e.g., lateral water /nutrient transport and specific management in some parts of a sub-basin cannot be simulated.



The fully distributed CEAP Watershed Model concept allows the consideration of such processes.



Recent Examples of Model Application to Enhance and Extend field Research

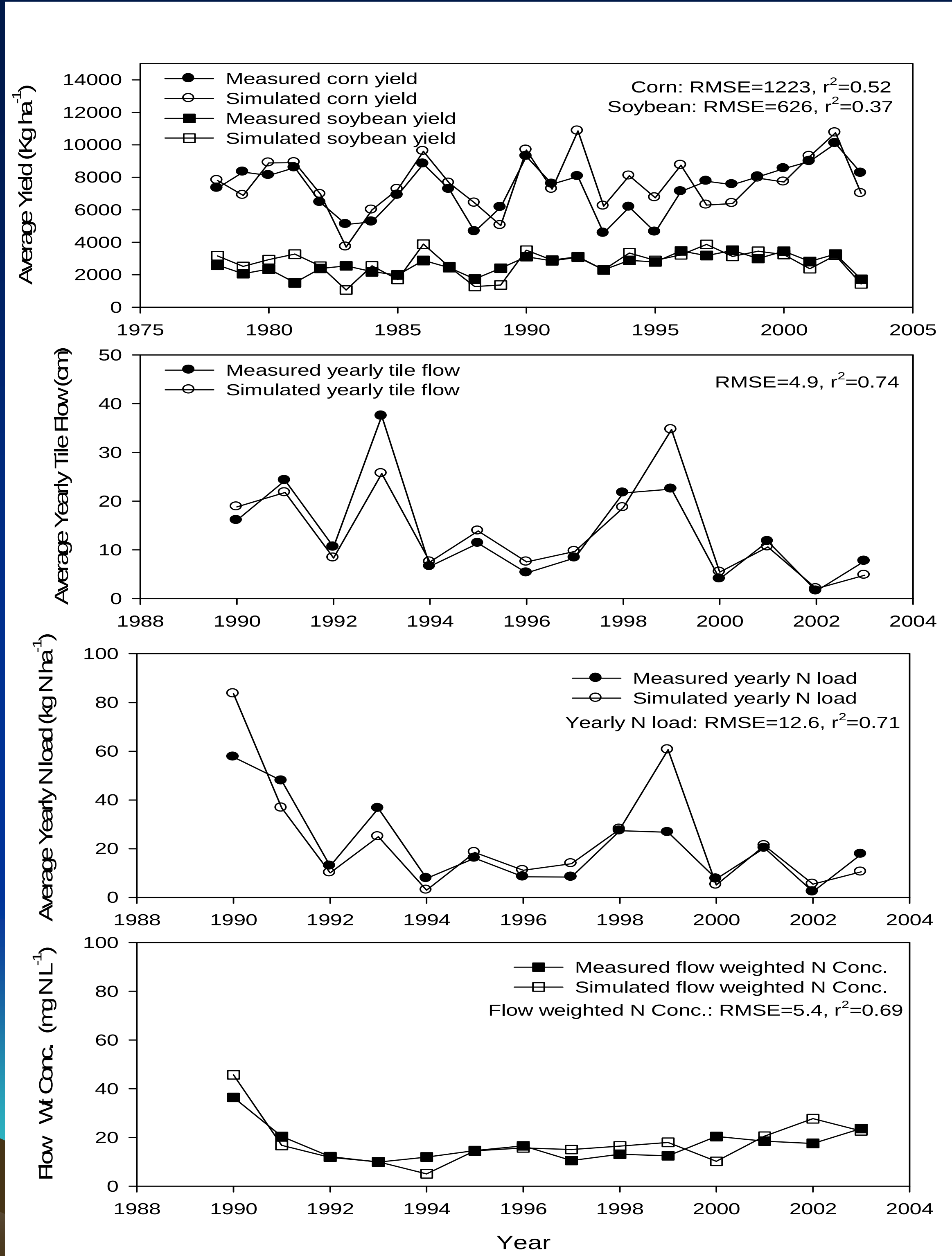
1. Water Quality Studies in Tile-Drained Cropping Systems (Nashua, Iowa)

Experimental Design

- 36 1-acre plots in Nashua, IA under tile drainage (at 120 cm depth); Variety of data over time from 1978 to 2003
- Two crop rotations: continuous corn (CC) and corn-soybean (CS) rotations
- Four tillage systems: moldboard plow (MP), ridge till (RT), chisel plow (CP), and no-till (NT)
- Fertlizers: anhydrous ammonium (AA) from 1977 to 1993; UAN from 1993 to 1998
- Swine manure from 1998 to 2003: fall & spring applications

Synthesis of Data:

Average values across treatments



Using Validated Model to Extend Results to multiple years and Create

Simpler Decision Tools

Simulated yearly water balance and crop production averaged over 24-yr for different crop rotation, tillage, and drainage scenarios. Results for corn-soybean rotation were taken as averages from CS and SC phases of the rotation (Ma et al., 2007b).

Scenarios	Drain flow (cm)	Lateral** flow (cm)	Runoff (cm)	ET*** (corn, cm)	Corn yield (kg/ha)	Corn biomass (kg/ha)	ET (soybean, cm)	Soybean yield (kg/ha)	Soybean biomass (kg/ha)
CC-NT-FD*	12.2	13.2	6.8	57.0	7878.3	18426.0	---	---	---
CC-MP-FD	10.6	11.4	6.8	60.4	7862.2	18384.4	---	---	---
CC-CP-FD	11.7	12.7	6.8	58.0	7886.9	18445.1	---	---	---
CC-NT-CD	8.7	15.2	7.4	57.8	7920.3	18433.5	---	---	---
CC-MP-CD	7.2	13.4	7.3	61.3	7908.0	18382.9	---	---	---
CC-CP-CD	8.3	14.7	7.4	58.8	7921.7	18433.2	---	---	---
CS-NT-FD	13.8	15.5	6.9	57.6	7879.7	18410.2	47.9	2971.5	8190.5
CS-MP-FD	12.8	14.4	6.9	58.9	7915.0	18443.1	50.9	3052.2	8544.2
CS-CP-FD	13.5	15.2	6.9	57.9	7915.7	18460.0	48.7	3001.3	8270.7
CS-NT-CD	9.8	18.2	7.6	58.4	7927.3	18428.6	48.4	3024.4	8281.8
CS-MP-CD	8.7	17.1	7.5	59.7	7959.0	18472.6	51.6	3098.3	8638.8
CS-CP-CD	9.5	17.9	7.6	58.8	7958.3	18487.6	49.3	3052.2	8356.0

* CC: continuous corn; CS: corn-soybean rotation; NT: no-till; MP: moldboard plow; CP: chisel plow; FD: free drainage; CD: controlled drainage.
** Lateral groundwater flow below the tiles
***Evapo-transpiration

Simulated yearly nitrogen balance under different crop rotation, tillage, and drainage scenarios. Units are in Kg N/ha unless stated otherwise. N application rate was 202 kg N/ha for CC and 168 kg N/ha on corn for CS and SC. Results for corn-soybean rotation were taken as averages from CS and SC phases of the rotation (Ma et al., 2007b).

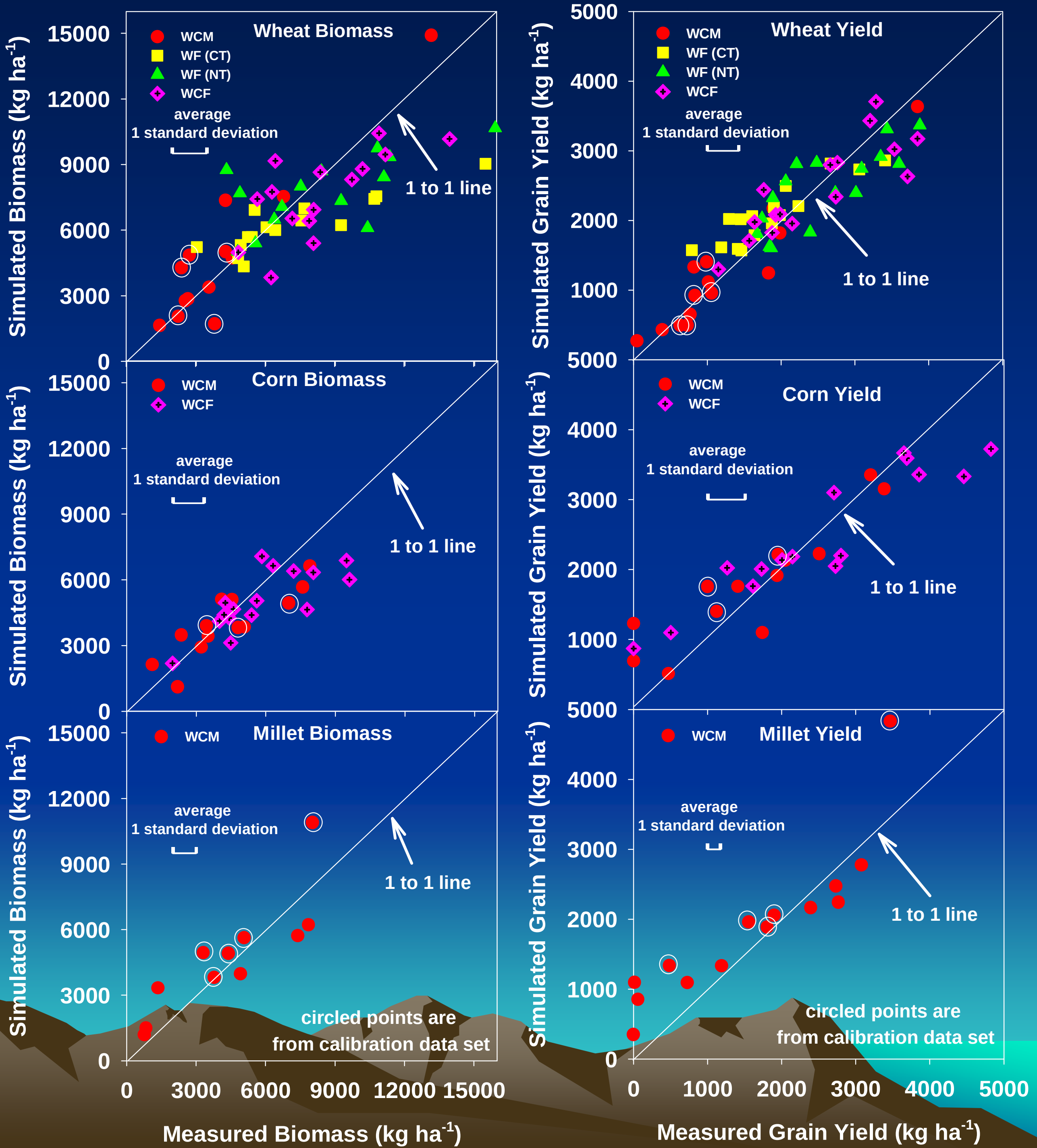
Scenarios	Flow-weighted N concentration (mg/L)	N loss in Tile	N loss to lateral flow	Net Mineralization	Denitrification	N uptake in corn biomass	N uptake in soybean biomass	N fixation	Δ inorganic N (1979-2002)	Δ organic N (1979-2002)
CC-NT-FD*	15.0	18.4	19.1	73.3	10.4	224.1	---	---	85.7	1642.6
CC-MP-FD	17.4	18.4	17.5	70.3	8.6	223.7	---	---	81.2	1637.6
CC-CP-FD	16.1	18.9	19.2	73.3	9.7	224.3	---	---	83.2	1639.6
CC-NT-CD	15.3	13.4	21.9	72.2	11.3	224.4	---	---	86.0	1647.6
CC-MP-CD	18.3	13.1	20.6	69.2	9.4	224.3	---	---	81.2	1641.6
CC-CP-CD	16.6	13.7	22.0	72.1	10.5	224.7	---	---	83.2	1644.6
CS-NT-FD	11.8	16.3	18.1	116.5	12.5	225.0	318.8	242.8	49.8	1672.7
CS-MP-FD	13.5	17.3	18.6	118.0	9.5	225.8	333.4	252.0	45.4	1793.6
CS-CP-FD	12.7	17.2	19.0	117.0	10.8	226.0	322.1	246.5	52.3	1679.9
CS-NT-CD	11.7	11.4	21.2	115.8	13.3	225.6	322.4	246.3	49.5	1727.6
CS-MP-CD	13.4	11.7	22.1	117.4	10.1	226.5	336.9	254.9	46.3	1798.6
CS-CP-CD	12.6	11.9	22.2	116.2	11.5	226.8	325.4	249.7	52.0	1684.7

