Information and Communication Technology Tools for Sustainable Agriculture

Mini Symposium

Professor Attachai Jintrawet, Chiang Mai University, Thailand &

Gerrit Hoogenboom, the University of Georgia, USA

Mini Symposium

- Forum for dialogue among researchers in the field of agriculture and systems applications

ICASA's Role in Sustainable Agriculture in the 21st Century

Gerrit Hoogenboom, University of Georgia, USA

J.W. White, USDA-ARS, USA

J.W. Jones, University of Florida, USA

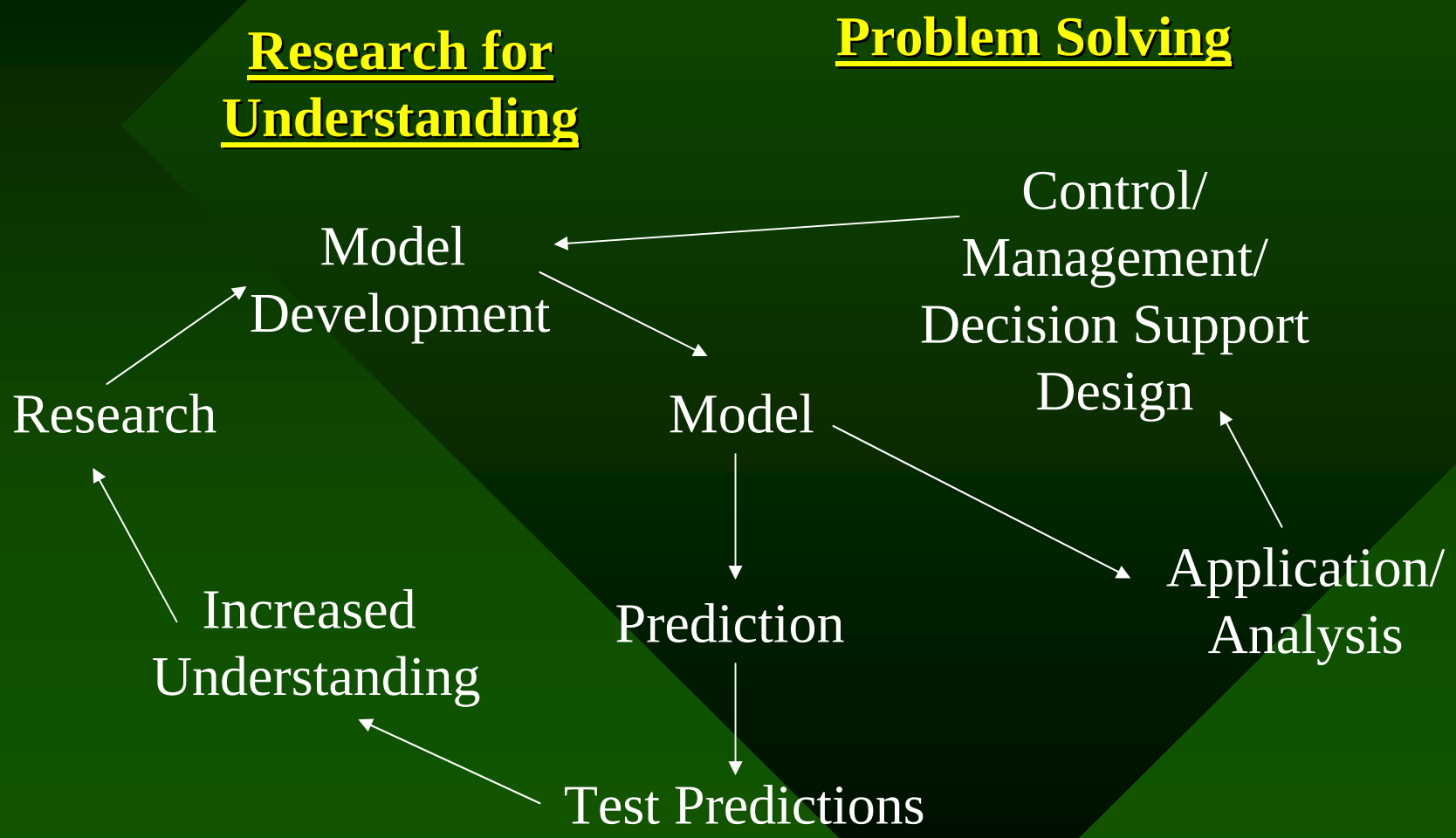
G.Y. Tsuji, University of Hawaii, USA

Attachai Jintrawet, Chiang Mai University, Thailand

What is Agriculture?

