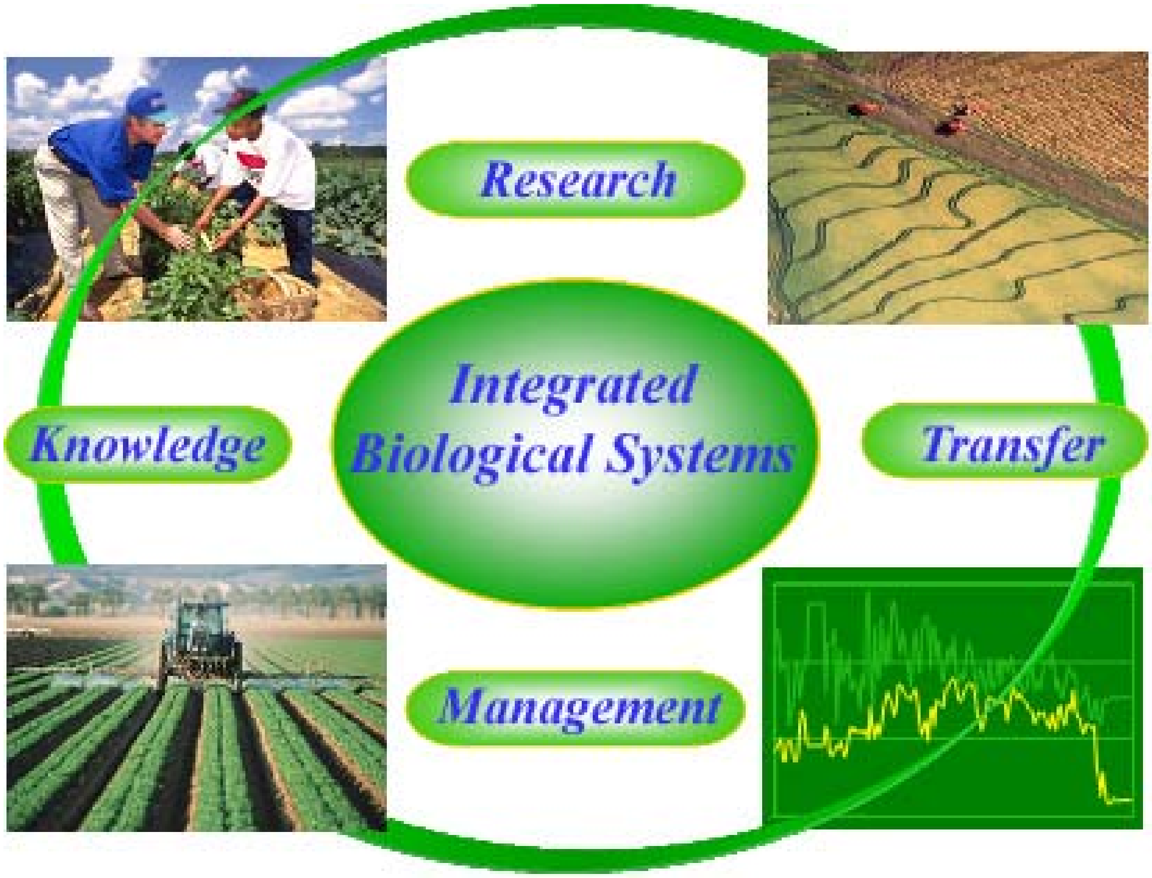
Integrated Biological Systems Conference



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Biological Systems Simulation Group (BSSG)

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Cropping Systems Research Lab (CSRL), USDA-ARS

Integrated Biological Systems Conference 2003

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Presentation Formats

- *Oral Presentations*
- *Poster Presentations*
- *Software Demonstrations*

Presentation Categories

- *Soil/Weather Data Acquisition, Synthesis, and Delivery*
- *Plant/Crop Systems: Biological Processes*
- *Plant/Crop Systems: Integration*
- *Management and Decision Support Systems*
- *Landscape and Watershed Level Systems*
- *Building and Maintaining the Bridge: From Research to Technology Transfer*
- *Synthesis and Recommendations*

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PROGRAM

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SUNDAY – APRIL 13, 2003

3:00-5:00 PM	On-Site Registration Holiday Inn Downtown/Market Square, 318 W. Durango Boulevard, San Antonio, TX 78204 (Telephone: 1-800-445-8475, Fax 210- 225-1125)

MONDAY – APRIL 14, 2003

8:00-9:30 AM	On-Site Registration Holiday Inn Downtown/Market Square, 318 W. Durango Boulevard, San Antonio, TX 78204 (Telephone: 1-800-445-8475, Fax 210- 225-1125)
10:00-10:10 AM	Welcome by **Ted Wilson**, Professor and Center Director, Texas A&M University System, Agricultural Research & Extension Center, Beaumont, TX
10:10-10:30 AM	Opening Remarks - *Developing And Delivering A Concept For Integrated Cropping Systems.* **Frank Gilstrap**, Associate Director, Texas A&M University System, Texas Agricultural Experiment Station, College Station, TX
Session I	**Program Chair: Robert Lascano** ***Soil/Weather Data Acquisition, Synthesis, and Delivery***
10:30-11:00 AM	(**Keynote Speaker**) *Soil and Weather Data Acquisition, Synthesis, and Delivery.* **Joyce Fox Strand**. Statewide IPM Program, University of California, Davis, CA
11:00-11:30 AM	*Mapping It Out: A New Approach in Collecting, Managing, and Analyzing Site-Specific Data.* **David Waits**. SST, Inc., Stillwater, OK
11:30-11:50 AM	*Historical Weather Patterns and Aeration Management in Stored Corn.* **Frank H. Arthur**[1], James E. Throne[1], and Dirk. E. Maier[2]. [1]Biological Research Unit, USDA-ARS-GMPRC, Manhattan, KS; [2]Agricultural Engineering Department, Purdue University, West Lafayette, IN
11:50-12:10 AM	*Architecture of an Internet-Based System to Provide Access to Weather Data and Crop-Weather Simulation Tools.* **Carlos J. Fernandez** and Neal T. Trolinger. Texas Agricultural Experiment Station, Texas A&M University System, Corpus Christi, TX
12:10-1:30 PM	Catered Lunch

Session II	**Program Chair: Jeff Baker** ***Plant/Crop Systems: Biological Processes***
1:30-2:00 PM	(**Keynote Speaker**) *Plant/Crop Systems: Biological Processes.* **Thomas R. Sinclair.** USDA- ARS, Agronomy Department, University of Florida, Gainesville, FL
2:00-2:30 PM	*Impacts of Drought, High Temperature and Carbon Dioxide on Rice Physiological Processes.* **J.T. Baker**[1], L.H. Allen, Jr[2]. and K.J. Boote[3]. [1]USDA-ARS, Big Spring, TX; [2]USDA-ARS, Gainesville, FL; [3]University of Florida, Gainesville, FL
2:30-2:50 PM	*Assessing the Impact of Management Practices on the Production of Pest Populations of the Mexican Rice Borer.* **F.P.F. Reay-Jones**[1], T.E. Reagan[1], and M.O. Way[2]. [1] Department of Entomology, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA; [2] Texas A&M University, Agricultural Research and Extension Center, Beaumont, TX
2:50-3:10 PM	*Optimal Sampling Design: Catching the Tail of Dispersal Kernels.* **A. Pielaat**, M.A. Lewis, S.R. Lele, and T. de-Camino-Beck. Centre for Mathematical Biology, University of Alberta, Alberta, Canada
3:10-3:25 PM	Break
Session III	**Program Chair: L.T. Wilson** ***Plant/Crop Systems: Integration***
3:25-3:55 PM	(**Keynote Speaker**) *Integrating Biological and Environmental Factors in Crop Systems Models.* **Andrew Paul Gutierrez**. Department of Environmental Science, Policy & Management, Division of Ecosystem Science, University of California, Berkeley, CA
3:55-4:25 PM	*Integrated Systems Research in the Texas High Plains: Corn, Grain Sorghum and Cotton.* **R.J. Lascano**[1], L.T. Wilson[2], T.A. Archer[3], and B.A. Onken[3]. [1]Cropping Systems Research Lab, Texas A&M University System/USDA-ARS, Lubbock, TX; [2]Texas A&M University System, Agricultural Research & Extension Center, Beaumont, TX; [3]Texas A&M University System, Agricultural Research & Extension Center, Lubbock, TX
4:25-4:45 PM	*Evaluating the CROPGRO-Soybean Model for Predicting Photosynthesis, Growth, and Yield Response to Carbon Dioxide Levels.* G. Alagarswamy[1], **K.J. Boote[1]**, J.W. Jones[2], and L.H. Allen, Jr.[3] [1] Dept. of Agronomy, Univ. of Florida, Gainesville, FL; [2] Dept. of Agric. and Biol. Engineering, Univ. of Florida, Gainesville, FL; [3] USDA-ARS, Univ. of Florida, Gainesville, FL
4:45-5:05 PM	*Comparison and Hybridization of Two Approaches for Maize Simulation.* **H.S. Yang,** K.G. Cassman, A. Dobermann, D. Walters, J. Lindquist, and T. Arkebauer**.** Department of Agronomy and Horticulture, University of Nebraska at Lincoln, Lincoln, NE

5:05-6:00 PM **Software Demonstration**

The Crop-Weather Program for South Texas: an Internet-Based System to Provide Access to Weather data and Crop-Weather Simulation Tools. **Carlos J. Fernandez** and Neal T. Trolinger. Texas Agricultural Experiment Station, The Texas A&M University System, Corpus Christi, TX

Comparison and Hybridization of Two Approaches for Maize Simulation. **H.S. Yang,** K.G. Cassman, A. Dobermann, D. Walters, J. Lindquist, and T. Arkebauer**.** Department of Agronomy and Horticulture, University of Nebraska at Lincoln, Lincoln, NE

A User Friendly Finite Element Grid Generator for 2DSPUD and Other 2DSOIL Based Models. **D.J. Timlin[1],** Geetha Reddy[1], and Yakov Pachepsky[2]. [1]USDA-ARS Alternate Crops and Systems Laboratory, Beltsville, MD; [2]USDA-ARS Animal Waste Pathogen Laboratory, Beltsville, MD