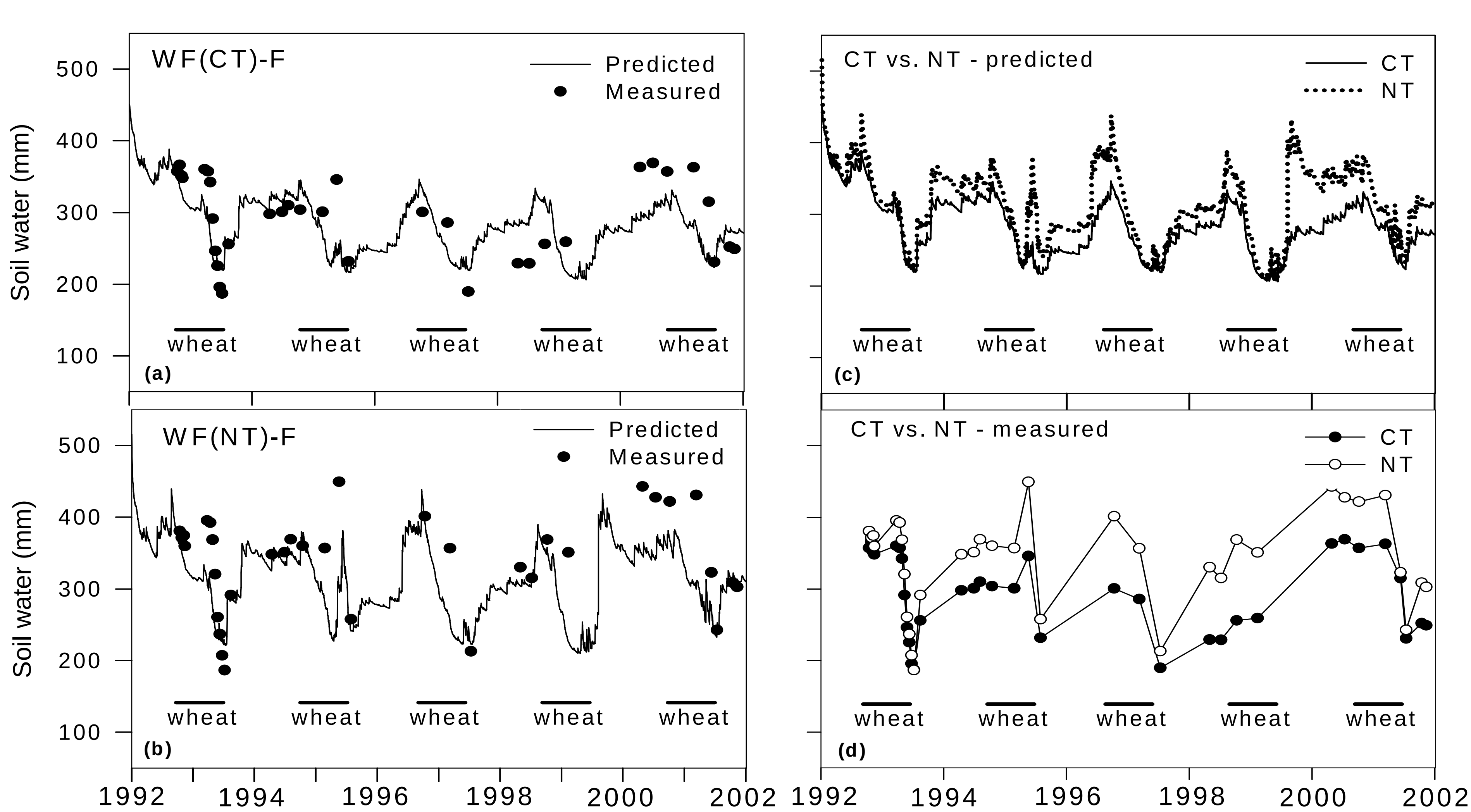
* CC: continuous corn; CS: corn-soybean rotation; NT: no-till; MP: moldboard plow; CP: chisel plow; FD: free drainage; CD: controlled drainage.
Δ = change from 1979 to 2002.

2. Dryland Copping Systems Studies in the Semi-Arid Central Great Plains (Akron, CO)

Alternative Crop Rotation Exp.

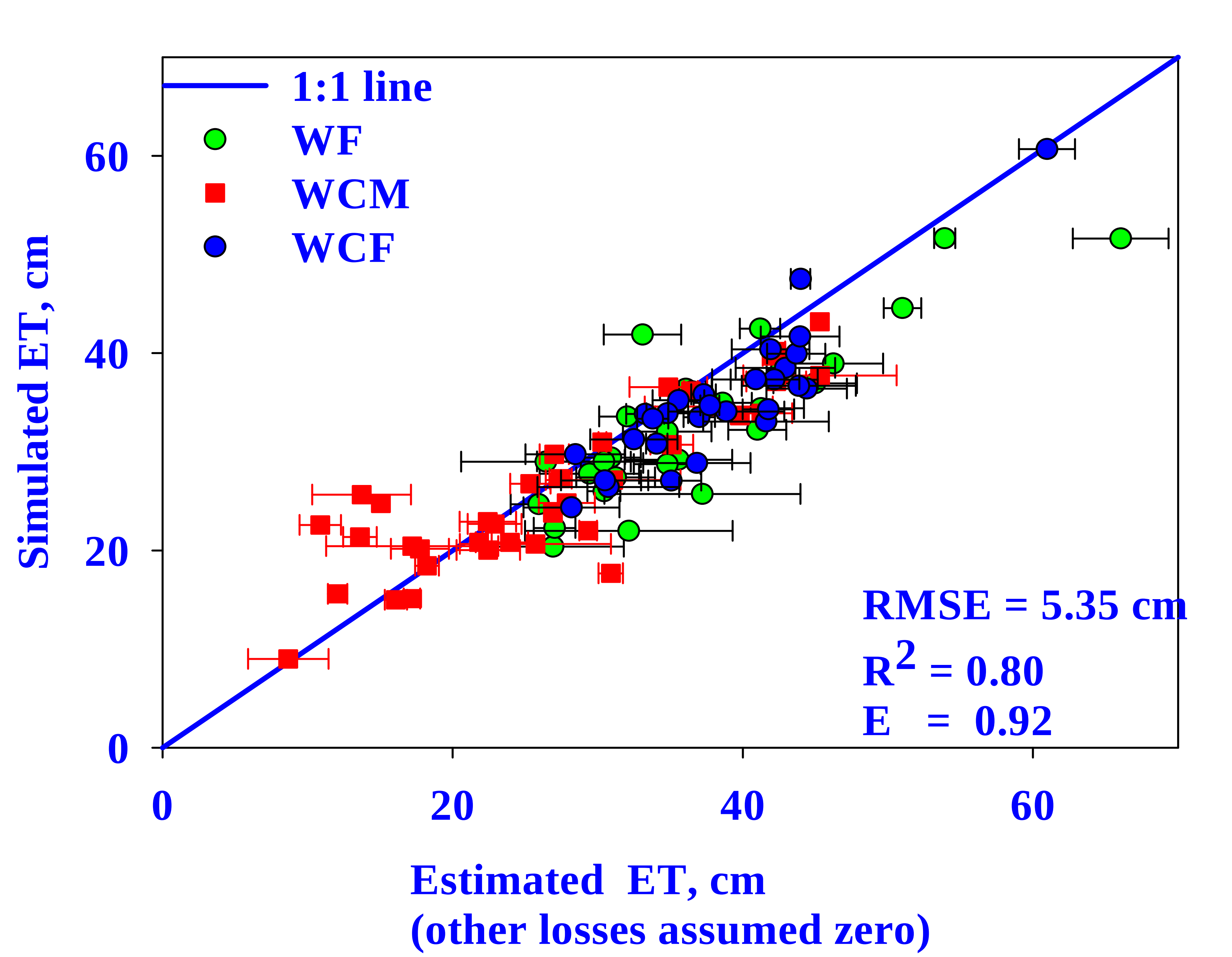
SYNTHESIS – Biomass and Yield in 4 Rotations