- Food (for human consumption)
- Feed (for livestock consumption)
- Fiber (for clothing and other uses)
- Fuel (for energy)

Systems Approach



ICASA's Role in Sustainable Agriculture in the 21st Century

Gerrit Hoogenboom, University of Georgia, USA

J.W. White, USDA-ARS, USA

J.W. Jones, University of Florida, USA

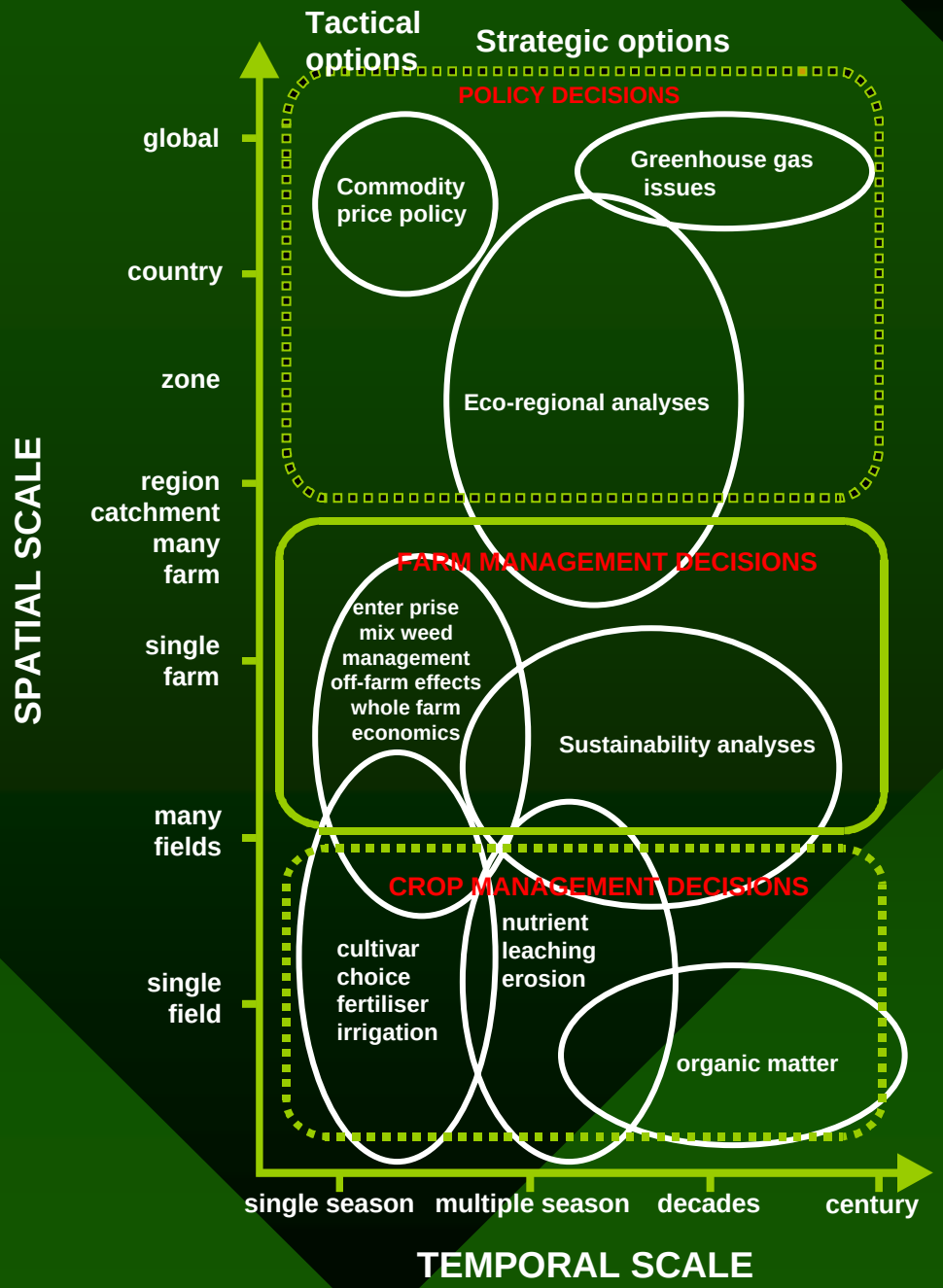
G.Y. Tsuji, University of Hawaii, USA

Attachai Jintrawet, Chiang Mai University, Thailand

Issues for Agriculture in the 21st Century

- Increased demands for agricultural products
- Increased pressures on natural resources, especially water
- Climate related risks
- Rapid changes in technology, ...
- Information needed for decision making
- Gap between information needed and that created by traditional agronomic research
- High and increasing costs of field experimentation
- Integration of knowledge is needed

Spatial and Temporal Issues



Agriculture

- The agricultural system is a **complex** system that includes many interactions between biotic and abiotic factors






Agriculture

- Abiotic factors = Non-Living
  - Weather/climate
  - Soil properties
  - Crop management
    - Crop and variety selection
    - Planting date and spacing
    - Inputs, including irrigation and fertilizer

Agriculture

- Biotic factors
  - Pests and diseases
  - Weeds
  - Soil fauna

Agriculture

- Socio-economic factors
  - Prices
  - Policies
  - Cultural settings
  - Human decision making

Agriculture

- The agricultural system is a **complex** system that includes many interactions between biotic and abiotic factors

- Management
  - Some of these factors can be modified by farmer interactions and intervention, while others are controlled by nature.