6:00 PM END OF THE DAY

TUESDAY – APRIL 15, 2003

Session I **Program Chair: Michael Bange**
Management and Decision Support Systems

8:00-8:30 AM (**Keynote Speaker**) *Building and Maintaining the Bridge: From Research to Technology Transfer*. **Michael P. Bange.** CSIRO Plant Industry, Australian Cotton Cooperative Research Center, Narrabri, Australia

8:30-9:00 AM (**Keynote Speaker**) *Decision Support Systems Based on Crop Models and Crop Sensors*. **Leo Marcelis**, R. Booij, A. Elings, and P. de Visser Cluster Cropping Systems, Plant Research International, Wageningen, The Netherlands

9:00-9:20 AM *Site-Specific Approaches For Cotton Integrated Pest Management.* **Jeffrey Willers**[1], Johnie Jenkins[1], James McKinion[1], Kenneth Hood[2], John Freeman[2], Doug Cauthen[2], and John Bassie, Sr.[2], Andy Zusmanis[3], Phillip McKibben[4], Paul Good[5], and Dale Weaver[5]. [1]USDA, ARS, Genetics and Precision Agriculture Research Unit, Mississippi State, MS; [2]Perthshire Farms, Gunnison, MS; [3]Leica Geosystems (ERDAS Support Services), Atlanta, GA; [4]McKibben Ag Services, LLC, Mathiston, MS; [5]Good's Longview Farm, Macon, MS

9:20-9:40 AM *Web-Based Yield Prediction Information Delivery System*. **Steve Maas.** Department of Plant and Soil Science, Texas Tech University, Lubbock, TX

9:40-10:00 AM *A Decision Support Tool Based on Reference Conditions and Empirical Distributions.* **David E. Legg** and Scott W. Miller. Department of Renewable Resources, University of Wyoming, Laramie, WY

10:00-10:15 AM Break

Session II **Program Chair: Jeff Willers**
Landscape and Watershed Level Systems

10:15-10:45 AM (**Keynote Speaker**) *Impacts of Environmental Change on Aphids throughout Europe.* **Richard Harrington**, et al. Division of Plant and Invertebrate Ecology, Rothamsted Research, Harpenden, UK

10:45-11:15 AM (**Keynote Speaker**) *Knowledge Engineering in a Landscape Ecological Context: An Approach to Integration*. **Robert N. Coulson**. Knowledge Engineering Laboratory, Department of Entomology, Texas A&M University, College Station, TX

11:15-11:35 AM *PL-566 Riparian Zone Water Dynamics from Hydrometric and Isotope Measurements.* **Ranjan S. Muttiah**[1], Joseph D. White[2], and Jacquelyn Duke[2]. [1]Texas A&M University System, Agricultural Experiment Station, Temple, TX; [2]Dept. Biology, Baylor University, TX

11:35-11:55 AM *The $\delta^{13}C_R$ Respiration Signature and Carbon Exchange Dynamics in Central Texas Rangelands from Tall Tower Measurement.* **Ranjan S. Muttiah**[1], Peter S. Bakwin[2], and Steve R. Potter[1]. [1] Texas A&M University System, Agricultural Experiment Station, Temple, TX; [2]NOAA/CMDL, Boulder, CO

11:55-1:30 PM Catered Lunch

Session III	**Discussion Leaders: Andy Gutierrez, Tom Sinclair, Leo Marcelis**
1:30-3:15 PM	Informal Discussion on Biological Systems Models
3:15-3:30 PM	Break
3:30-5:00 PM	**Poster Presentations**
P.1	*Enzyme Activities in Semiarid Agricultural Soils.* **V. Acosta-Martínez**[1], T.M. Zobeck[1], T.E. Gill, and A.C. Kennedy. [1]USDA-ARS, Plant Stress and Water Conservation Laboratory, Lubbock, TX
P.2	*Soil Enzyme Activities in Semiarid Systems: Conservation Reserve Program, Native Rangeland and Cropland.* **V. Acosta-Martínez1**[1], Susanne Klose, and Ted M. Zobeck. [1]USDA-ARS, Plant Stress and Water Conservation Laboratory, Lubbock, TX
P.3	*Estimating Carbon Dioxide Leakage Rates in Controlled Environment Chambers Using Nitrous Oxide.* **J.T. Baker**[1], S.H. Kim[2], D.C. Gitz[2], D.J. Timlin[2], and V.R. Reddy[2]. [1]USDA-ARS, Cropping Systems Research Lab, Big Spring, TX; [2]USDA-ARS, Alternate Crops and Systems Laboratory, Beltsville, MD
P.4	*Simulating Water Use of Irrigated Corn on the Texas High Plains.* **T.J. Gerik**, T.A. Howell, J.R. Williams, W.L. Harman, and E. M. Steglich. Blackland Research Center, Texas Agricultural Experiment Station, Texas A&M University System, Temple, TX
P.5	*Simulation of Brush Removal Within an Urban Watershed in Texas.* **W. Rosenthal[1]**, W.Dugas[1], R.Muttiah[1], S.Bednarz[2], T.Dybala[2], and C. Amonett[2]. [1]Blackland Research Center, Texas Agricultural Experiment Station, Temple, TX. [2]Natural Resource Conservation Service, Temple, TX
P.6	*A Simulation Model of Competitive Interactions among Polygyne Fire Ant Colonies for Foraging Space and Resources*. **Ronald D. Weeks[1], Jr.**, L.T. Wilson, S.B. Vinson, and M.J. Yoder. Department of Entomology, Texas A&M University, College Station, TX
P.7	*Stability of Radiation Use Efficiency of Peanuts for a Diverse Set of Sites.* **J.R. Kiniry**[1], C.E. Simpson[2], A.M. Schubert[3], and J.D. Reed[3]. [1]USDA-ARS, Temple, TX; [2]Texas A&M University System, Agricultural Research & Extension Center, Stephenville, TX; [3] Texas A&M University System, Agricultural Research & Extension Center, Lubbock, TX
P.8	*Soil Water Dynamics, Surface Energy Balance, and Canopy Microclimate in Dryland Cropping Systems: The USDA-ARS Facility in Big Spring, Texas.* **R. Scott Van Pelt**. USDA-ARS Cropping System Research Laboratory, 302 W. I-20, Big Spring, TX
6:30 PM	**Conference Dinner**

WEDNESDAY – APRIL 16, 2003

Session I	**Program Chair: Jeff Baker** ***Plant/Crop Systems: Biological Processes***
8:00-8:20 AM	*Simulation of Leaf and Canopy Photosynthesis of Maize under Elevated* CO_2 *and Various Temperatures.* **S.H. Kim**, D.C. Gitz III, R.C. Sicher, D.J. Timlin, J.T. Baker, and V.R. Reddy. Alternate Crops and Systems Lab., USDA-ARS, Beltsville, MD
8:20-8:40 AM	*Delayed Senescence and Reduced Disease Severity in Cover Crop Mulch-Cultivated Tomato Plants is Linked to Accumulation of Specific Gene Products*. **Vinod Kumar**, Douglas J. Mills, James D. Anderson and Autar K. Mattoo. USDA-ARS, Plant Sciences Institute, Beltsville, MD
8:40-9:00 AM	*Soil Physical Properties, Crop Water Availability, Canopy Temperature, and Incidence of Green Bugs and Maize Dwarf Mosaic Virus in a Heterogeneous Dryland Sorghum Field.* W. Payne, **A. Fernando**, J. Michels and C. Rush. Texas Agriculture Experiment Station, Bushland, TX
Session II	**Program Chair: Ken Boote** ***Plant/Crop Systems: Integration***
9:00-9:30 AM	*Rice Systems Research: From Cultivar Development to Integrated Systems Management.* **L.T. Wilson** and Yubin Yang. Texas A&M University System, Agricultural Research & Extension Center, Beaumont, TX
9:30-9:50 AM	*An Individual-Based Rice Cropping System Model*. **Yubin Yang** and L.T. Wilson. Texas A&M University System, Agricultural Research & Extension Center, Beaumont, TX
9:50-10:10 AM	*2DSPUD, a Two-Dimensional Model of Potato Growth and Development.* **D.J. Timlin[1],** S. H. Kim[1], Y. Pachepsky[2], V. R. Reddy[1], C. Fraisse[3], A. Alva[4], and J. T. Baker[1]. [1]USDA-ARS Alternate Crops and Systems Laboratory, Beltsville, MD; [2]USDA-ARS Animal Waste Pathogen Laboratory, Beltsville, MD; [3]Washington State Univ., Pullman, WA, [4]USDA-ARS Vegetable and Forage Crop Research Unit, Prosser, WA
10:10-10:25 AM	Break
Session III	**Discussion Leaders: Jeff Willers, Robert Lascano, Bob Coulson, Ted Wilson**
10:25-12:00 PM	Informal Discussion on Spatial and Landscape Analysis
12:00-1:30 PM	Catered Lunch

Session IV	**Program Chair: Ted Wilson** ***Synthesis and Recommendations***
1:30-1:35 PM	**Joyce Fox Strand** (*Soil/Weather Data Acquisition, Synthesis, and Delivery*)
1:35-1:40 PM	**Thomas R. Sinclair** (*Plant/Crop Systems: Biological Processes*)
1:40-1:45 PM	**Andrew Paul Gutierrez** (*Plant/Crop Systems: Integration)*
1:45-1:50 PM	**Michael Bange** (*Management and Decision Support Systems*)
1:50-1:55 PM	**Leo Marcelis** (*Management and Decision Support Systems*)
1:55-2:00 PM	**Richard Harrington** (*Landscape and Watershed Level Systems*)
2:00-2:05 PM	**Bob Coulson** (*Landscape and Watershed Level Systems*)
2:05-2:15 PM	**Ted Wilson** (*Concluding Remarks*)
Session V	**Business Meeting**
2:15-3:30 PM	**Biological Systems Simulation Group (BSSG)**
3:30 PM	END OF THE CONFERENCE

Abstracts

MONDAY – APRIL 14, 2003

10:10 AM	Opening Remarks by Frank Gilstrap	
10:30 AM	Session I	Program Chair: Robert Lascano
1:30 PM	Session II	Program Chair: Jeff Baker
3:25 PM	Session III	Program Chair: L.T. Wilson
5:05 PM	Software Demonstrations	

DEVELOPING AND DELIVERING A CONCEPT FOR INTEGRATED CROPPING SYSTEMS

Frank E. Gilstrap

Texas A&M University System
Agricultural Experiment Station, College Station, Texas, U.S.A

This paper describes a concept Texas is developing to address research and education needs in support of Texas cropping systems. The concept foundation is borrowed from Australia, and from the Agricultural Production Systems Research Unit (APSRU) of Queensland. Texas will use key elements of the APSRU creation, i.e., a practical and scientific computer-aided planning and decision-making tool that uses on-farm monitoring of soil to assess soil moisture, computer simulations to explore available management options, and discussion among farmers, advisors and researchers. The paper describes the author's perception of the APSRU concept and how it is used in Australia, draws a few key parallels between Queensland-New South Wales and Texas, and finally describes what Texas must do to implement a Texas version of the Australian concept.