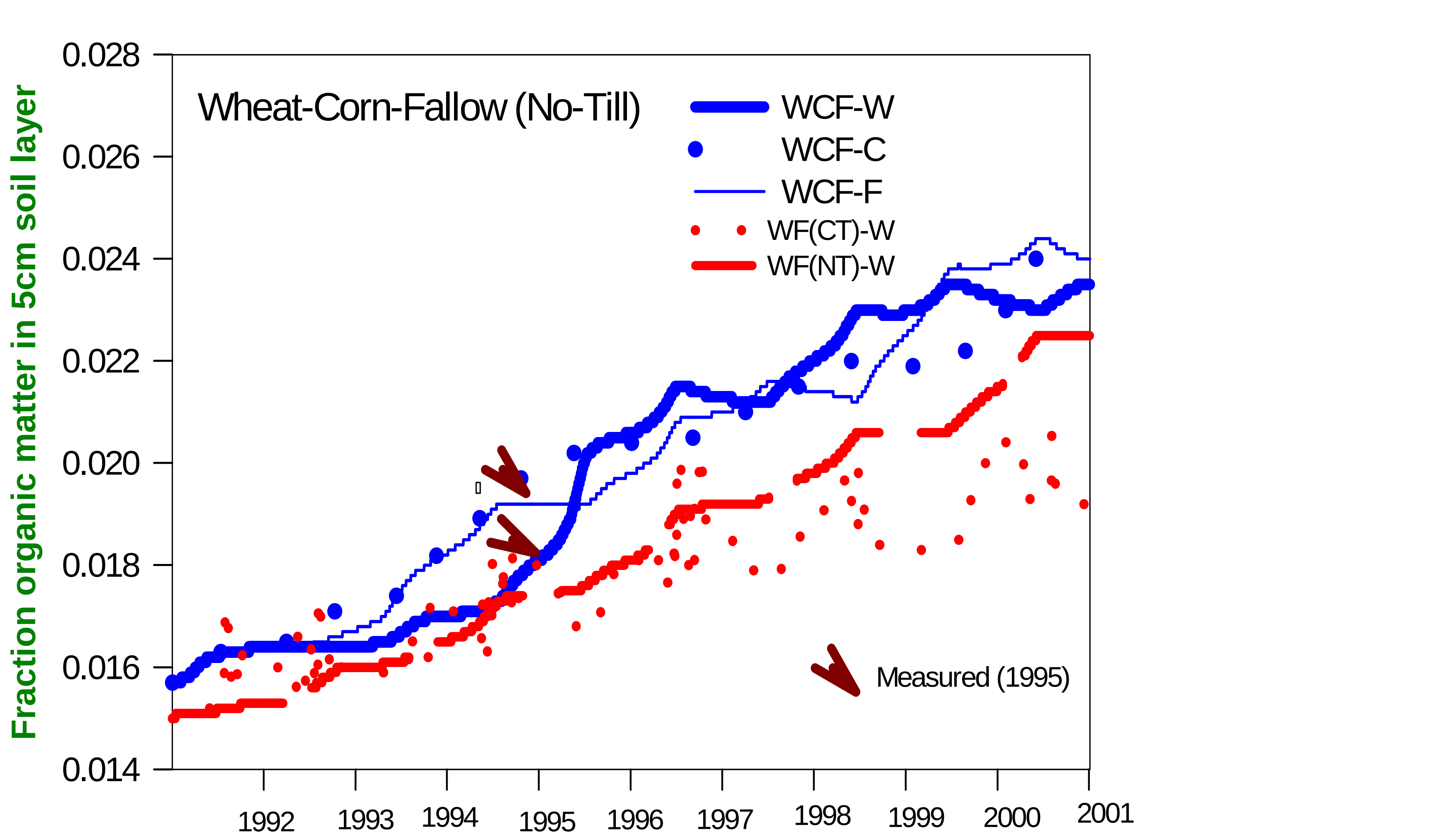




Measured and predicted (RZWQM) total profile (180 cm) soil water under wheat fallow (WF) for the beginning fallow data set. (a) conventional tillage (CT), (b) no-till (NT), (c)comparison of predicted soil water under WF(CT) and WF(NT), (d) comparison of measured soil water under WF(CT) and WF(NT) (Saseendran et al., 2005).

ET - composite





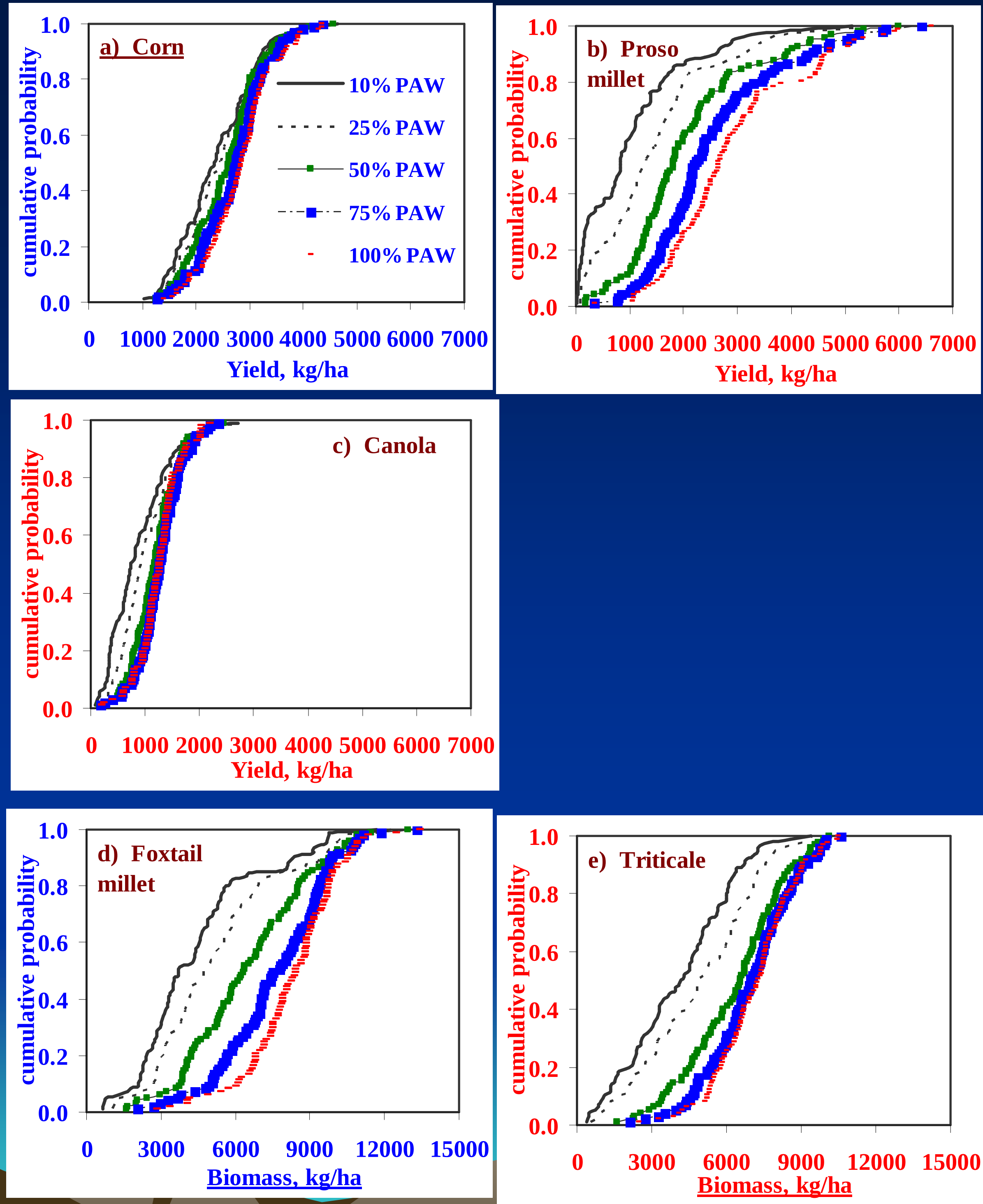
FOM in the first 5 cm soil layer under W, C, and F phases of WCF, and W phase of WF(CT) and WF(NT) during 1992 to 2002.