Systems Approach

- Traditional agronomic approach:
  - Experimental trial and error
- Systems Approach
  - Computer models
  - Experimental data
- Understand → Predict→ Control & Manage
  - (H. Nix, 1983)

What is a model ?

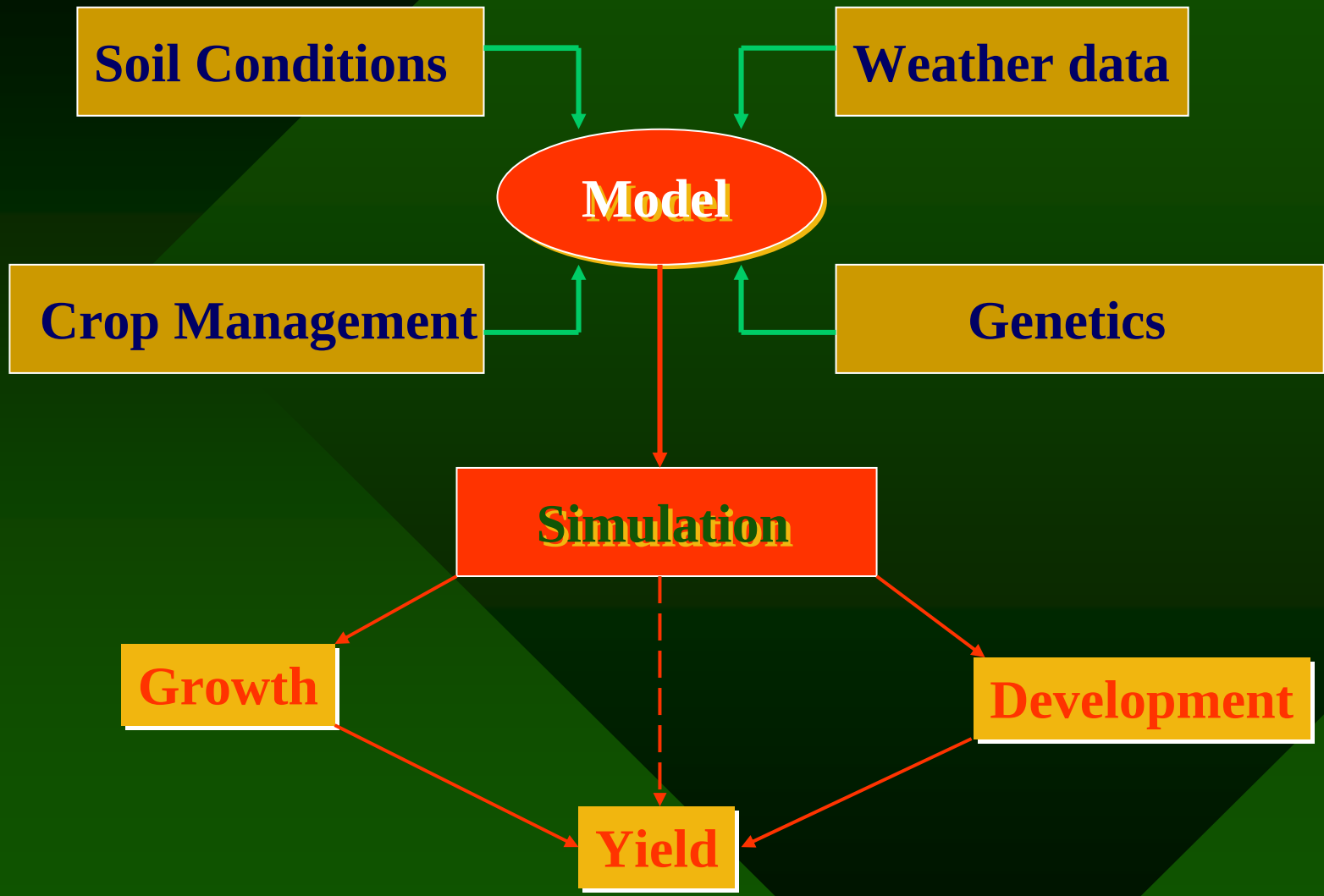
- A model is a mathematical representation of a real world system.
- The use of models is very common in many disciplines, including the airplane industry, automobile industry, civil eng., industrial eng., chemical engineering, etc.
- The use of models in agricultural sciences traditionally has not been very common.