SOIL AND WEATHER DATA ACQUISITION, SYNTHESIS, AND DELIVERY

Joyce Fox Strand

Statewide IPM Program, University of California, Davis, CA, USA

Today, more easily than ever, massive amounts of weather data can be collected, quality controlled, and stored for analysis and integration with related biological and environmental data, then readily delivered to various users in formats that facilitate use. Basic soil and weather data needs in both biological research and management of biological systems have been well defined, although details of time step, sensor specifications, and sensor deployment may differ for specific applications. Typically, data representing soil variables such as temperature or moisture, weather variables of temperature, humidity, wind, and radiation are required. In addition to traditional, site-specific measurements, we can have ready access to data produced through remote sensing, and statistical or physical models of the atmosphere or soil system. Significant advances in technology have increased our capabilities to produce, collect, and distribute these data to research and end users alike. Challenges remain in measurement or modeling of unusual variables, standardization of specific data needs, and agreed-upon formats for delivery and exchange.

For ambient measurements, existing public (and some commercial) monitoring networks measure most of the standard variables, are sufficiently reliable, and in many areas provide adequate coverage to meet recurring needs. The standardized monitoring within large networks; timely collection; and central quality control, archival, and distribution make them useful for model testing and validation, and often for climatic studies, advisory services to growers, or regional analyses such as crop production estimates. If decision tools have been built and packaged with these central sources in mind, data may also be useful for local agricultural and natural systems management.

However, for research (and sometimes localized decision-making), regional networks may not be adequate. They give a researcher no control over which variables are monitored, specific monitoring practices, or selection of sensors with critical characteristics. In these cases, setting up one's own stations or modeling unavailable variables may be more desirable approaches to collecting required weather or soil data.

Fortunately, there have never been so many choices in weather monitoring devices for research or implementation projects. Since the early1990s numerous manufacturers have entered the field, building data-logging devices compatible with a number of easy-to-use sensors of various designs and precision. Remote collection of data from these in-field weather stations through telemetry has largely replaced the chore of off-loading data from a logger in the field, much improving data availability.

Some researchers are approaching the data-gathering challenge by using standard public networks for conventional data, then deriving unavailable variables through statistical or physical models. In some cases, they add satellite observations as inputs into surface energy-balance models to derive in-canopy microclimate conditions, rather than monitoring at in-field locations. Retrieval of near-real-time satellite data sets has become feasible, and these may be coupled with ambient data for input into models of the plant-soil-atmosphere system. A similar technique may be used to integrate forecast model output into decision tools.

Whether measured or derived, data may be extrapolated or interpolated for use at regional or microclimate scales, using standard techniques such as those employed by geographic information systems and resulting in both point and gridded data sets available for delivery to users. Additional information about how less-standard variables change over terrain and distance would improve estimates generated by these methods.

Once the data values are available, they must be packaged into forms that can be readily used in applications. Although standardized data exchange formats have been developed to facilitate hydrometeorological data sharing, these are not in widespread use except among some U.S. federal agencies. Increased usage of these, or development of others, would significantly enhance the ability to share data and use it widely for a variety of purposes.

Regardless of the source of data, there are many ways to store large amounts in computer databases and prepare them for integration with other environmental or biological data. Where applications rely solely on locally collected values, weather station manufacturers are increasingly interested in programming biological models and decision tools into the software that accompanies stations they sell. For a centralized approach, the Internet has become indispensable to data and application delivery. Data files are e-mailed or available through FTP, and the World Wide Web can provide a simple interface to data and programs stored anywhere in the world. The Web has the capacity to give users access to research and management tools that can be coupled with online data sets appropriate for the application and customized for the user. Through the Web, databases and computerized tools can be developed and maintained centrally, eliminating difficulties with platform dependence and distribution of updates.

MAPPING IT OUT: A NEW APPROACH IN COLLECTING, MANAGING, AND ANALYZING SITE-SPECIFIC DATA

David Waits

SST, Inc., Stillwater, OK, USA

Site-specific management for agriculture depends on the collection of geo-referenced data from various sources and different devices. The knowledge gained from analysis of site-specific data helps a grower make more profitable decisions about his farming practices. With the introduction of *SST Summit* & *SST Stratus* software, agriculturalists can now effectively utilize farm management operations in addition to site-specific data, such as soil fertility, yield, and soil type data. Consider how often yield is affected by any one or more of the following farm management variables: Planting date, Tillage method, Hybrid selection, Pesticide application, etc.

Using *SST Summit* & *SST Stratus* the producer can now record farm management operations using a portable in-field computer. Farm management data can then be combined with site-specific data for a more thorough picture of variables that impact crop yield. Since the data collected are standardized, the producer has options for working with a service provider who can analyze the grower's own farm data and compare it to other farms in a regional database.

SST Stratus

SST Stratus is designed to run on Pocket PC and allows growers to record daily farm management activities, including tillage, planting, fertilizer applications, herbicide/insecticide applications, weed, insect, disease, and crop scouting, fungicide treatments, harvest information, irrigation, growth regulator, and manure applications.

Growers enter data quickly and efficiently with drop down lists. Each of the farm management operations contains a number of *attributes.* For example, the planting operation contains attributes, such as planting date, seeding rate, seed company, variety/hybrid, row depth, starter fertilizer and more. These attributes appear as pick lists to the grower. The grower simply taps the correct selection with a stylus. SST populates the pick lists with an extensive reference database. For instance, a grower can select corn as the crop, and then select the correct hybrid from a complete list of corn seed companies' hybrids. Similarly, if the grower is scouting insects in the corn crop later in the growing season, he can select from the list of insects from the associated pick list. The pick lists can be edited to display only those relevant attributes for a farm. For example, the lists can be narrowed down to display only certain seed companies, tractors, tillage implements, used by a particular farm for even faster data collection.

Several key features make SST Stratus a useful tool for agricultural producers. SST Stratus is streamlined for ease-of-use in the field because the data records are input through pick lists, which eliminates clumsy typing. Furthermore, data consistency is ensured, which is crucial on farms where more than one person is recording data, and for a farmer who will compare several years of data. In addition, the farm management records are tied to the field boundary so that the data has a spatial aspect. This allows a grower to split fields using GPS or using built-in measuring tools for recording various hybrid/variety plantings. Growers can also load aerial maps from Terraserver, DOQs, soil test maps, soil type maps, and yield maps as background images behind field boundaries. This feature gives a grower the ability to scout fields more effectively. Scouting features are being added to *SST Stratus* that will enable growers, consultants, or researchers to map areas inside the field boundaries to note infestations of weeds or insects by using interior polygons, points or lines.

SST Summit

SST Summit is the desktop companion software that provides the means to import field boundary files from other sources to create the Client, Farm, Field structure. If a grower does not have a source for his field boundaries, he can connect to the Internet and then through *SST Summit*, he can easily download aerial images of his fields using Terraserver, and digitize the boundaries on-screen. Then, once data have been collected in *SST Stratus*, the grower syncs his handheld computer to his desktop computer back in the office and transfers the data into *SST Summit* for reporting. Reports can be customized with a farm name and logo, with user-selected color settings and map sizes. In just a few steps a grower can make reports for a single field or multiple fields, as well as a single operation or multiple operations.

SST's Reference Database

The reference database within *SST Stratus* is extensive and essential to the adoption and success of information management in agriculture. SST constantly updates this database and encourages its users to request additions to the database via a user-friendly Internet request form. An update button in *SST Summit* downloads the latest reference database to *SST Stratus* on the Pocket PC.

Data consistency is key for a farm where multiple people are recording field operations. In addition, the technology exists and is being used throughout the United States, in South Africa, Australia, and Europe where these data can be combined in a regional pool so that a grower's data can be compared with other growers' data in a user-defined area (identities protected) utilizing similar practices. For example, a grower can derive valuable regional information on how yield performance by hybrid/variety relates with factors such as soil type or fertility ranges.

HISTORICAL WEATHER PATTERNS AND AERATION MANAGEMENT IN STORED CORN

Frank H. Arthur[1], James E. Throne[1], Dirk. E. Maier[2]

[1]*Biological Research Unit, USDA-ARS-GMPRC, Manhattan, KS, USA*
[2]*Agricultural Engineering Department, Purdue University, West Lafayette, IN, USA*

The purpose of low-volume aeration with ambient air is to modify and alter the temperature of bulk grain mass to levels that reduce or prevent insect growth and development, and should not be confused with drying grain to proper levels for storage. Aeration recommendations in the United States (USA) are given as CFM (cubic feet per minute)/bushel (bu), and airflow rates for stored wheat are generally 0.1 to 0.3 CFM/bu (0.0013$m^3/s/m^3$). In contrast, airflow rates used for moisture control usually exceed

1.5 CFM/bu and can also involve heated air to facilitate drying. Aeration often is not fully utilized for stored commodities, particularly in the warmer regions of the United States. Most stored-grain insects cease development at about 15.6 to 18.3 C° (60 to 65° F), but many older aeration recommendations were based on temperatures lower this developmental threshold. In addition, there was usually little attempt to control the aeration process to produce cooling cycles for discrete time intervals.