Using Validated Model to Explore Drought Management Strategies

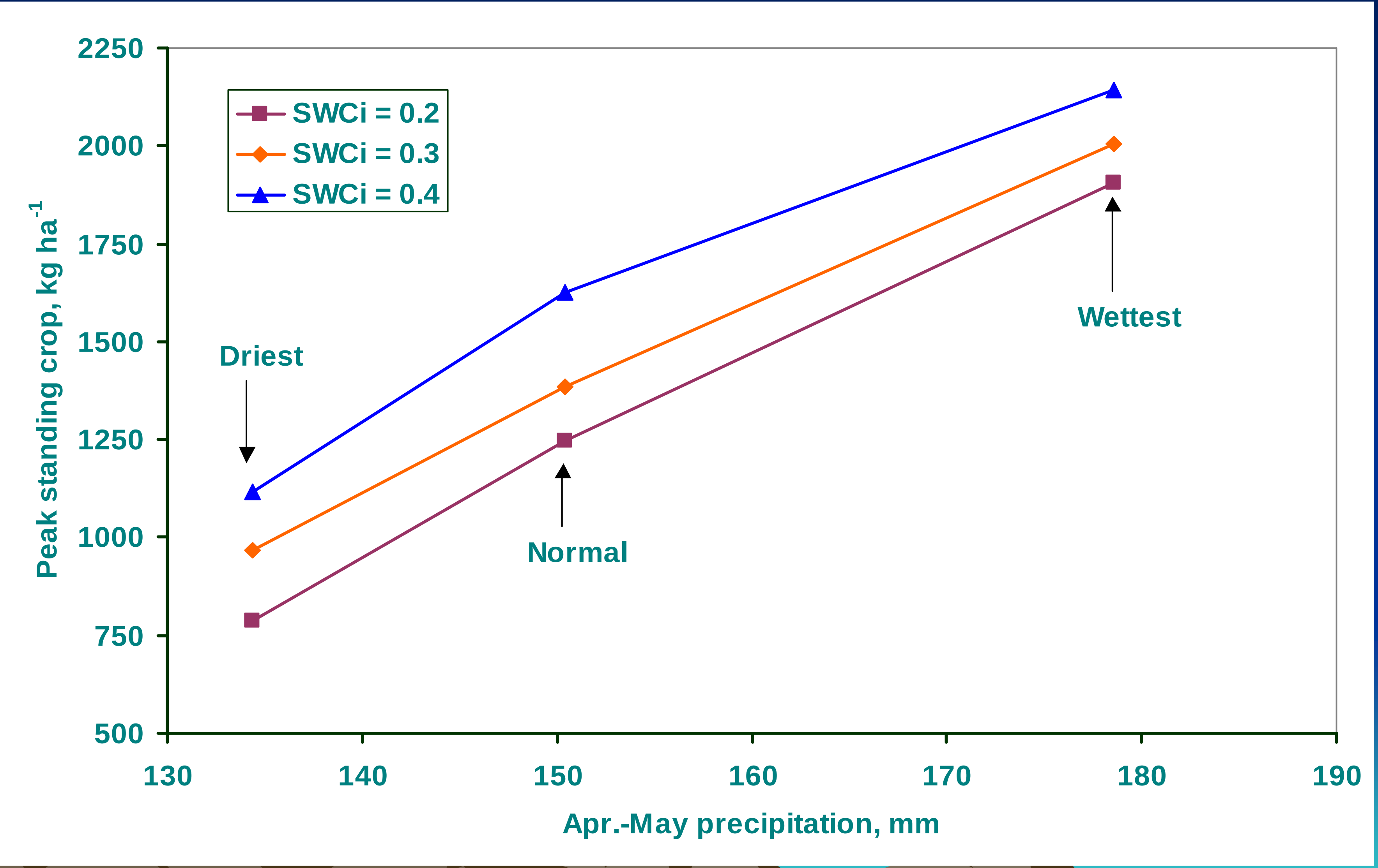
Summer Crop Selection in Rotation with Wheat Based on Initial Water

Cumulative probabilities of Grain yields of Corn, Proso millet and Canola, and Biomass of Foxtail millet and Triticale planted with Plant Availalble Water at planting from 0 to 100%

Note: PAW in the soil profile below 45 cm was constrained not to exceed 50% of PAW at field capacity.

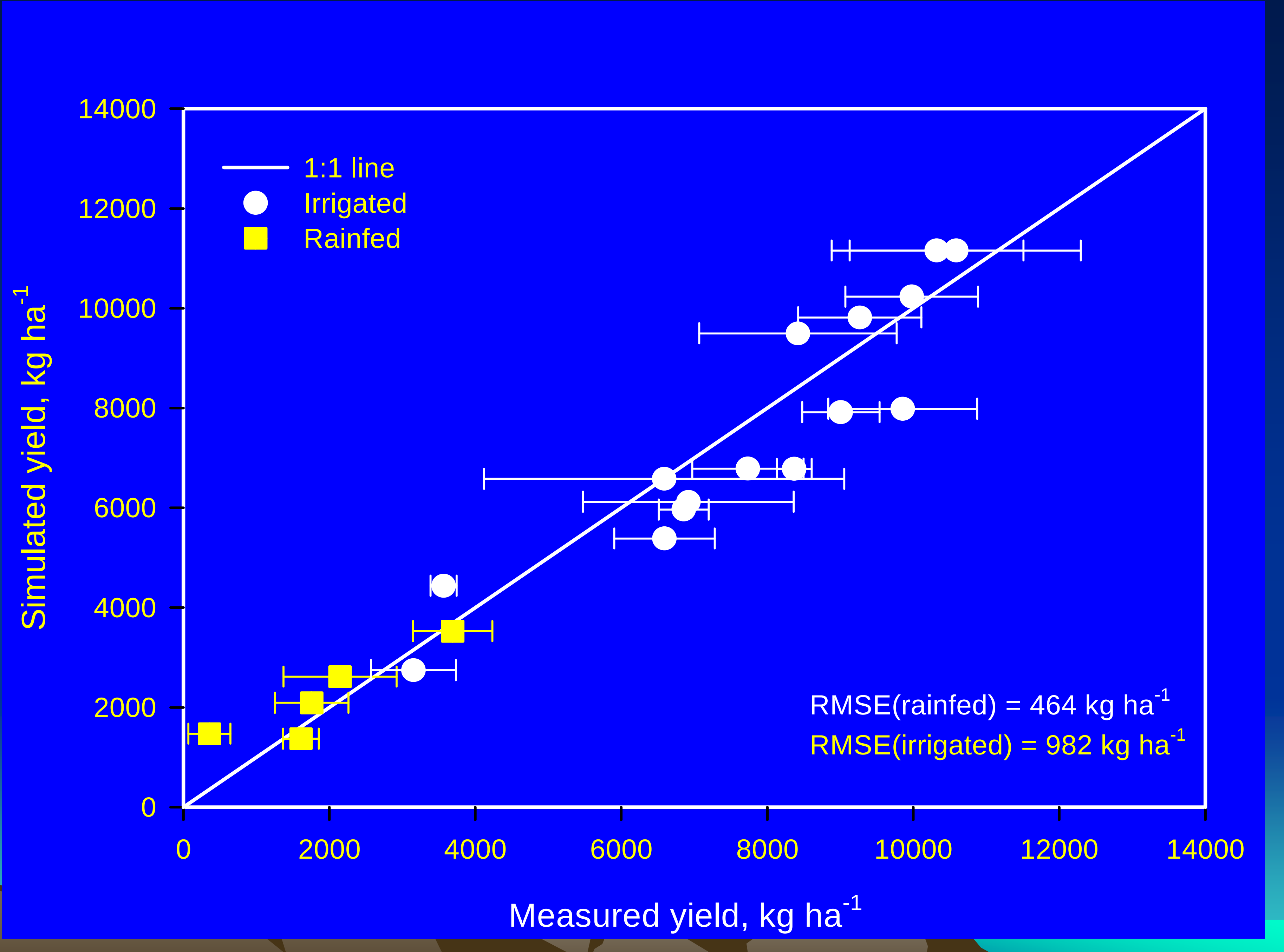


Predicting Peak Standing Crop (rangeland biomass) at different levels of initial soil water Contents (SWC) and April-May precipitation



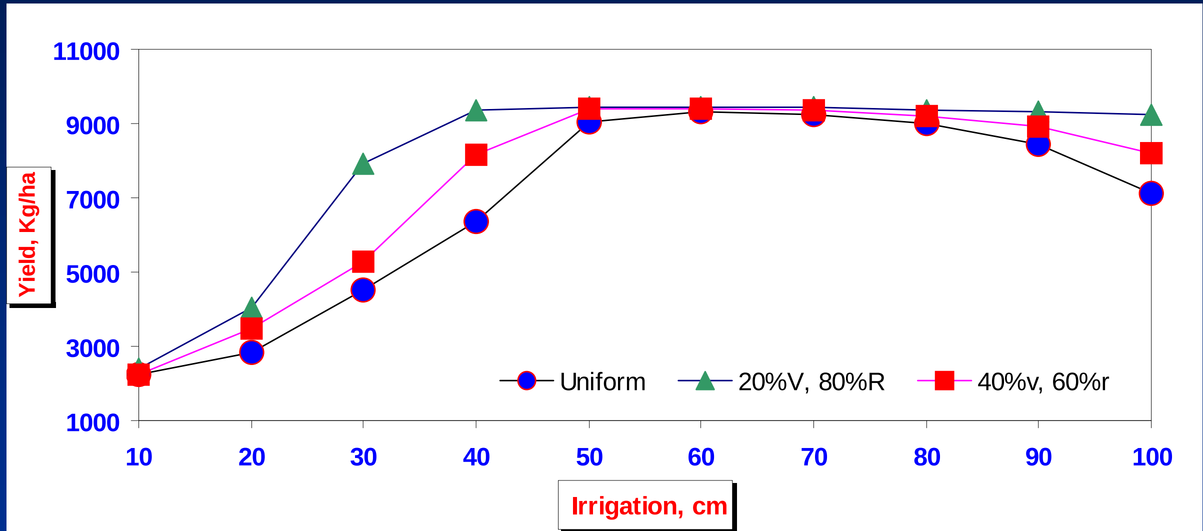
Limited Irrigation Studies on Corn in the Central Great Plains