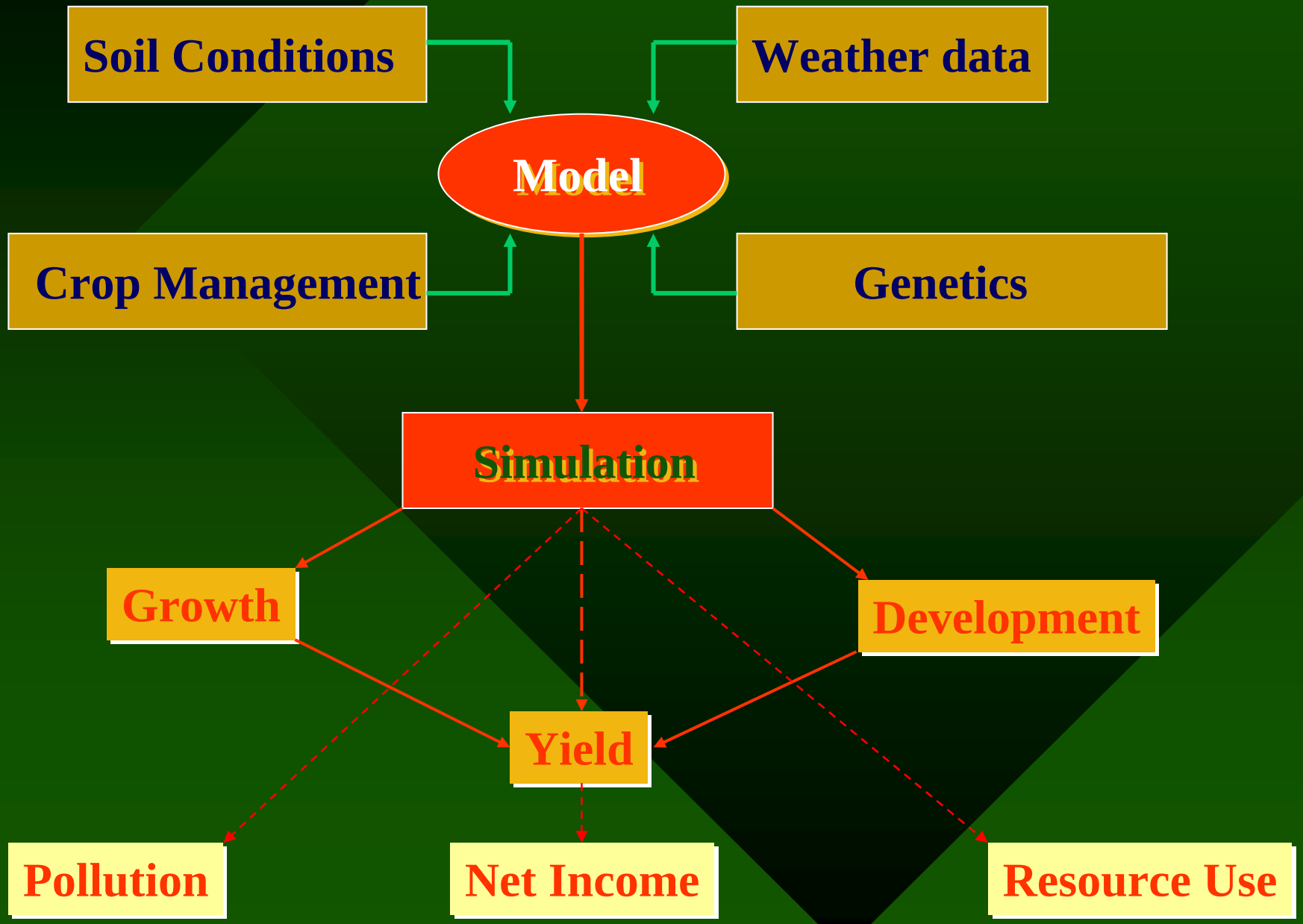
Crop Simulation Models

- 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.

Agricultural Models

- Crop simulation models in general calculate or predict ***crop growth and yield*** as a function of:
  - Genetics
  - Weather conditions
  - Soil conditions
  - Crop management