Historical weather data were used to estimate hours below 15.6°C in September and October and classify the southern USA into 5 climatic regions. Specific sites within those regions were then used to predict temperatures in unaerated and aerated corn, using an engineering bin-cooling model. Data from the engineering model were in turn used in an entomological model to predict population development of *Sitophilus zeamais*, the maize weevil, a major internal insect pest of stored corn.

The best combination for aeration in the southern USA would be15.6°C at an airflow rate of 0.0013$m^3/s/m^3$. Depending on the climatic zone, predicted temperatures in aerated corn were predicted to drop to 15.6°C within 6 weeks, compared with 2 to 4 months in unaerated corn. This would in turn impact development of maize weevil, particularly during the autumn months, and predicted population levels were several orders of magnitude lower in aerated corn than in unaerated corn. A similar study was done for corn stored in the northern USA, and while aeration also reduced predicted *S. zeamais* populations, results were not as dramatic as in the southern USA because of the cooler temperatures and later harvest times.

These concepts and simulations using historical weather data have been expanded for hard red winter wheat in the USA and for rice stored in Japan. Currently they are being used to develop new aeration management programs for peanuts stored in Georgia, Alabama, and North Florida, and for rice stored in the south-central USA.

ARCHITECTURE OF AN INTERNET-BASED SYSTEM TO PROVIDE ACCESS TO WEATHER DATA AND CROP-WEATHER SIMULATION TOOLS

Carlos J. Fernandez and Neal T. Trolinger

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The Crop Weather Program for South Texas (CWP) has been developed for the Internet using state-of-the-art dynamic HTML technology. **CWP** was first launched in March 2000. **CWP** is an Internet-based suite of applications designed to help cotton crop managers by providing them with easy access to weather data and easy-to-use yet powerful crop/weather calculation tools through the web site http://cwp.tamu.edu/. These easy-to-use tools allow crop managers to monitor weather and crop growth and development, crop water use, and soil water storage at particular field management units so that they can make more informed crop management decisions. Two interacting dedicated servers share hosting of this web site with access to high speed Internet connection. Weather data from 23 weather stations dispersed in 11 Texas coastal counties are retrieved hourly using a central computer located at TAMUAREC-Corpus Christi. The newly acquired data is then uploaded to http://cwp.tamu.edu/ where a computer program automatically inspects the new data for integrity and appends the approved new data to databases. This web site provides easy and speedy access to weather databases (hourly data, including "today's up-to-theHour" data, and daily data) for each individual weather station in the network. **CWP** also allows users to register and create their own password-protected web site (**MyCWP**) within http://cwp.tamu.edu/ through which they access a suite of crop-weather simulation tools that can be used to estimate a wide range of useful crop, soil, and weather-related state variables. Registered users then can use these calculation outputs as valuable information for making crop or farm management decisions.

PLANT/CROP SYSTEMS: BIOLOGICAL PROCESSES

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Plant/crop systems are extremely complex and it is not possible to incorporate into a model the full reality of all the physiological details of growth and development. This is especially true considering the myriad of variables in the abiotic and biotic environment that influence plant performance. Rather than attempt the impossible objective of reproducing reality in a computer, a more realistic goal is to capture the essence of crop behavior relative to specific objectives in such a way as to produce a robust, heuristic tool.

Since the range of objectives for models is immense, it is necessary to define precise objectives so that only essential processes and approaches are included in the construction of each plant/crop model. From this perspective, therefore, it is inappropriate to attempt the development of universal plant/crop models for use across a wide range of objectives, in spite of efforts by some to apply a limited family of models to nearly all plant/crop issues.

Common elements for all models are that they should be transparent and offer explanation when applied to specific problems. To serve a heuristic role, models must be accessible to the user so that the components and their interactions are readily identifiable and understandable. A complex model with a number of interactions may fail to provide a tool for truly learning about the factors and processes that influence performance of the plant/crop system. Transparency by itself, however, is not sufficient since the model must provide insight about the behavior of the real-world system. While it is not necessary to reproduce exactly what has been observed, it is essential that the model offer insights about response trends in real-world systems.

In many cases, transparency and explanation are greatly enhanced by using descriptions in models at the simplest level possible. This is reminiscent of famous quotation from Einstein, "Things should be made as simple as possible, but not any simpler." Fortunately, in plant science detailed studies of the interaction between the environment and physiological response have lead to simplified and/or summary expressions that for many objectives allow considerable complexity to be avoided in models. Three such examples are (1) radiation use efficiency to describe the net accumulation of carbon dioxide and mass by crops, (2) water use efficiency to describe canopy transpiration rate as a function of mass accumulation, and (3) seed growth rate described as a function of a linear increase in harvest index during seed fill.

IMPACTS OF DROUGHT, HIGH TEMPERATURE AND CARBON DIOXIDE ON RICE PHYSIOLOGICAL PROCESSES

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Field crops under drought often experience two quite different but related and simultaneous stresses: soil water deficit and high temperature stresses. Separating the effects of these two different stresses and then studying their interaction is difficult in field experiments. In this paper we examine the effects of these two stresses separately as well as the interactions of these two stresses with elevated atmospheric carbon dioxide concentrations for rice experiments conducted in naturally sunlit, controlled environment chambers by the University of Florida and USDA-ARS at Gainesville, FL, USA. For rice, we found that soil water deficit, high temperature stresses and elevated atmospheric carbon dioxide concentration affected specific physiological processes quite differently. Both vegetative biomass accumulation and canopy photosynthesis had broad temperature optimums while canopy evapotranspiration increased exponentially with increasing air temperature treatment. Grain yield had a clear temperature optimum near 26ºC and declined by about 10% per 1ºC increase above this optimum. Soil water deficit accelerated leaf senescence, reduced leaf area and aboveground biomass and delayed crop ontogeny. Severe water deficit resulted in the complete photosynthetic collapse of rice canopies. Both soil water deficit and high temperature stress more severely affected reproductive than vegetative growth. Elevated CO_2 increased rice growth, grain yield and canopy photosynthesis while reducing evapotranspiration by about 10%. During drought stress cycles, this water savings under elevated CO_2 allowed photosynthesis to continue for one to two days longer compared with the ambient CO_2 treatment so increased drought avoidance. Elevated atmospheric CO_2 concentration ameliorated, to various degrees, the negative impacts of soil water deficit and high temperature stresses on specific crop physiological processes.

ASSESSING THE IMPACT OF MANAGEMENT PRACTICES ON THE PRODUCTION OF PEST POPULATIONS OF THE MEXICAN RICE BORER

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The Mexican rice borer, *Eoreuma loftini* Dyar, is the major insect pest of sugarcane in the Lower Rio Grande Valley of Texas. It also causes substantial damage to rice in the Texas Rice Belt. Introduced from Mexico in 1981, the insect has spread through Texas north and east for the past 20 years. *E. loftini* now represents a potential threat to sugarcane in Louisiana and is an increasing threat to rice production in Southeastern Texas and Southwestern Louisiana. Pheromone trap monitoring and sampling were initiated in 2000 in the Texas Rice Belt, around new sugarcane production in eastern Texas, and in western Louisiana. At least one county has been newly infested over each of the last three years, and the insect is now within 50-75 miles of the western Louisiana border. Currently, the sugarcane-growing area in Southeastern Texas is approximately 400 hectares, initiating a new agricultural industry for Southeast Texas. Some of this sugarcane is being transported into the central Louisiana sugarcane production area for mill processing (during 2000-02), and if infested could rapidly introduce *E. loftini* into Louisiana.

Our proactive research on pest management includes the evaluation of Louisiana and Texas sugarcane and rice cultivars for resistance to *E. loftini*. A 2-yr study to evaluate resistance of sugarcane cultivars to *E. loftini* was conducted in two locations in Texas, chosen for having different infestation pressures. Criteria for resistance assessment included percent bored internodes as well as using adult emergence holes, which were used to quantify production and determine the relative impact of each cultivar on the potential areawide buildup (or reduction) of *E. loftini* populations. One of the newer high yielding cultivars, HoCP 85-845, appeared to lose a portion of its resistance under heavy *E. loftini* infestation pressure, indicating its value only in moderate to low infestation conditions. Cultivar CP 70-321 was the most resistant in both locations. Results from both locations indicated that cultivars HoCP 91-555 and LCP 85-384 were significantly the most susceptible cultivars when considering both criteria, even more so than NCo 310, traditionally the most susceptible cultivar produced in Texas. In 2001, LCP 85-384, which now represents 80 percent of the production acreage in Louisiana, had the greatest moth production per hectare (17052) under the lower infestation pressure, significantly higher than NCo 310 (4926).

Surveys in Texas have shown increased *E. loftini* damage on stressed sugarcane. The sugarcane in a cultivar experiment at Ganado showed signs of stress across an entire replication of the randomized block design. Soil samples at a depth of 15-30cm showed high levels of sodium and magnesium in this replication compared to all others. *E. loftini* damage to sugarcane in this replication compared to the others was the most severe. However, this replication effect did not appear in two cultivars, HoCP 91-555 and CP 70-321. Our interpretation of these results is that salt stress was associated with greater damage and higher infestations. The most common stress-inducing factor on sugarcane in Texas appears to be drought, causing a major enhancement of *E. loftini* populations. Sugarcane growers in the LRGV of Texas are able to irrigate their crop when enough water is available, thus reducing damage due to this pest. In Louisiana, a less arid climate precludes the common use of irrigation. Therefore, damage in Louisiana is likely to be less drastic due to the different moisture availability. However, droughts in recent years have created ideal conditions for enhancing *E. loftini* populations. Cultivar resistance is anticipated to serve a major role in keeping infestations below economic thresholds, as well as decreasing populations on an areawide basis.

The rice study indicated significant differences in damage among cultivars, with higher percentages of whiteheads found in the rice cultivars Priscilla and Cocodrie than in Madison, Jefferson, TX5012, and Wells in 2001. The fewest number of whiteheads was found in Madison, which also produced the highest yield. The 2002 rice cultivar study also involves yield differences in insecticide treated versus untreated comparisons. The variety Priscilla again was one of the most susceptible cultivars having significantly greater yield loss than any other. The XL8 cultivar was among the most resistant. In rice, it may be necessary to count whiteheads to estimate moth production. For each rice cultivar, applications of lambda-cyhalothrin at 14, 32 and 45 days after flood were efficient in reducing yield loss. Both in sugarcane and rice, it is our assessment that plant resistance offers the greatest potential for future management.