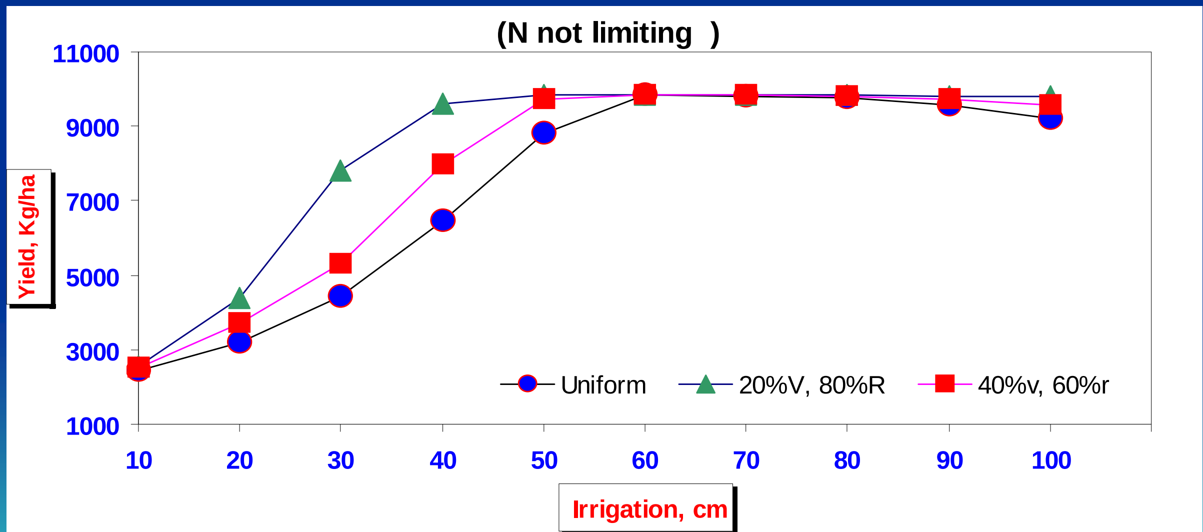
Synthesis of Data: Grain Yield of Corn



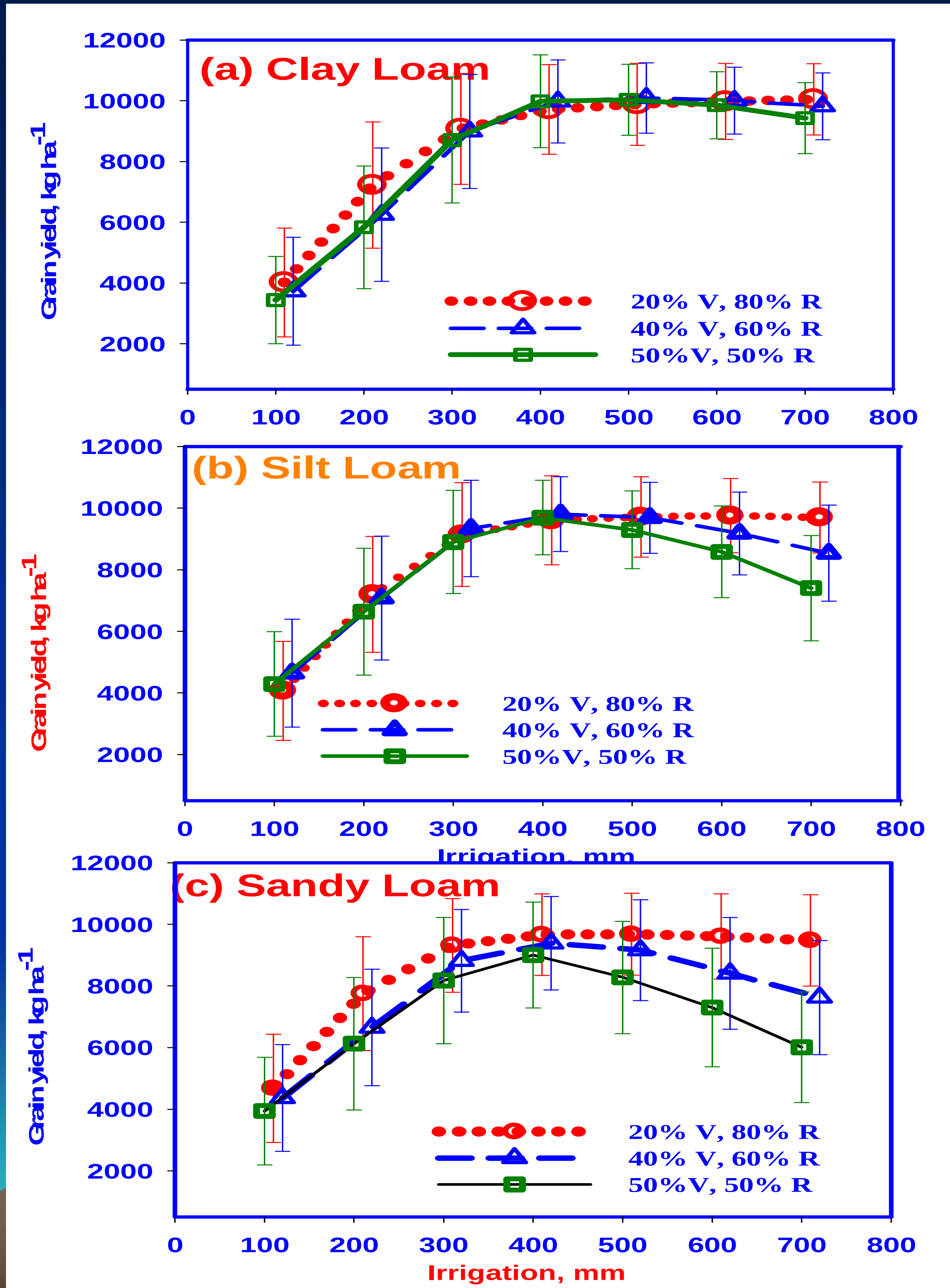
Using Validated Models to Explore alternative Scenarios for Managing Limited Irrigation Water

Rain out experiments with different levels of irrigation in Corn
(Seasonal PET=90 cm, irrigated weekly)



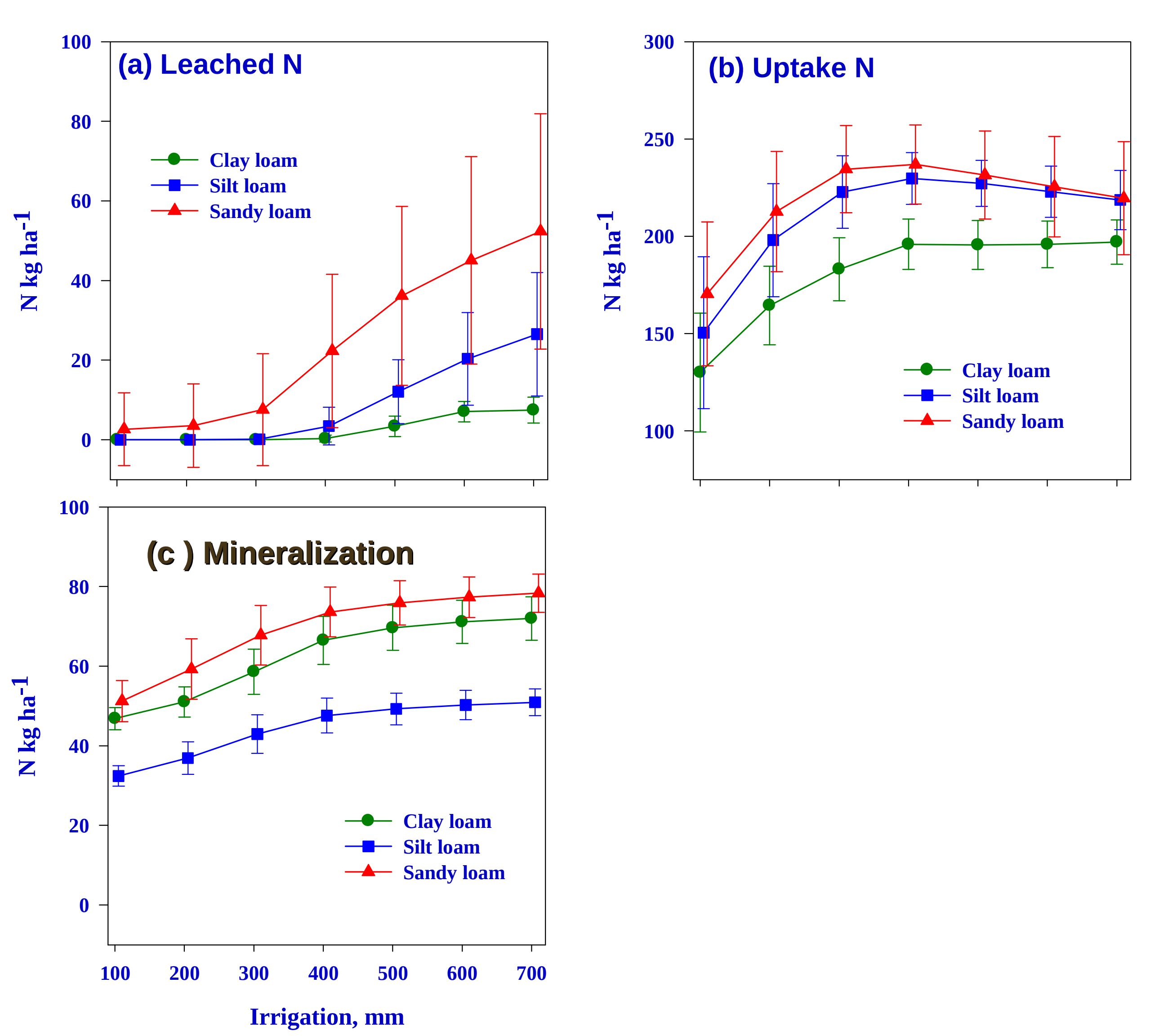


Grain Yield (20:80, 40:60 & 50:50 split - 94 year average)