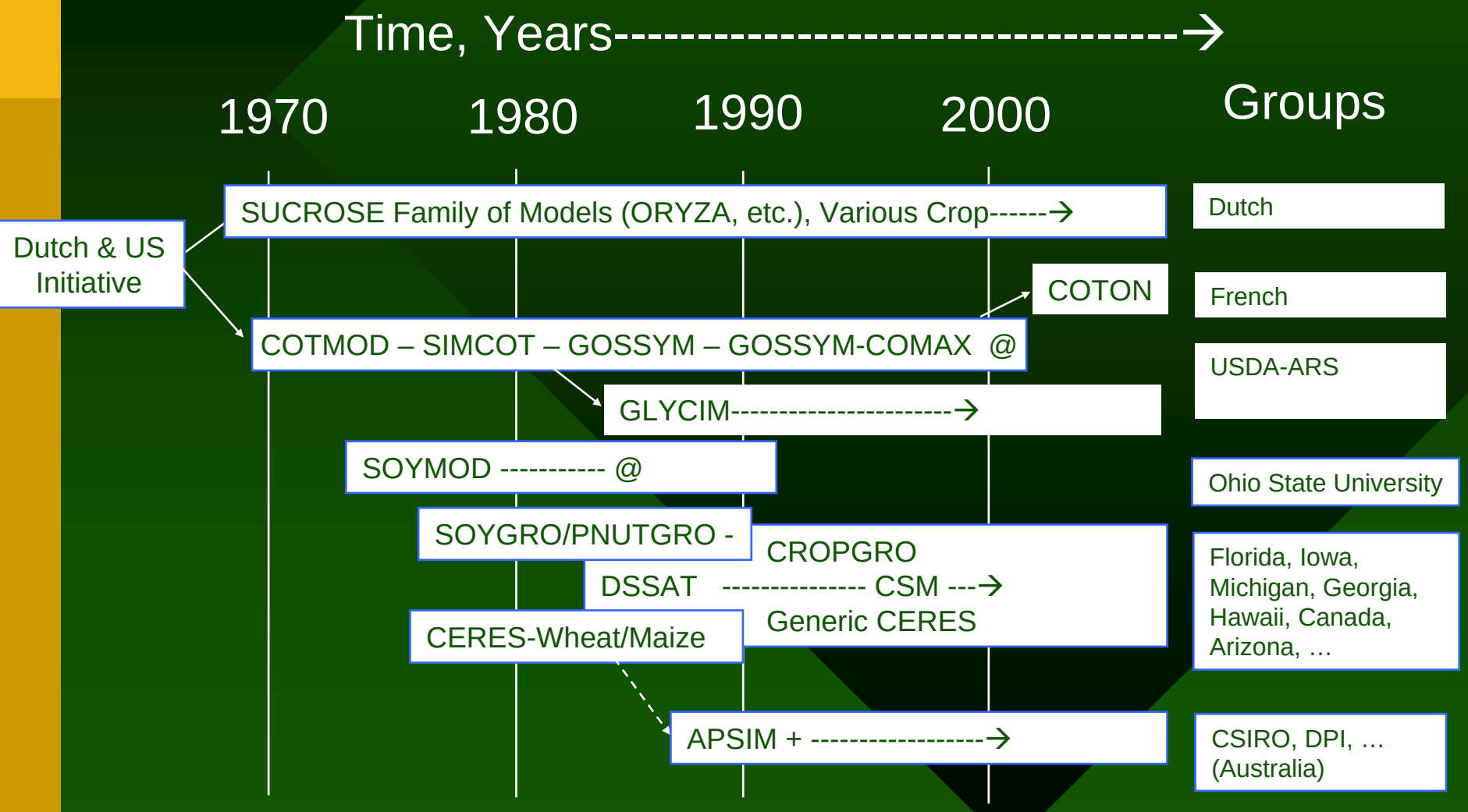

Soil Conditions
Weather data
Model
Crop Management
Genetics
Simulation
Growth
Development
Yield


Soil Conditions
Weather data
Model
Crop Management
Genetics
Simulation
Growth
Development
Yield
Pollution
Net Income
Resource Use

Where/When Crop Modeling Started: The Dutch & US Cotton Researchers

- Started in late 1960's
- Wanted method to predict crop growth and yield to better design management systems and to quantify effects of weather, risk
- C. T. de Wit (The Netherlands)
- Bill Duncan, Herb Stapleton, Jerry Lambert, Don Baker, Bob Peart, Bruce Curry (USA)
- Evolved into Dutch models (SUCROS) and US Cotton Models
- Also, created crop modeling community, which still functions today (Biological System Simulation Group)

Evolution of Several Major Families of Crop Models



Current Groups (with strong crop components)

- APSRU (Australia)
- STICS (France)
- SUCROS (Netherlands)
- DSSAT (USA, Canada, others …)
- DEMETER (Germany, Max Planks Institute)

Other Significant Crop Modeling Efforts

- EPIC and ALMANAC (USDA, Temple, Texas. J. Williams, C. A. Jones et al.)
- CROPSYST (Washington State University. C. Stockle, M. Donatelli)
- RZWQM (Colorado, ARS)
- Many others who are affiliated with one or more of the above groups, i.e., in Canada, Australia, USA, UK, Denmark, Germany, Argentina, Spain, Italy, Japan, Thailand, ….