OPTIMAL SAMPLING DESIGN:
CATCHING THE TAIL OF DISPERSAL KERNELS

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Rapid spread of vegetation is caused by huge numbers of seeds being dispersed over long distances from the parent plant. The spread rate is used as a measure of invasiveness and can be calculated using information on the dispersal kernel (Kot, et al. 1996). The dispersal kernel is the probability density function describing the relative frequencies of distances the seeds disperse. This calculation only needs two inputs:

R_0: Basic reproductive number
K: Dispersal kernel

Accurate field measurements are a prerequisite to obtain a realistic dispersal kernel for the calculation, and an 'optimal' sampling design is the basis to achieve this goal. Up till now most algorithms for optimal sampling designs are based on minimizing the variance of the estimator with respect to the true surface area under the dispersal kernel (Assunção and Jacobi, 1996). Since this method results in putting most sample effort at short distances from the source, this technique is not applicable to catch the tail of dispersal kernels. Therefore, a different approach to accurately measure long distance seed dispersal using invasiveness of plants will be presented. The design is based on the invasion speed (*c*) of species (Lewis et al., *in preparation*), i.e.

$$c = \min_{s>0}\{\frac{1}{s}\ln(R_0 K(s))\},$$

where *s* is the slope of the traveling wave and K(s) is the empirical moment generating function for the dispersal kernel. This equation shows that in order to calculate an invasion speed, initial information on the distribution of seeds in the field is needed. Recently, Bullock and Clarke (2000) fitted field data of *Calluna vulgaris* to an empirical model. This model is used to calculate an initial 'true' wave speed. Subsequently, the procedure is based on the placement of a limited number of seed traps in the field surrounding a source of plants. This is done in such a way that the Mean Squared Error of the then estimated wave speed is minimized with respect to the 'true' wave speed.

The algorithm, resulting in an 'optimal' configuration of seed traps surrounding a source of plants will be presented. Several extensions of the algorithm will show how the seed trap configuration changes when biologically relevant information is added to the procedure, i.e. when realistic wind characteristics from field measurements are implemented and a line source of plants instead of a point source is used.

References

Assunção, R. and C.M. Jacobi 1996. Optimal sampling design for studies of gene flow from a point source using marker genes or marked individuals. Evolution 50: 918-923.

Bullock, J.M. and R.T. Clarke 2000. Long distance seed dispersal by wind: measuring and modeling the tail of the curve. Oecologia 124: 506-521.

Kot, M., M.A. Lewis, and P. van den Driessche 1996. Dispersal data and the spread of invading organisms. Ecology 77: 2027-2042.

Lewis, M.A., H. Caswell, J. Clark, and M. Neubert (*in preparation*). A guide to calculating invasion rates from data for discrete-time models.

INTEGRATING BIOLOGICAL AND ENVIRONMENTAL FACTORS IN CROP SYSTEMS MODELS

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Population regulation in tritrophic systems result from top-down control by consumers and bottom-up control by limiting resources, and of course these interactions are greatly influenced by weather. Plant growth and development may be limited by the availability of light, soil nutrients and water and the action of herbivores from a wide variety of taxa as well as weather. Herbivores are limited bottom-up by the availability of plant resources that may have age and physiological attributes and of course natural enemies from above. Similarly, all higher trophic levels have bottom up limiting factors and all except the top predator have top down regulation. *The problem has been - How to integrate these trophic level interactions as modified by abiotic factors and how much information is required to develop useful field models is rapidly.* The solution is becoming apparent with the question of how much detail to include in a model depending on the questions to be addressed.

The most useful models are tritrophic, include the plant as the base level, are physiologically based, and are driven by weather and edaphic factors. Such models are based on modeling processes and only secondarily from parameter estimates derived from field data. The basic premise of this approach is that all organisms face the same problems of resource (energy) acquisition and allocation, and that the allocation priority: first to respiration, then to reproduction and, if assimilate remains, to growth. The same models are used across trophic levels with only the units and interpretation of flow rates differing among species. The same acquisition (i.e., functional response) and maintenance costs (i.e., Q_{10}) are used with the net of the two being the amount of resources available for allocation. Each organism is assumed to try to satisfy a physiologically based demand for resources, but the search process is imperfect hence the supply of resource obtained is always be less than the maximal demand. In the model, the rates of growth, reproduction and survival are reduced from the maximum by the ratio of supply to demand. In this paradigm, biotic and abiotic factors affect either the supply (production) or the demand (sinks, e.g. fruits) side of the supply/demand ratio, but in some cases, both sides may be affected. This supply-demand paradigm simplifies model development and allows assessment of impact on the plant and compensation by the plant in the face of herbivore damage. These analogies allow the same model to describe the dynamics of all interacting species in a food web.

The biology of a species may be embedded in a distributed maturation time dynamics model (Vansickle 1977) wherein cohorts of individuals born at the same time have a characteristic mean developmental time and variance (e.g., time invariant distributed maturation time). Assume we are modeling the number (N_n) or mass of the n^{th} of ns functional populations that comprise a tritrophic system, then the dynamics of the i^{th} age class ($N_{n,i}(t)$) ($i = 1,\ldots,k_n$) may be modeled using eqn. [1] (functional population subscript n ignored).

$$\frac{dN_i(t)}{dt} = r_{i-1}(t) - r_i(t) - \mu_i(t)N_i(t) \qquad [1]$$

The net gain or loss as a rate to the i^{th} age class (N_i) may be due to aging into ($r_{i-1}(t)$) or out ($r_i(t)$) of the age class, or due to mortality, growth and net immigration that are all components of $-\infty < \mu_i(t)N_i(t) < +\infty$. Time-varying age-specific mortality may occur in any age class. The birth and death rates of all functional populations are affected by the interplay of the appropriate supply-demand ratios and other factors (see below). Developmental time is a function of temperature but it may be influenced by nutrition, toxins (e.g., Bt toxins) and other time varying factors that also influence the mean and variance of size, fecundity and other factors. In such cases a time varying distributed maturation time model is more appropriate. Other complications of a species' biology may be easily imbedded in such models. The models are modular and lend themselves to object oriented programming approaches and inclusion or exclusion in the system using simple Boolean variables. Developing the models from first principles gives them the property that they are independent of time and place, and by driving them with weather and integrating them in a geographic information systems (GIS) allows the population dynamics of a species to be projected as a regional time series.

Physiologically based tritrophic models have been developed for many agricultural crops worldwide (e.g., alfalfa, cassava, coffee, conventional and Bt cotton, olive/olive fly, grape, rice/fish systems and others).

INTEGRATED SYSTEMS RESEARCH IN THE TEXAS HIGH PLAINS: CORN, GRAIN SORGHUM AND COTTON.

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In 1996 the Texas Legislature funded a Precision Agriculture (PA) initiative in the Texas High Plains (THP). Precision agriculture, also known as site-specific management, refers to the practice of applying agronomic and pest management inputs, mainly fertilizers and other chemicals, across a farm at variables rates based on soil nutrients or chemical tests, soil textural changes, weed and pest pressures, and/or yield maps, for each field in the farm. An advantage of PA is that it provides an umbrella whereby multidisciplinary and systems research can be executed. Initially, PA research was dominated by engineers mainly working on hardware development and by soil scientists working on variable rate application of fertilizers. In PA, a research area that has received inadequate attention is integrated systems, which was the objective of our work. We recognized that crop yield variability across the landscape is caused by the interaction of many biotic and abiotic factors. Our approach was to first understand crop yield variability and develop management tools and to then transfer this technology by working on farmers field. To address these objective we assembled a team of agronomists, entomologists, soil scientists, economists, engineers, and plant breeders and physiologists. The objective of this presentation is to give a summary of our experimental work and a synthesis of results obtained.

The THP is characterized by a semiarid climate with approximately 475 mm of rain and a variety of soil types. The northern region is predominantly a grain-based system with winter wheat, corn and grain sorghum as the main crops; whereas, in the southern region cotton is the principal crop. Our PA cotton research was conducted at Lamesa, TX and our PA summer grain research was conducted at Halfway, TX. Both research sites have pivot irrigation system and represent typical production fields for this region. Our experimental approach was to first do a detailed soil sampling (20 – 30 m grid) of each location. Soil samples were collected as a function of depth (0.0 – 1.5 m) and analyzed for soil NO_3-N, P, texture, pH, organic matter and other chemicals. In addition, a detailed soil topographic survey was done for each site. All data collected was geo-referenced and incorporated into a GIS database. At the cotton site, the experimental procedure was to delineate two 800 m transects 64 m apart across the field where the landscape was the source of variability and each transect was irrigated with a different quantity of water (Li et al., 2001; 2002). On each transect, every 20 m, we collected information on soil-water use, plant phenology, plant reflectance, and soil NO_3-N during the growing season. The experimental procedure used for the summer grains was two irrigation levels, using both a drought tolerant and susceptible cultivar, and to study the combined effects of soil properties and arthropods and diseases on grain yield (Machado et al., 2000; 2002a, b).

Our results indicated that the use of classical statistics, such as regression analysis and analysis of variance, failed to completely explain the cause and effect between crop yield and measured soil and plant variables. Instead, there are other more appropriate statistical tools to relate the variability of soil and plant parameters measured in space and time. For example, the spatial structure between variables can be determined using autocorrelation and cross-correlation functions. The spatial association between several variables can be described using state-space analysis, which is a multivariate autoregressive technique. Another technique is to identify crop yield values that are related to each other in space using a hierarchical clustering approach. Regardless of the method used, our results indicated that in PA a practical approach is to define crop management zones (CMZ) that are derived from spatial analysis of the data influencing crop yield. These zones involve differentially managing the within-field variability of the crop-growing environment according to soil and other environmental attributes, and crop requirements. For example, in the cotton site our state-space analysis revealed that three variables described lint yield variability across the landscape: water applied and soil nitrogen available to the crop, and elevation (topography). The first two variables can be managed and elevation is a surrogate variable that describes the soil hydrology, i.e., soil-water holding capacity in the root zone, for each site. In the summer grain site, the CMZ's defined using cluster analysis revealed identical results as those obtained for cotton. However, the effects of arthropods, diseases and crop stress due to drought and N were less clearly defined and as a result less predictable. For example, spider mite and common smut damage occurred under hot and dry conditions, and spider mite infestations were high in areas with high soil NO_3-N. However, a cooler year with higher humidity favored the incidences of southwestern corn borer and common rust. Our general conclusion is that integrated systems research at the landscape level provides knowledge to explain yield variability and that management of PA is improved when the effects of biotic and abiotic factors are considered.