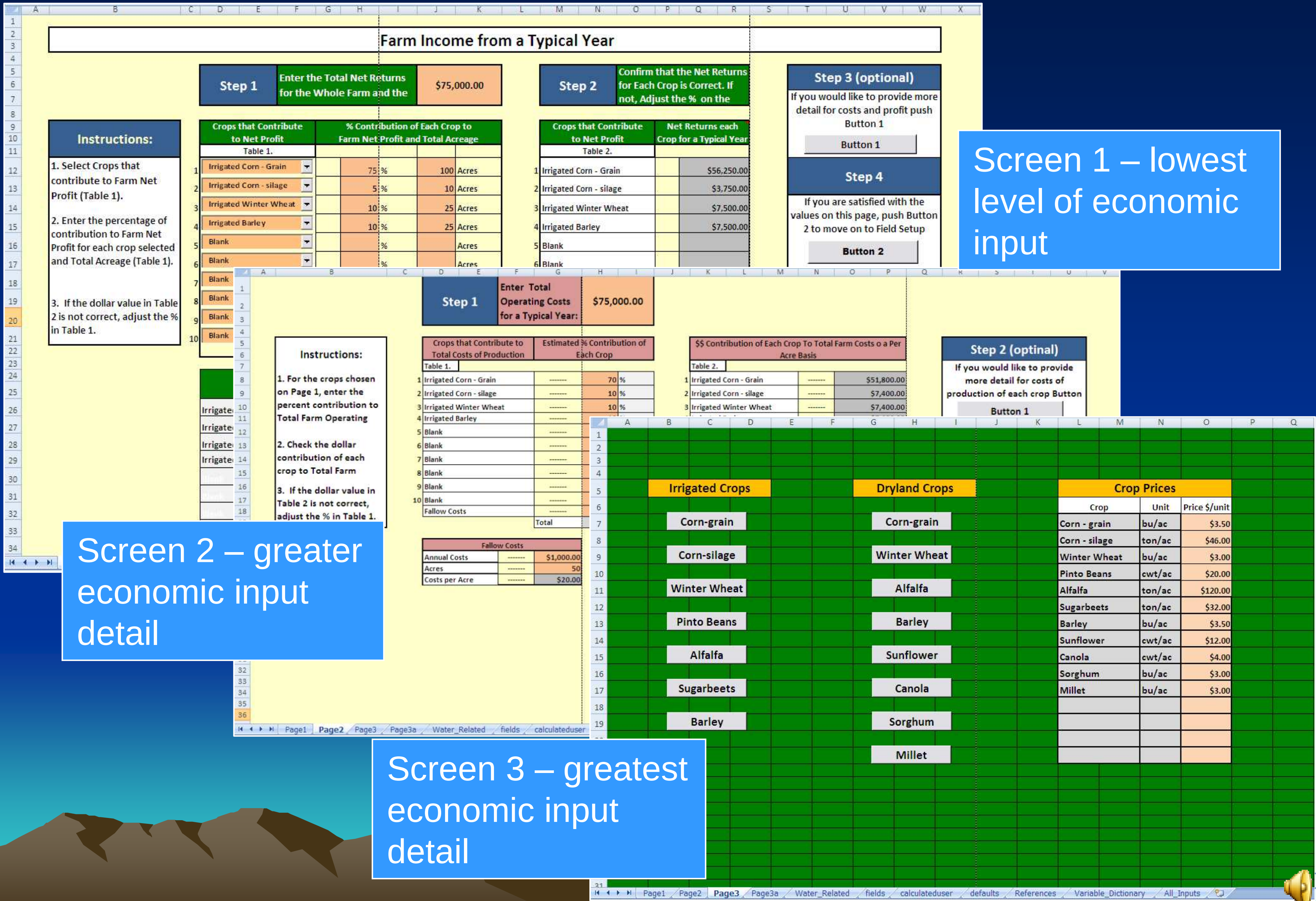


N balance

(20:80 split - 94 year average)



Limited Water Optimization Tool Interface



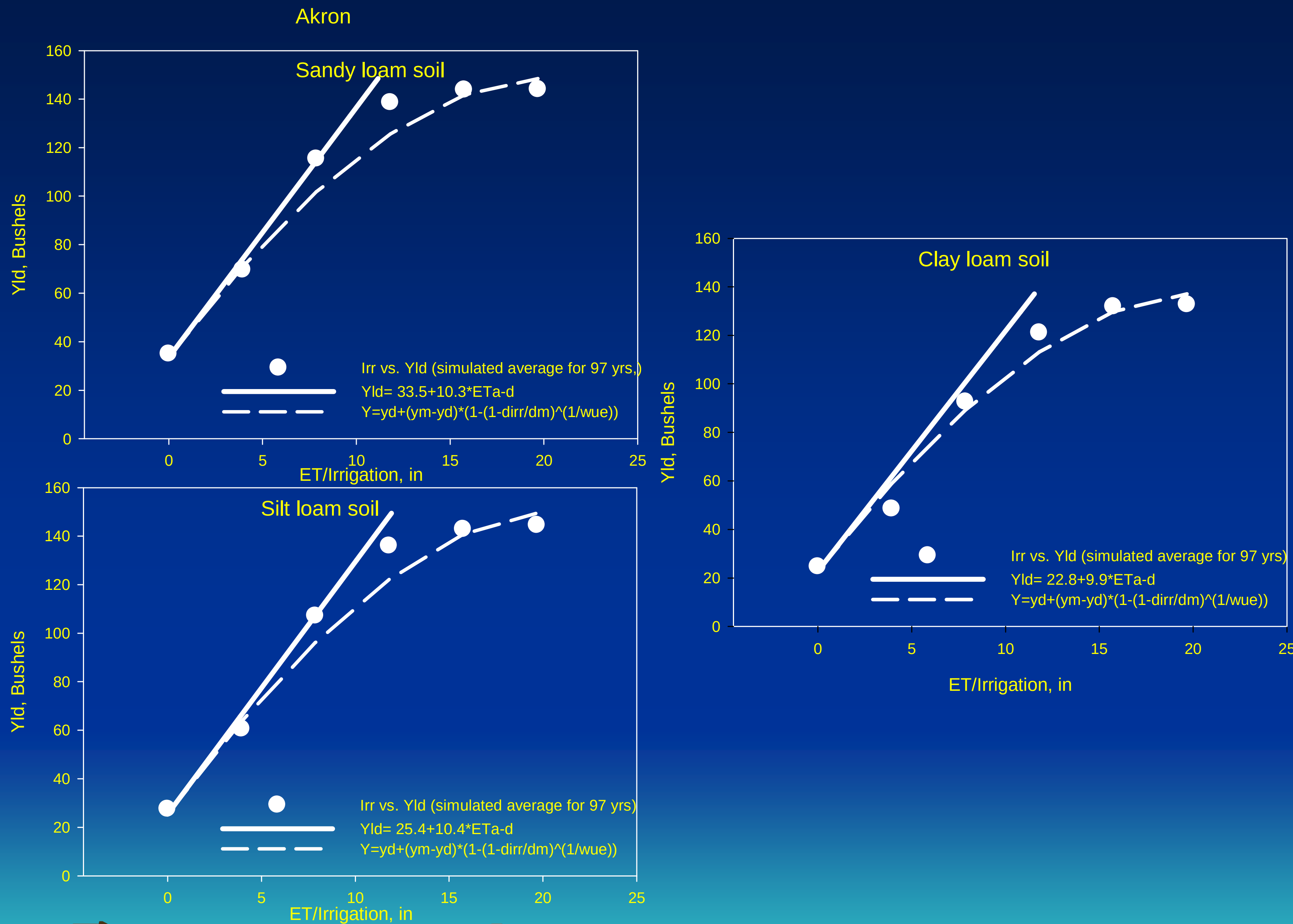
Screen 1 – lowest level of economic input

Screen 2 – greater economic input detail

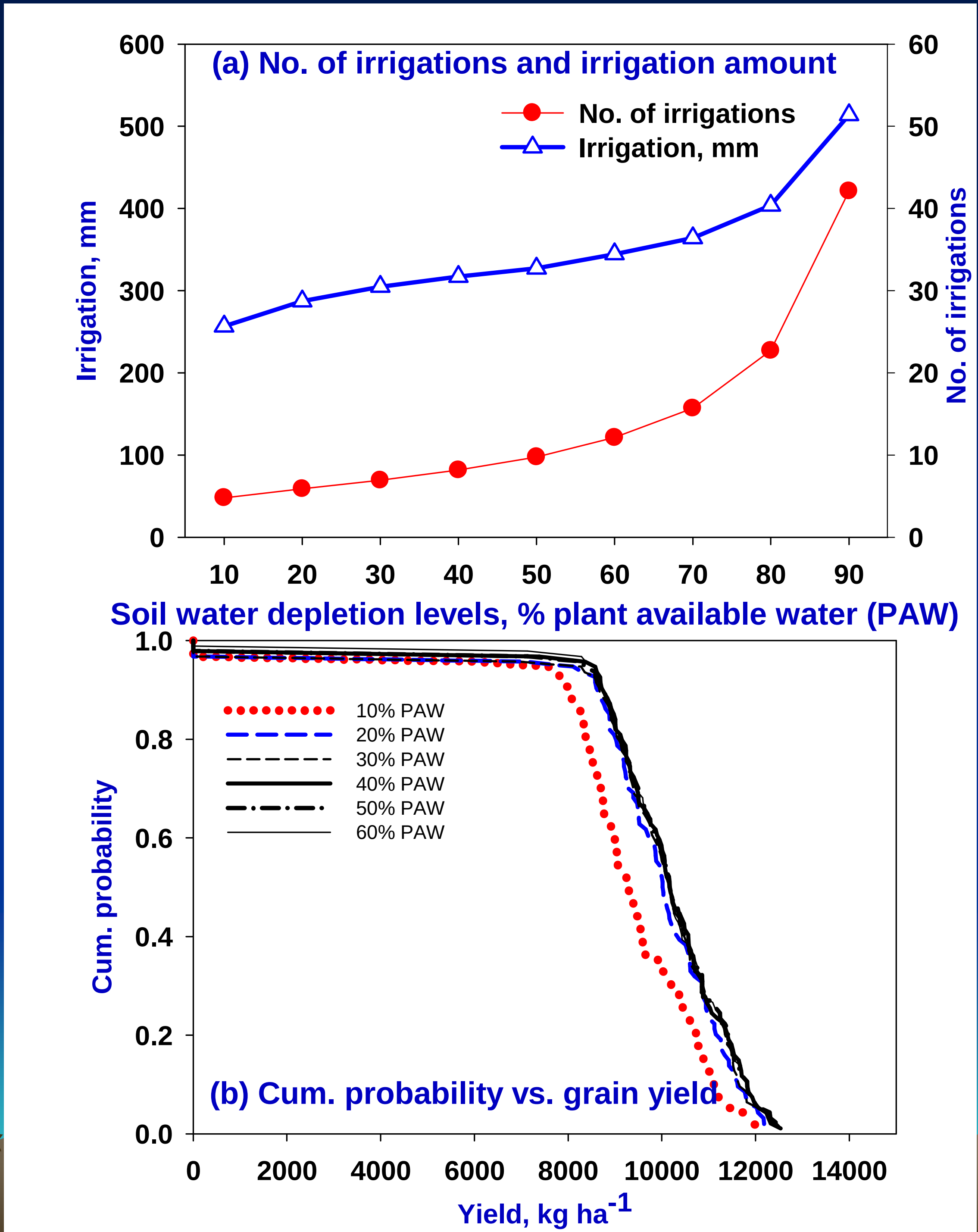
Screen 3 – greatest economic input detail