Acronyms

- IBSNAT
  - International Benchmark Sites Network for Agrotechnology Transfer
- ICASA
  - International Consortium for Agricultural Systems Applications
- DSSAT
  - Decision Support System for Agrotechnology Transfer

IBSNAT Project

- Funded by the U.S. Agency for International Development
- 1982 – 1993
  - No continuation of financial support since 1993
- University of Hawaii
  - Michigan State University, University of Florida, Int. Fertilizer Development Center

IBSNAT - Approach

- To provide support to developing countries based on a systems analysis approach
- To use computer models and data in agricultural sciences in contrast to a traditional agronomic approach (trial and error)
- Understanding → Prediction→ Control & Manage (H. Nix, 1983)

IBSNAT - Outcomes

- A global network of:
  - Crop model developers
  - Crop model users
- A computerized product for decision support
  - **DSSAT**
- Data standards for model applications
- Data sets for model evaluations across many environments

International Consortium for Agricultural Systems Applications

- Combined former IBSNAT with the Netherlands Systems Science Effort
- Started in December 1993 in Thailand
- Board of Directors
- Global Network of participating scientists & institutions
- Joint activities (workshops, meetings, etc.)
- www.ICASA.net

ICASA **Vision**

- Broad acceptance and application of systems research in agricultural sciences and resource management.
- Wide participation of researchers in the development and application of compatible models, tools, and data, using modular approaches.
- Enhanced quality of agricultural systems science products, tools, and information.

ICASA Membership

- Initial Phase (1993-1996)
  - IBSNAT + Wageningen Agric. Univ. Group
- Expansion (1997-2002)
  - Added APSRU and Indian Systems Groups
- Widespread Participation (2003 -)
  - Open invitation to participate
- Membership form at www.ICASA.net
  - No dues
  - Benefits and contributions
- No financial support

ICASA Mode of Operation

- Participatory (design, development, application)
- No central funding
- Share tools, code, data, etc.
- Members give and receive
- Web-based system

ICASA Activities

- Training and workshops
- Standards, protocols, modularity
- Data archiving and data exchange
- Development of toolkits
- Projects
- Conferences and symposia
- Publications and dissemination

Science-Based Tools

- Biophysical Crop-Soil-Weather-Management Models

- Data preparation and analysis tools and application packages and programs

Crop Simulation Models

- Based on understanding of plants, soil, weather and management interactions
  - Morphological and phenological development
  - Photosynthesis, respiration, partitioning and growth
  - Root water and nitrogen uptake
  - Stress effects on growth processes
- Predict growth, yield, timing (Outputs)

Crop Simulation Models

- Require information (Inputs)
  - Field and soil characteristics
  - Weather (daily)
  - Cultivar characteristics
  - Management
- Can be used to perform “what-if” experiments

Decision Support System for Agrotechnology Transfer

- DSSAT:

➔A single software package that facilitates the application of crop simulation models in *research*, *teaching*, *outreach*, *service* and *decision making.*

DSSAT - software

- A software program that includes:
  - Crop simulation models
    - CERES, CROPGRO, SUBSTOR, CANEGRO, CROPSIM, AROID, OILCROP, and others
  - Utilities and tools for data handing
    - Experimental, soil, weather, economics
  - Application programs
    - Seasonal, crop rotational, and spatial analysis

DSSAT - components

- A simple shell to access all programs, tools and utilities
- 15+ programs, utilities and tools
  - Mixture of languages, including Fortran, Visual Basic, Delphi, Excel, etc.
- Experimental, crop, weather, soil, pest, genotype and economic data files

DSSAT - operation

- Two key components:

➔A strict set of data standards, file formats, and file naming conventions

➔A standard protocol for communication between individual modules and components

DSSAT - distribution

• DSSAT v2.1	1989	589
• DSSAT v3.0	1994	433
• DSSAT v3.1	1996	138
• DSSAT v3.5	1998	429+
• DSSAT v4B	2002	Workshop @ UGA
• DSSAT v4C	2003	Thailand workshop
• DSSAT V4.0	2004	Workshop @ UGA
• **DSSAT v4.02**	**2005**	**293+**
• DSSAT v4.02	2006	Workshop @ UGA

- Users in over than 90 countries

DSSAT Development Team

- University of Hawaii: Distribution
- University of Georgia: Coordination
- University of Florida
  - Jones & Boote
- Mississippi State University
  - Batchelor
- International Center for Soil Fertility and Agricultural Development (IFDC)
  - Wilkens, Singh and Bowen
- University of Guelph
  - Hunt
- Others:
  - USDA-ARS: J.W. White; CIAT: A. Gijsman

Linkage between experimental data and simulations

- Model credibility and evaluation
- Experimental data needs

DSSAT
Minimum Data Set

- Level 1 - Operate crop simulation models
- Level 2 - Evaluate model performance

  - Calibrate, estimate parameters
- Level 3 - Develop models (Maximum)

➲Standard files, formats designed, documented, and implemented in DSSAT and its crop models