References

Li, Hong, R.J. Lascano, Jill Booker, L.T. Wilson, and K.F. Bronson. 2001. Cotton lint yield variability in a heterogeneous soil at a landscape level. Soil & Tillage Research 58:245-258.

Li, Hong, R.J. Lascano, Jill Booker, L.T. Wilson, K.F. Bronson, and E. Segarra. 2002. State-space description of field heterogeneity: water and nitrogen use. Soil Sci. Soc. Am. J. 66:585-595.

Machado, S., E.D. Bynum, T.L. Archer, R.J. Lascano, L.T. Wilson, J. Bordovsky, and E. Segarra. 2000. Spatial and temporal variability of corn grain yield: Site-specific relationships of biotic and abiotic factors. Precision Agriculture 2:343-360.

Machado, S. E.D. Bynum, T.L. Archer, R.J. Lascano, L.T. Wilson, J. Bordovsky, E. Segarra, K. Bronson, D.M. Nesmith, and W. Xu. 2002a. Spatial and temporal variability of corn growth and grain yield: implications for site-specific farming. Crop Sci. 42:1564-1576.

Machado, S., E.D. Bynum, T.L. Archer, J. Bordovsky, D.T. Rosenow, G. Peterson, K. Bronson, D.M. Nesmith, R.J. Lascano, L.T. Wilson, and E. Segarra. 2002b. Spatial and temporal variability of sorghum grain yield: Influence of soil, water, pests and diseases influences. Precision Agriculture 3: 389-406.

EVALUATING THE CROPGRO-SOYBEAN MODEL FOR PREDICTING PHOTOSYNTHESIS, GROWTH, AND YIELD RESPONSE TO CARBON DIOXIDE LEVELS

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The objective of this research was to comprehensively test the CROPGRO-Soybean model for ability to predict processes of leaf and canopy photosynthesis as well as growth and final yield, as affected by carbon dioxide concentration ([CO_2]). The CROPGRO-Soybean model has hourly leaf-level photosynthesis, based on an adaptation of rubisco kinetics of Farquhar and von Caemmerer, and incorporated into the hedge-row light-interception canopy assimilation module developed by Boote and Pickering. However, the CROPGRO-Soybean model has not been adequately tested against leaf and canopy assimilation measurements and plant growth data for soybean grown under different [CO_2] treatments in controlled-environment chambers and phytotrons. To accomplish this objective, we retrieved data from a 1984 experiment where instantaneous canopy assimilation light response curves were measured on soybean grown at different [CO_2] of 160, 220, 280, 330, 660, 800, and 990 ppm. Data on leaf and canopy assimilation responses to [CO_2] and in response to range of irradiances (diurnal time courses) were retrieved from a 1983 study of soybean grown at two levels of [CO_2], 330 and 660 ppm. These and other experiments were conducted in sunlit, controlled-environment chambers located at the University of Florida, Gainesville. In some cases, season-long canopy carbon exchange, dark respiration, and transpiration measurements were available as well as in-season growth, final seed yield, total biomass, and maximum leaf area index. Model simulations were conducted with CROPGRO-Soybean (V4.0) with no changes to model code, species files, or cultivar attributes. Bragg soybean reproductive phenology was simulated within 2-4 days of observed, with no model modifications, so we left everything unchanged.

Model-simulated light response curves for canopy assimilation were compared to observed data, for Bragg soybean grown and measured at six [CO_2] levels: 160, 220, 280, 330, 660, 800, and 990 ppm. For these simulations at 34 days after sowing, we input the hourly irradiance, [CO_2] level, temperature, observed LAI and observed specific leaf area. The simulated canopy photosynthesis gave reasonably good fits to the observed light response curves, with a tendency to under-predict assimilation for 330, 660, and 990 [CO_2] levels. Uncertainties or default assumptions that may have contributed to these differences include: 1) insufficient bordering, known to occur in controlled-environment chambers, 2) insufficient fraction diffuse (the entered irradiance had been reduced to 88% of values external to the chamber walls, but fraction diffuse had not been accordingly increased, yet we know increased fraction diffuse will increase rate), and 3) default use of LFMAX of 1.00 mg CO_2 m^{-2} s^{-1} for light-saturated leaf rate at ambient [CO_2] and questions concerning the specific leaf weight at which light-saturated rate is defined. We will also present comparisons of model-simulated canopy and leaf assimilation against data from other experiments.

The CROPGRO-Soybean model was compared for ability to predict seed yield, final biomass, seed harvest index, and maximum leaf area index for Bragg soybean grown and measured at six [CO_2] levels: 160, 220, 280, 330, 660, 800, and 990 ppm. For the simulations, we input the daily irradiance, [CO_2] level, temperature, sowing date, and the time period for daylength extension. The daily irradiance was reduced to 88% of external daily irradiance to account for attenuation by chamber walls. The fraction diffuse was automatically increased by the weather routines of the model. The model under-predicted the final seed yield, final biomass, and maximum leaf area index, but it correctly predicted the shape of the CO_2 response. Model under-predictions (or excessively high chamber-measured values) could be partially attributed to insufficient bordering in the sunlit, controlled-environment chambers, particularly for the higher [CO_2] treatments which were taller with higher LAI. For example, model-simulated yields were 561, 1028, 1301, 1473, 2065, and 2272 kg ha^{-1} for the 160, 220, 280, 330, 660, 800, and 990 ppm treatments, respectively. These yields are relatively low, but this was anticipated, considering the short life cycle (94 days) and low irradiance associated with September 14 sowing. The observed yields were 1154, 1588, 1850, 2972, 3570, and 2746 kg ha^{-1}, respectively. The 990 ppm treatment yield was reduced by late-season spider-mite damage. Biomass and maximum LAI were under-estimated in a similar manner. We will discuss influence of aspects such as bordering, correct diffuse light, and model inputs for single leaf rate upon land-area-dependent traits such as biomass and seed yield. The seed harvest index (HI) was predicted well (model predictions were only 0.04 units low) and predictions showed the same decline in HI with increasing [CO_2] as the experimental data showed (0.61 to 0.54 as [CO_2] increased from 160 to 990 ppm). Model simulations confirm that declining HI, reported frequently with increased [CO_2], is merely a mathematical artefact of increased vegetative mass produced prior to grain filling.

These model evaluations against observed data are the beginning of a major effort to benchmark or test the CROPGRO-soybean model for correct responses to [CO_2], temperature, water deficit, and other ecosystem factors. Our objective is to determine whether there is a need to improve the CROPGRO-Soybean model ability to predict ecosystem response to future climate change factors. So far, we have tested against canopy assimilation, single leaf assimilation, seed yield, final biomass, and seed HI in several sunlit, controlled-environment chamber studies. We are generally pleased with results of evaluations so far. We will continue this work with additional data from our work, and invite collaboration with interested persons who have published data that may be of value for such tests.

COMPARISON AND HYBRIDIZATION OF TWO APPROACHES FOR MAIZE SIMULATION

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Two approaches dominate simulation modeling of maize growth: (1) a generic approach, represented by the family of crop models developed by Dutch scientists at the Wageningen University, e.g. SUCROS (Spitters et al, 1989), WOFOST (Diepen at al, 1989) and INTERCOM (Kropff and van Laar, 1993), and (2) a maize-specific approach, represented by CERES-Maize (Jones and Kiniry, 1986) and its derivatives such as the maize module in DSSAT, and the MSB model developed by Muchow et al. (Muchow et al, 1990). These two approaches differ in three aspects. First, maize development in generic models is driven primarily by availability of assimilate from photosynthesis, while temperature is the primary driving force in the maize-specific models. Second, growth respiration and maintenance respiration are explicitly accounted for in the generic models to determine net dry matter production, while the maize-specific approach derives net dry matter production directly from intercepted solar radiation by means of a fixed value of radiation use efficiency (RUE) that implicitly accounts for respiration costs. Third, the generic approach requires phenology specification of growing degree days (GDD) to anthesis and does not consider hybrid differences in traits such as sensitivity to daytime length, potential number of kernels and potential grain filling rate, while the maize-specific approach requires specification or estimation of several phonological events and hybrid-specific parameters.

A generic model (INTERCOM) and a maize-specific model (CERES-Maize, standard version) were evaluated with regard to their requirements for input parameters and their accuracy in predicting maize dry matter accumulation, leaf area expansion, and final grain and stover yields. Detailed field measurements from a 3-year study in which maize was grown with minimal possible stress were used for validation. Results suggest that CERES-Maize, in which temperature determines the potential leaf and stem growth, performed better than INTERCOM in which availability of assimilate is the primary driving force. In contrast, the separate routines for photosynthesis and respiration in INTERCOM provided greater sensitivity for crop response to temperature than CERES-Maize, which mostly relies on a fixed value of RUE for determining dry matter accumulation. Whereas INTERCOM requires specification of (GDD) to anthesis as an input parameter, CERES-Maize predicts anthesis from the GDD interval from emergence to end of the juvenile phase, and this 'juvenile-phase' parameter is not readily available for most hybrids.

Both models consistently underestimated maize yields under near-optimal growth conditions: grain yield was underestimated by 6% (±3%) and stover yield by 20% (±3%). Such underprediction would result in reduced estimates of C sequestration, especially in high-yield environments where the potential for C sequestration may be large. They would also underpredict nutrient requirements for fertilizer recommendations based on yield potential.