Production Function for Water Optimizer

Simulate yield response to irrigation and ETcrop



SOIL WATER DEPLETION LEVEL FOR IRRIGATION

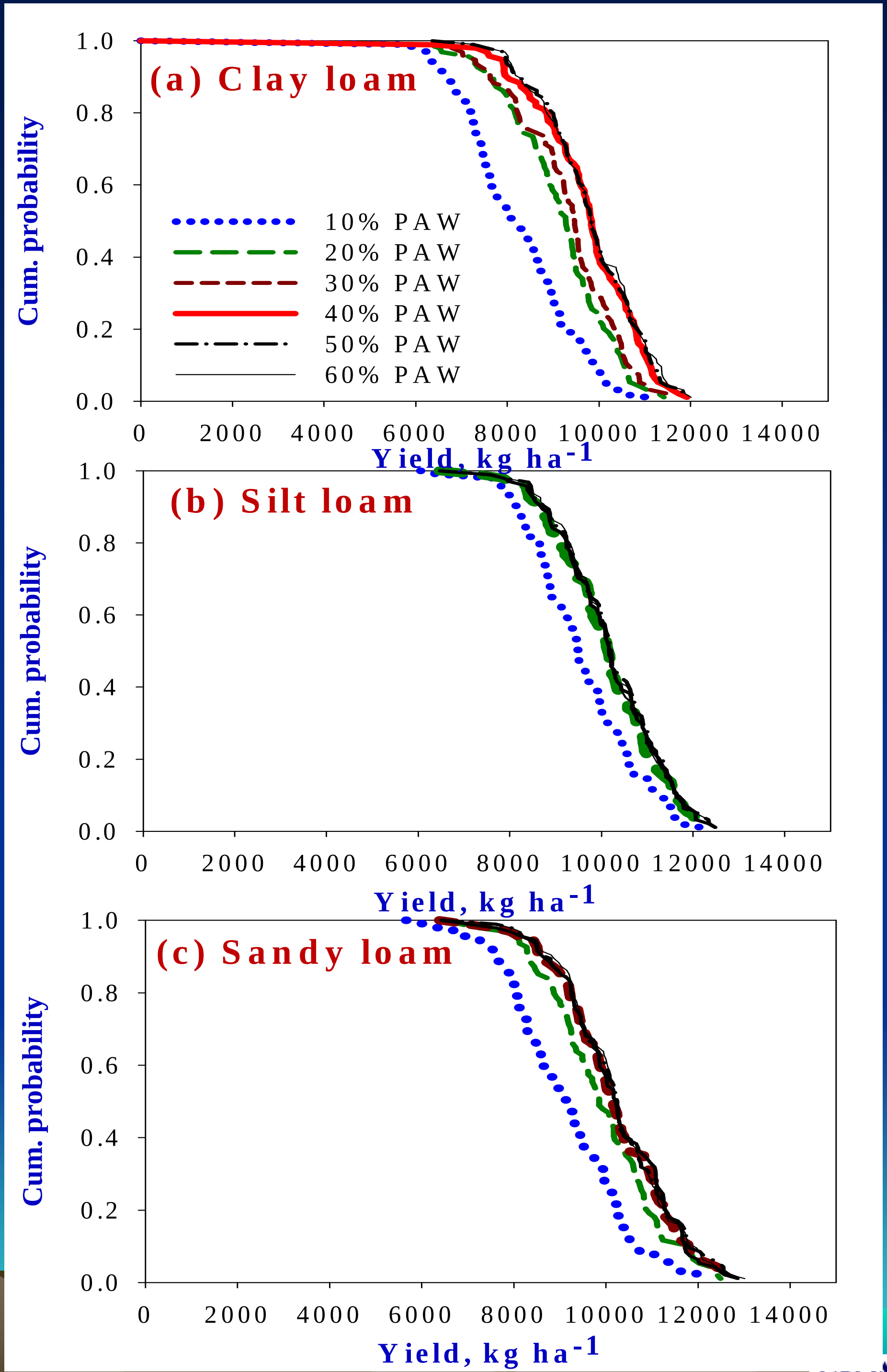


Simulated corn grain yield response to initiation of irrigation at different soil water depletion levels at Akron, Colorado

(a) number of irrigations and irrigation amounts simulated with the 94-yr weather record in response to initiation of irrigations at soil water depletions until 10 to 90% plant available water (PAW), and

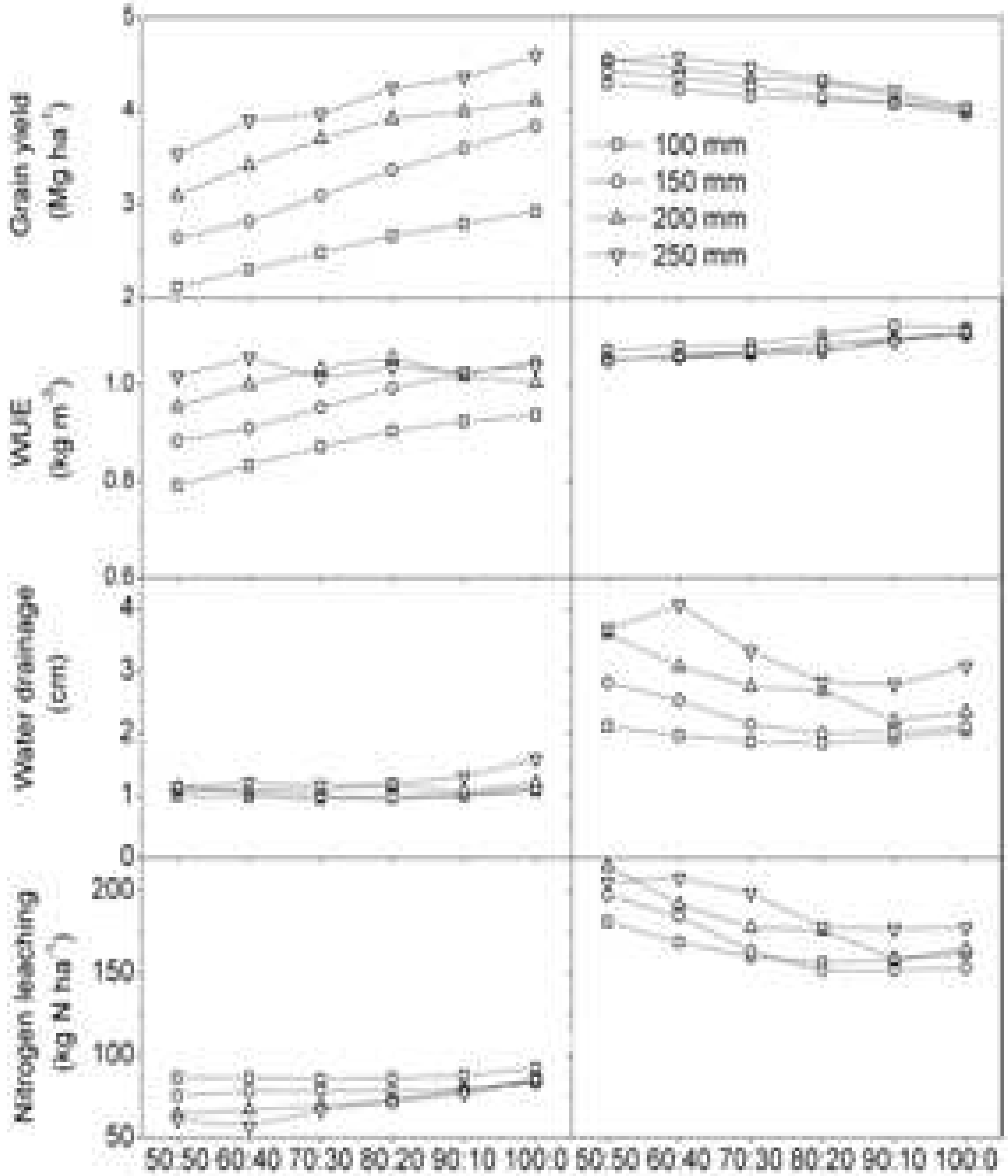
(b) cumulative probabilities for corn grain yields simulated with the 94–yr weather record in response to initiation of irrigations at soil water depletions until 10 to 40% PAW. Bars represent one standard deviation above the mean.