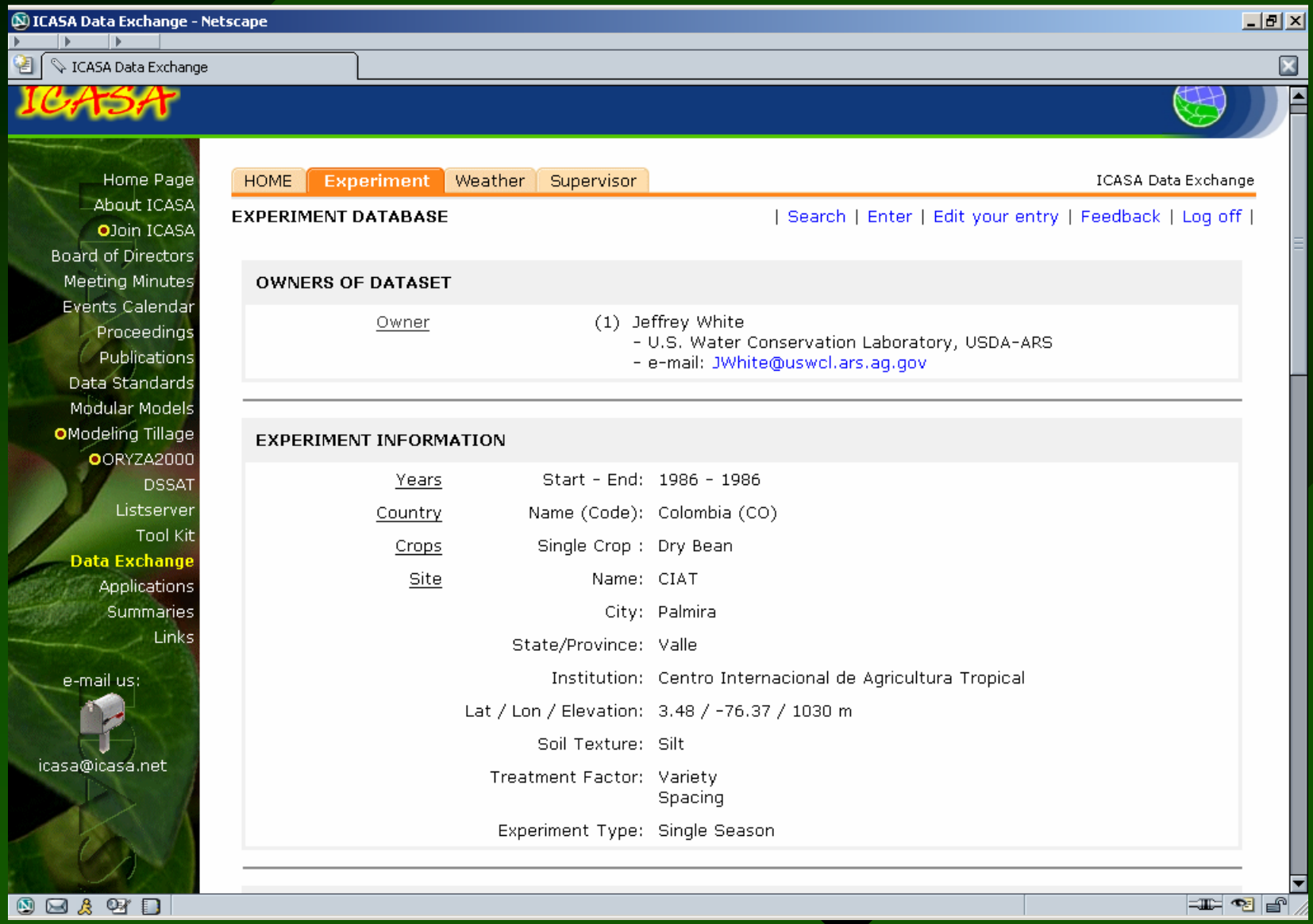
Experimental Data

- “Golden child” of experimentalist
- Experimental data are under-utilized
- Experimental data “disappear” upon retirement or transfer of a scientist
- Many granting agencies now require sharing and public access of experimental data