A new maize simulation model, Hybrid-Maize, was developed by combining the strengths of the two modeling approaches and modification of several other growth functions. It features temperature-driven maize phenological development, vertical canopy integration of photosynthesis, organ-specific growth respiration, and temperature-sensitive maintenance respiration. It also requires fewer hybrid-specific parameters without sacrificing the prediction accuracy. For example, the close linear relationship between GDD to anthesis and GDD to maturity was used to improve prediction of anthesis because information about GDD to maturity is available for most commercial hybrids. Hybrid-Maize simulated maize dry matter accumulation, final grain and stover yields more accurately and more consistently than INTERCOM and CERES-Maize in the high-yielding environments in which they were evaluated. In addition, the program has a Windows-based user interface, and comprehensive graphic presentation of simulation results, climate data, and cross-year comparisons for time-series simulations. Efforts are currently in progress to develop and validate water and nitrogen balance components so that maize can be simulated in suboptimal environments with these limitations.

References

Diepen, C.A., J. van Wolf, H. van Keulen, and C. Rappoldt. 1989. WOFOST: a simulation model of crop production. Soil Use and Management. 5, 16-24.

Jones, C.A. and J.R. Kiniry. 1986. CERES-Maize. A Simulation Model of Maize Growth and Development. Texas A&M University Press, College Station.

M.J. Kropff and H.H. van Laar. 1993. Modeling Crop-Weed Interactions. CAB International, UK.

Muchow, R.C., T.R. Sinclair, and J.M. Bennett. 1990. Temperature and solar radiation effects on potential maize yield across locations. Agronomy Journal, 82, 338-343.

Spitter, C.J.T., H. van Keulen, and D.W.G. van Kraalingen. 1989. A simple and universal crop growth simulator: SUCROS87. In: Simulation and Systems Management in Crop Protection. Eds: R. Rabbinge; S.A. Ward and H.H. van Laar. Simulation Monographs 32. Pudoc, Wageningen, pp. 147-181.

Software Demonstrations

THE CROP-WEATHER PROGRAM FOR SOUTH TEXAS: AN INTERNET-BASED SYSTEM TO PROVIDE ACCESS TO WEATHER DATA AND CROP-WEATHER SIMULATION TOOLS

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The Crop Weather Program for South Texas (CWP) is an Internet-based suite of applications designed to help cotton crop managers by providing them with tools for easy access to weather data and easy-to-use yet powerful crop/weather calculators through the web site http://cwp.tamu.edu/. This hand-on, on-line presentation demonstrates the easy-of-use of this program and provides application examples including the creation and management of field profiles that registered users need to run its various simulation tools and sample runs with tools that are currently available.

Software Demonstrations

COMPARISON AND HYBRIDIZATION OF TWO APPROACHES FOR MAIZE SIMULATION

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Two approaches dominate simulation modeling of maize growth: (1) a generic approach, represented by the family of crop models developed by Dutch scientists at the Wageningen University, e.g. SUCROS (Spitters et al, 1989), WOFOST (Diepen at al, 1989) and INTERCOM (Kropff and van Laar, 1993), and (2) a maize-specific approach, represented by CERES-Maize (Jones and Kiniry, 1986) and its derivatives such as the maize module in DSSAT, and the MSB model developed by Muchow et al. (Muchow et al, 1990). These two approaches differ in three aspects. First, maize development in generic models is driven primarily by availability of assimilate from photosynthesis, while temperature is the primary driving force in the maize-specific models. Second, growth respiration and maintenance respiration are explicitly accounted for in the generic models to determine net dry matter production, while the maize-specific approach derives net dry matter production directly from intercepted solar radiation by means of a fixed value of radiation use efficiency (RUE) that implicitly accounts for respiration costs. Third, the generic approach requires phenology specification of growing degree days (GDD) to anthesis and does not consider hybrid differences in traits such as sensitivity to daytime length, potential number of kernels and potential grain filling rate, while the maize-specific approach requires specification or estimation of several phonological events and hybrid-specific parameters.

A generic model (INTERCOM) and a maize-specific model (CERES-Maize, standard version) were evaluated with regard to their requirements for input parameters and their accuracy in predicting maize dry matter accumulation, leaf area expansion, and final grain and stover yields. Detailed field measurements from a 3-year study in which maize was grown with minimal possible stress were used for validation. Results suggest that CERES-Maize, in which temperature determines the potential leaf and stem growth, performed better than INTERCOM in which availability of assimilate is the primary driving force. In contrast, the separate routines for photosynthesis and respiration in INTERCOM provided greater sensitivity for crop response to temperature than CERES-Maize, which mostly relies on a fixed value of RUE for determining dry matter accumulation. Whereas INTERCOM requires specification of (GDD) to anthesis as an input parameter, CERES-Maize predicts anthesis from the GDD interval from emergence to end of the juvenile phase, and this 'juvenile-phase' parameter is not readily available for most hybrids.

Both models consistently underestimated maize yields under near-optimal growth conditions: grain yield was underestimated by 6% (±3%) and stover yield by 20% (±3%). Such underprediction would result in reduced estimates of C sequestration, especially in high-yield environments where the potential for C sequestration may be large. They would also underpredict nutrient requirements for fertilizer recommendations based on yield potential.

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References

Diepen, C.A., J. van Wolf, H. van Keulen, and C. Rappoldt. 1989. WOFOST: a simulation model of crop production. Soil Use and Management. 5, 16-24.

Jones, C.A. and J.R. Kiniry. 1986. CERES-Maize. A Simulation Model of Maize Growth and Development. Texas A&M University Press, College Station.

M.J. Kropff and H.H. van Laar. 1993. Modeling Crop-Weed Interactions. CAB International, UK.

Muchow, R.C., T.R. Sinclair, and J.M. Bennett. 1990. Temperature and solar radiation effects on potential maize yield across locations. Agronomy Journal, 82, 338-343.

Spitter, C.J.T., H. van Keulen, and D.W.G. van Kraalingen. 1989. A simple and universal crop growth simulator: SUCROS87. In: Simulation and Systems Management in Crop Protection. Eds: R. Rabbinge; S.A. Ward and H.H. van Laar. Simulation Monographs 32. Pudoc, Wageningen, pp. 147-181.

Software Demonstrations

A USER FRIENDLY FINITE ELEMENT GRID GENERATOR FOR 2DSPUD AND OTHER 2DSOIL BASED MODELS

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Potato is an intensively managed crop that requires large amounts of nutrients and water. Potato is also planted on hills or ridges which imposes a strong two-dimensional structure to infiltration and runoff. Our goal is to develop a mechanistic simulator of potato growth and development that is coupled with comprehensive two dimensional models of soil and atmospheric processes. The model calculates two-dimensional fluxes of water and movement of chemicals between rows and within the soil profile to simulate row position effects. The purpose of the model is to provide information on crop development stage, irrigation timing and amount, nitrogen fertilizer requirements and timing, and expected time to harvest.

There are a number of useful computer programs for the simulation of soil and atmospheric processes, and potato growth and development. Much of the modeling code that is currently available has also seen extensive use and testing. The ability to re-use code is a critical requirement to make full use of our investments. The use of a modular structure can facilitate the ability to choose the best tested and most appropriate code from an existing model and incorporate it into a new model. This will also allow us to match the level of detail between the plant and soil components. We have developed 2DSOIL, a modular two dimensional simulation model of soil and atmospheric processes, to be used for soil processes simulation in crop models. 2DSOIL is modular in the sense that components of the model can be added or removed with only minor modifications to the existing computer code. This model uses a finite element description of solute and water flow. Much of the code was adapted from SWMS_2D (water, solute and heat movement), SOIL-N (nitrogen dynamics), and GLYCIM (atmospheric and root processes). For potato growth and development we chose the model SIMPOTATO (Hodges, 1992). The model SIMPOTATO uses a daily time step and models photosynthesis on a canopy level using a parameter to model daily carbon assimilation as a function of the daily solar radiation integral. Temperature, nitrogen and water stresses are modeled using stress indices.

The 2DSOIL model was incorporated into the potato simulation model, SIMPOTATO, (Hodges, 1992) to build the new model, 2DSPUD.

In order to simulate photosynthesis on a more mechanistic level, we added a coupled, leaf level model of photosynthesis, stomatal conductance, and transpiration (Kim, 2001). This allows a coupling of the supply function of diffusion of CO_2 through the stomata (as controlled by stomatal resistance) to the demand function of the CO_2 fixation reaction. Recent advances in gas-exchange systems greatly simplify the parameterization of the model. The model was parameterized using data from leaf level photosynthesis measurements. Canopy level photosynthesis measurements from the Alternate Crops and Systems Laboratory's SPAR (Soil Plant Atmosphere Research) chambers were used to evaluate the performance of the photosynthesis model. Simulated photosynthesis values did follow the measured data at the extremes of the temperature ranges. However, uncertainties in leaf age and canopy light interception were sources of error.

The use of a more detailed model of photosynthesis will allow us to model the effects of environmental stresses with less dependence on stress factors and provide a more realistic method to model the effects of climate change. The results suggest that a good canopy radiative transfer model is important to be able to scale leaf level photosynthesis to the canopy level. Future work will be directed toward this area. The addition of a more mechanistic model of photosynthesis will help us better understand the photosynthetic process in potatoes and the effects of environmental variables.

References

Hodges, T. 1992. A modular structure for crop simulation models: implemented in the SIMPOTATO model. Agron. J. 84:911-915

Kim, S.H. 2001. Photosynthesis models and canopy management optimization in cut-flower roses. Ph.D., University of California, Davis.

TUESDAY – APRIL 15, 2003

8:00 AM	**Session I**	**Program Chair: Michael Bange**
10:15 AM	**Session II**	**Program Chair: Jeff Willers**
1:30 PM	**Session III**	**Discussion Leaders: Andy Gutierrez, Tom Sinclair, Leo Marcelis**
3:30 PM	**Poster Presentations**	

BUILDING AND MAINTAINING THE BRIDGE: FROM RESEARCH TO TECHNOLOGY TRANSFER

Michael P. Bange

CSIRO Plant Industry
Australian Cotton Cooperative Research Center, Narrabri, Australia

A bridge is ‘a structure carrying a road or path across a stream, ravine or road etc.’, thus to move on the bridge easily it needs to well designed and constructed, and adequately maintained. It is an apt term used in the case of taking information generated by research and delivering it in an appropriate form to the user, as it implies that infrastructure and resources need to be put in place from the start. One of the ‘bridges’ that has been used in agriculture to effect technology transfer is computerised decision support systems (DSS). Like any form of information transfer it also requires the above analogy to be applied in being planned and constructed.