Late Initiation of irrigation - Comparison between soils



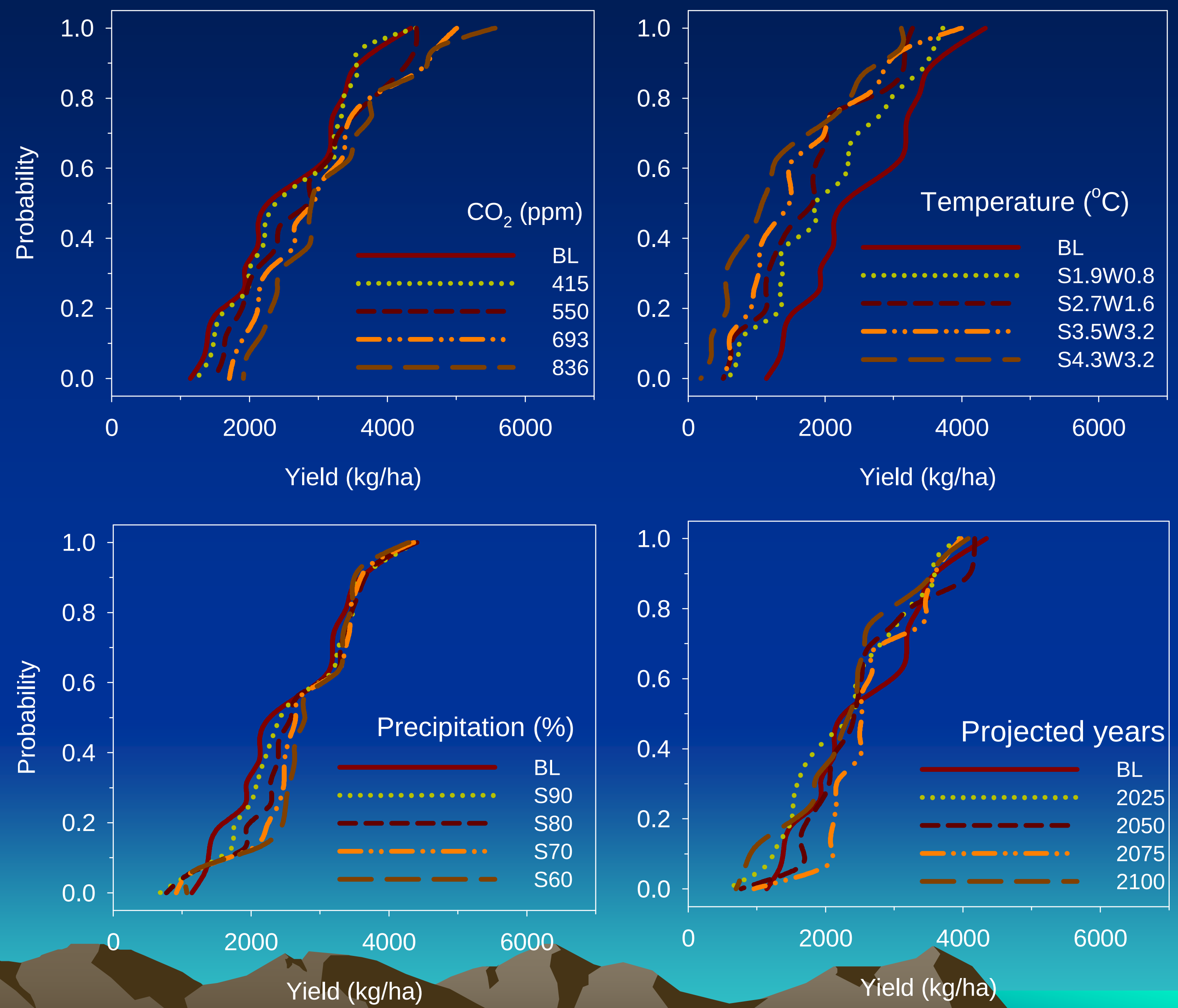
3. Water and N Management for Wheat-Maize Double-Cropping System in China

Grain yield, water use efficiency (WUE), water drainage, and N leaching for wheat (A) and maize seasons (B) at the four limited available water levels (100 mm, –□–; 150 mm, –○–; 200 mm, –△–; 250 mm, –▽–) simulated by RZWQM2 from 1961 to 1999.

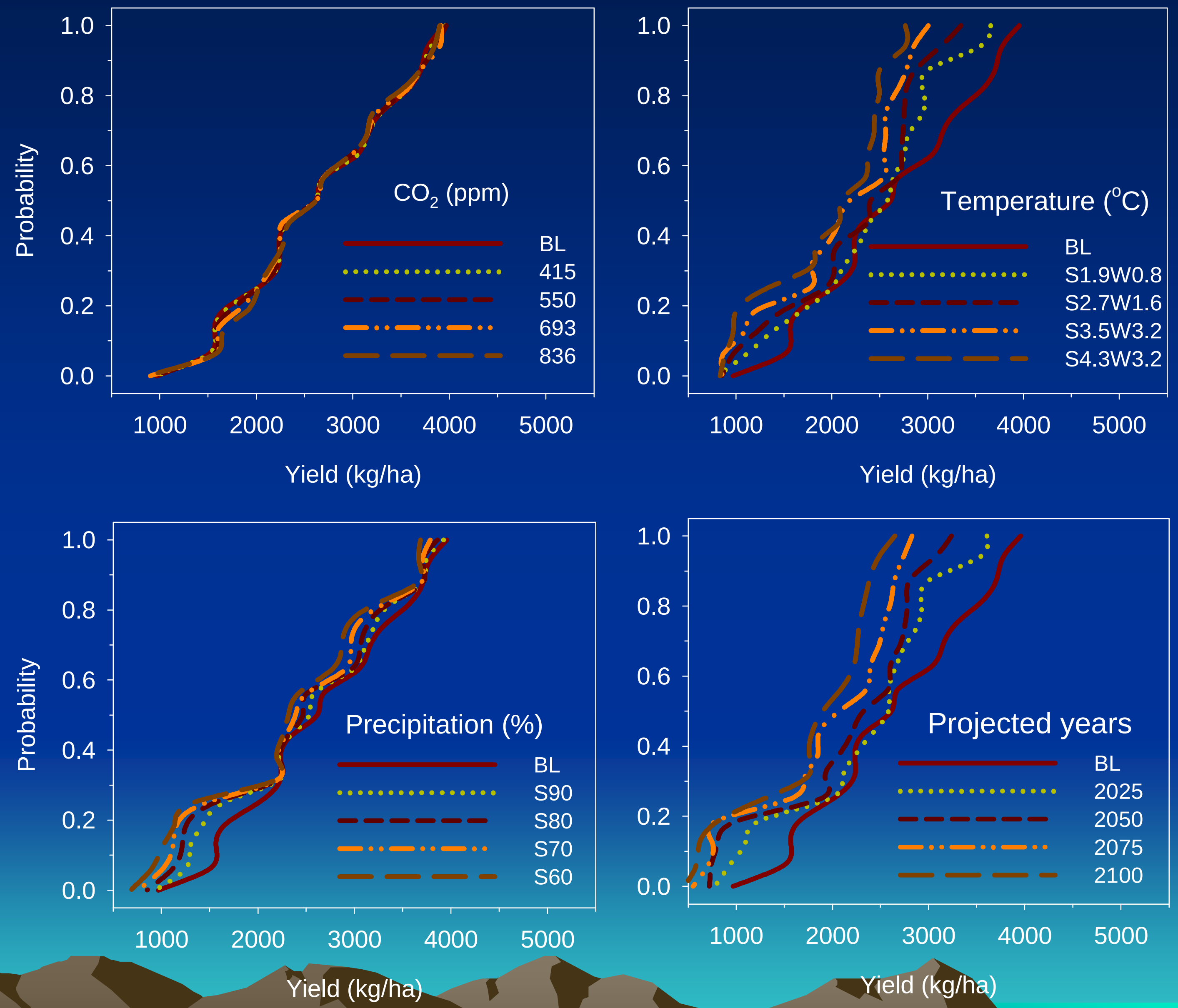


Climate Change Effects on Cropping Systems in the Central Great Plains

Wheat Yield in WCF for Projected Scenarios Over the Baseline Experiment Years, 1992 to 2007



Maize Yield in WCF for Projected Scenarios Over the Baseline Experiment Years, 1992 to 2007



Thank you very much for your attention

USDA ARS United States Department Of Agriculture Agricultural Research Service

International Collaborations

1. Enhancing applications of existing models in field research
2. Easier parameterization of models for field scientists—effective properties of soils/crops
3. Improving model components, e.g., water stress response, N uptake, management effects, ----

International Collaborations Contd.

4. Developing next-generation, stand-alone modular process components
5. Sharing model components and databases
6. Possibly developing a common modular modeling framework, with parameterization, visualization, and analysis tools

ASA-SSSA-CSSA Initiatives to Advance Models and Applications

A. A new book series on Advances in Ag Systems Modeling:

1. Response of crops to limited water
2. Introducing system models in field research
3. Root-soil interactions
4. Quantifying soil structure effects
5. Quantifying soil carbon changes in cropping systems

ASA-SSSA-CSSA Initiatives to Advance Models and Applications

B. Ad-hoc Committee on Modules, Models, and Databases:

1. E-publish well-documented code for process modules, after having them peer reviewed for quality of science, documentation and meta data, industry-standard code structure, and pre-published validation.

2. E-publish the models built from peer-reviewed modules, after peer review of the model interfaces and pre-published validations.

Ad-hoc Committee Contd.

3. E-publish experimental databases needed for modules and models after peer review for quality of measurements, spatial representation, and completeness for calibration/validation

4. Maintain a library of peer-reviewed modules, models, and databases on the CSA website or website of a contractor or collaborator

Purpose of the Proposed Activities

- Advance science through synthesis and quantification of processes and interactions in the form of code, which scientists can use to build future models.

- Promote sharing of modules, models, and databases, which will reduce duplication and encourage the best science in the modules contributed by the experts for each process.

- E-publishing and web storage of modules, models, and databases will provide publishing credit to the contributors, an essential motivation for time consuming tasks of using standard code structure and documentation.

- Important Note:

  The above proposed activities are not supposed to interfere with or impede further development and applications of existing models. Rather, they are meant to help future enhancement of these models by providing peer-reviewed components.

The Tri-Societies welcome your feedback on these initiatives

And future collaborations