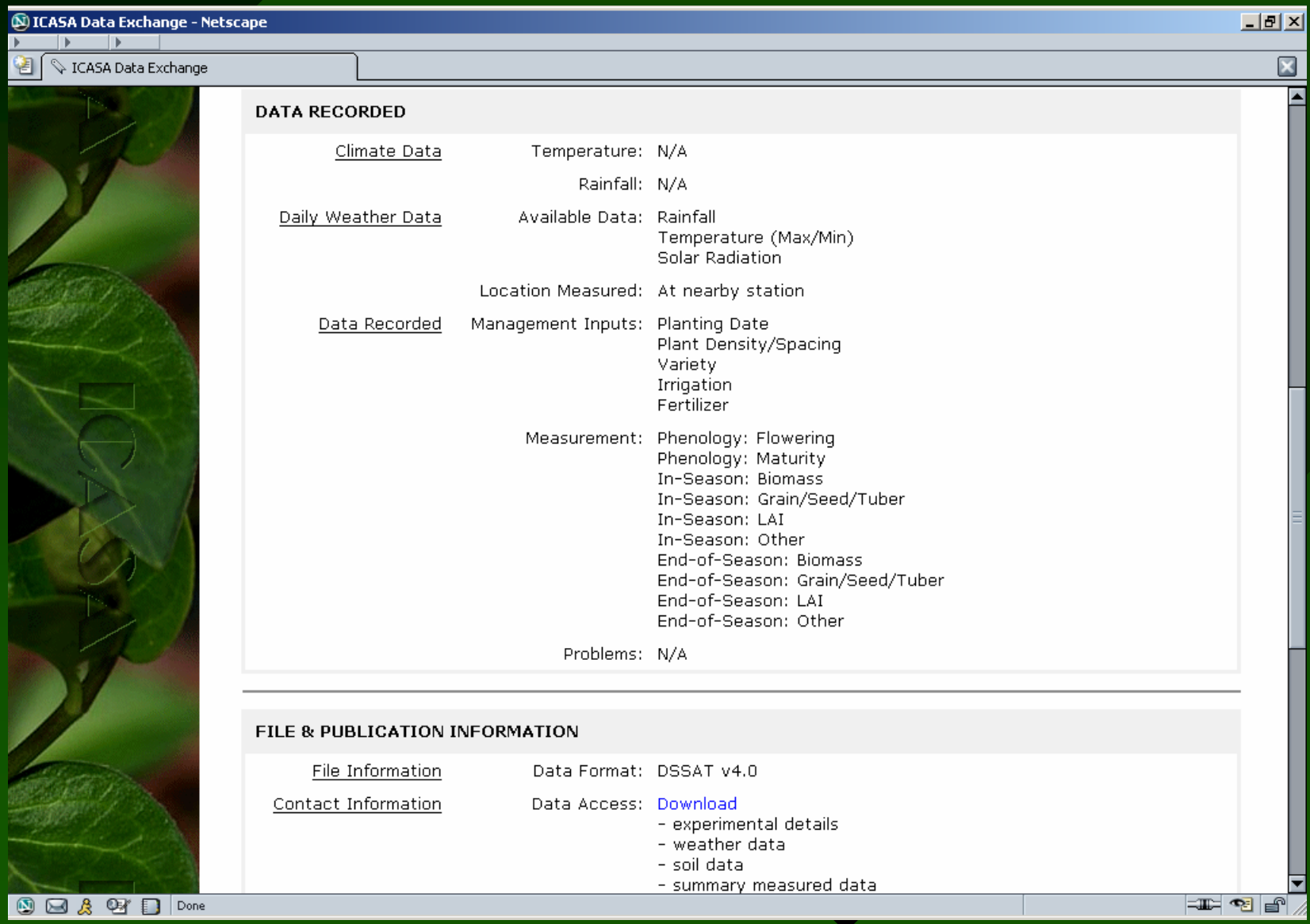
ICASA Data Exchange

- Internet-based system:
  - www.ICASA.net
- Documenting, archiving and exchanging cropping system, experimental and/or weather datasets.
- Users can enter metadata that describe their datasets
  - Upload their dataset files
  - Edit their entries
  - Search for data using specific criteria
  - Browse metadata of datasets in the system, and
  - Download datasets from the system.

IDE Example Data



IDE Meta Data



Who Uses DSSAT and its Models?

- Agricultural researchers
- Educators
- Extension Service and other farmer advisors
- Private sector
- Policy makers

Applications

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

Applications

- Adaptive management using climate forecasts
- Climate variability
- Climate change
- Soil carbon sequestration
- Land use change analysis
- Targeting aid (Early Warning)
- Biofuel production

DSSAT Tools Under Development

- New Crops (Cotton, sugarcane, pasture, …)
- Tillage module for DSSAT
- Improvements in various modules
  - Residue management, decomposition
  - Phosphorus
  - Soil water balance (runoff, evaporation, uptake by plants)
  - Crops

DSSAT Tools Under Development

- Updated ICASA data standards
- Data base management for data standards
- Climate prediction application tools
- Data assimilation (Integrating models and measurements to improve predictions)
- Tools to help estimate cultivar-specific paramaters
- Linkage between biotechnology and crop modeling (Gene-based modeling)
- Scaling up predictions (Linkage to GIS, etc.)
- Linkage with other models (Water quality & livestock)

Upcoming Crop Modeling Training Workshops

- Third DSSAT Training Workshop in Sub-Saharan Africa (Winter 2007)
- DSSAT Training Workshop for the Middle East (Jordan, Spring 2007)
- DSSAT Training Workshop for the Caribbean (Trinidad and Tobago 2007)
- DSSAT Training Workshop for Southeast Asia (Thailand 2007 [?])
- General Crop Modeling and DSSAT Training Workshop (University of Georgia, May 2008)

ICASA: www.ICASA.net