A need and a demand for DSS have been demonstrated in the Australian cotton industry. Over the last twenty five years two generations of DSS were developed, named SIRATAC and CottonLOGIC. All stakeholders, including participating scientists, have benefited from DSS. The DSS have had a major impact on crop management in the industry, which now accepts DSS as providing objective standards. In addition development of DSS has facilitated communication between farmers and scientists, and also among scientists themselves. DSS have influenced the way we do agricultural science and deliver it.

This presentation revisits the SIRATAC experience in the light of more recent developments. The purpose is to elicit new learning from reflection on the old as well as the recent, and particularly on events which threaten the continuity of DSS development. The presentation also outlines current strategies and efforts into DSS development for Australian cotton production and the significant challenges that remain.

Choice of an appropriate structure which aims to develop and deliver DSS generated from research is not simple. An important aspect to recognize is that the process does not simply include software development. Successful development, delivery and adoption of DSS by industry encompass many different processes from the conception of an idea through to delivery and support. Some of the important functions and activities that a decision support team should consider are:

- Scientific foundation;
- Software engineering and research;
- Software development;
- Packaging and distribution;
- Field validation;
- Promotion, education and training;
- User Support;
- User feedback and project evaluation;
- Scientific review; and
- Project administration.

This more formal approach to DSS development explicitly identifies the need to allocate resources to specific tasks. Establishing these processes can be difficult in traditional research institutions with the specific aim to conduct research. Serious consequences in the delivery of DSS in the Australian cotton industry have resulted because some of these elements have been ignored.

Developing DSS involves steering a pragmatic course among numerous potential conflicts, ranging from the ideological extremes of some stakeholders to the pre-conceived ideas of others. DSS may generate conflict when their use confronts the entrenched views of some stakeholders. Industry politics and the egos of scientists, farmers and consultants influence the development and adoption process. These views must be confronted in order to make progress in crop management; progress involves social change to manipulate biology.

Conflicting opinions may result in serious tension amongst stakeholders. This can be avoided if an appropriate technology transfer structure is used and appropriately financed, remains flexible, and if the scientists are aware of the social dynamics and respond sensitively. In an endeavor to overcome some of these issues it has been important to define and promote widely consistent and equitable strategies based on simple philosophical and ethical principles to meet the needs of all stakeholders. This has required significant effort.

Some lessons from SIRATAC have been learnt, but others were not, so that mistakes were repeated with CottonLOGIC. Significant challenges still remain and the story of DSS in the Australian cotton industry will continue to evolve. Working with the cotton industry in Australia we are however, in an enviable position with an agricultural industry that has a rich record of success with computerised DSS. With an agreed and coordinated approach, working close with industry we endeavor to maintain this success. The ‘bridge’ continues to be maintained even while we seek new ways to boost the foundation and surface to lead us somewhere better. In the case if SIRATAC and CottonLOGIC our aim has been to provide tools for more sustainable cotton production systems.

DECISION SUPPORT SYSTEMS BASED ON CROP MODELS AND SENSORS

L. Marcelis, R. Booij, A. Elings, and P. de Visser

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Yields of most agricultural and horticultural crops strongly increased over the last decades. In general, also the inputs of natural resources, chemicals and capital investment, as well as farm size increased. Furthermore, governmental regulations and consumers' concern have forced farmers to produce in an environmental friendly and socially accepted manner. Modern production systems are in general characterized by intricate relationships and a high level of development, where improvements are only realized by sophisticated and well-balanced modifications of the system and subsequent fine-tuning of the adapted production system. Farmers have to make many decisions each day. The increased complexity of the production systems has increased the need for tools that assist the farmer in decision making. A Decision Support System (DSS) may be such a tool. A DSS is a tool that provides information to help improving management or control decisions. The DSS may take the decision or it may advice on a decision.

DSSs in agriculture and horticulture have been developed for more than two decades. Nevertheless, the use of DSSs by farmers is still limited. A successful DSSs must be simple to operate (only a few and easily accessible input parameters), be easy to interpret, deal with questions that are relevant to the farmer, be robust, have a short run time and must produce results that are reliable. Many DSSs have failed because they lacked more than one of these characteristics. Often a scientifically sound DSS does not solve the decision problem of the farmer. Team work between farmers, advisors, researchers, and IT companies is needed to close the gap between development and practical application of a DSS. The users of the DSS should be involved from the beginning onwards in a project in which a DSS is developed. They should be involved in the definition of the problems to be addressed by the DSS, as well as its design, evaluation and refinements.

The actual benefits of a DSS are often more in terms of knowledge transfer than in decision support. Often the term Discussion Support System better reflects the use of a DSS than Decision Support System. There are examples of good DSSs that are used for only a limited period, because it had fulfilled its task of knowledge transfer.

DSSs may be based on models, databases and/or expert knowledge. A model is a simplified description of part of the reality. For several variables it assumes average conditions. Consequently, in specific situations, model results may deviate from actual results. This has hampered the practical application of models as well as DSSs based on models.

By supplying the model with feed-back information on some parameters from the actual system, the reliability of the model can be increased substantially. This information can be obtained from sensors in the field or greenhouse, from recordings on crop, soil or cultivation methods or from recordings of production and product quality in the past of the specific field or greenhouse.

Here two examples of decision support based on models and sensors are briefly described.

Example 1. Nitrogen (N) fertilization in crops in the open field (e.g. potato, leek) aims at maximum yield, high product quality and minimum losses of N to the ground or surface water. A system has been developed where initially only a low rate of N fertilization is applied.

Subsequently, the crop N status is monitored during the growing season and additional N is supplied when the crop N status is too low. For monitoring the crop N status, measurements of light reflectance from a canopy are used. Based on a simple model of N demand of the crop, it is calculated whether additional N fertilization is needed. This system has shown its usefulness in terms of reduced environmental pollution by N and optimum yield and product quality.

Example 2. A schematic representation of a DSS for control of water and nutrient supply in closed greenhouse systems is presented in Figure 1. In this system a dynamic crop model predicts growth as well as the demand of a crop for water and individual ions, based on environmental conditions and crop properties. The crop model considers physiological processes and obtains feed-back from actual on-line measurements of photosynthetic activity, light interception by the crop and crop weight. The crop model is linked to a substrate model. The latter model predicts the fertigation strategy to meet the demand of the crop, while no undesired accumulation of nutrients in the soil or substrate occurs. Results with a tomato crop showed that the use of water and nutrients as well as growth and quality can be controlled efficiently.

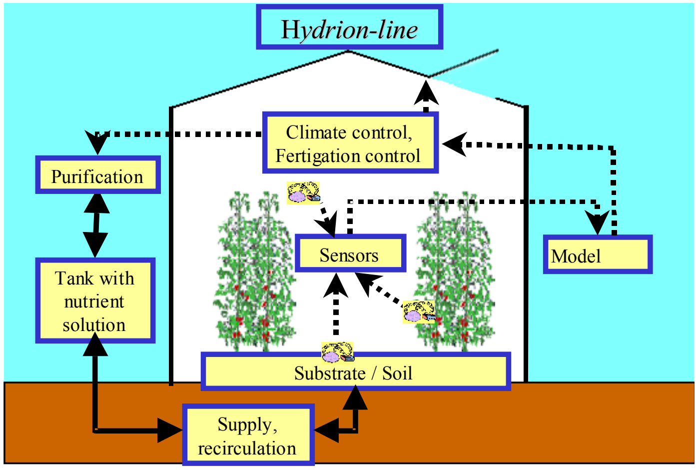

Fig. 1. Schematic representation of a control system for process water and crop growth in closed greenhouse systems.

SITE-SPECIFIC APPROACHES FOR COTTON INTEGRATED PEST MANAGEMENT

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Insect control is a major cost in cotton production. The simultaneous effect of the high cost of insect control and loss of many pesticides due to environmental pressures means that alternative strategies and tactics have to be developed for cotton pest management. The employment of diverse spatial technologies (*e.g.*, remote sensing, global position systems (GPS), geographic information systems (GIS)) and modern sampling designs are being investigated as tools that comprise a system of insect control that reduces cost, while protecting yield potential, and increasing grower profits. This presentation describes how spatial prescriptions can be developed and applied for the control of many fruit-feeding cotton pests of transgenic or non-transgenic cotton. Perspectives on how these spray decisions vary over the course of the production season (especially how some prescriptions need to be built using temporally separated remote sensing images) are discussed. Information on the probable interaction of these pesticide applications with other site-specific inputs such as plant growth regulators and foliar fertilizers is provided.

Site-specific pest management for cotton insect control depends strongly upon the integration of concepts from sampling theory and the spatial representation of data in a GIS. Remote sensing (RS) processing is also closely tied to variable-rate technology (VRT) uses in pest management and all these components must be linked to the experience of the producer and field consultants. As a result, the need for precise, numerically based decisions are dramatically lessened with use of imagery because it apportions the field into various habitats relevant to the population biology of the pest. Image information, coupled to other spatial information managed by the GIS, is the primary domain where most numerical information resides. Fortunately, sensor systems on aerial platforms and VRT equipped machinery (while some limitations yet remain) rapidly captures most of this information and at high spatial resolutions.

However, some information needed for pest management decisions still has to be obtained by fieldwork using skilled personnel. If correctly sized sample units are employed and examined in regions where the imagery indicates the location of the preferred habitat of the pest, then large acreages can be efficiently scouted with small sample sizes. These data, along with the skill and judgement of consultants can be combined to delineate these different habitats at a fine spatial scale (*i.e.*, 4 m^2/pixel), easily creating maps of pest abundance. The map that results from the integration of objective (*i.e.*, the image) and subjective (*i.e.*, the consultant) information provides an assessment of pest severity on a spatial scale. This mapped information provides the basis for the development of a spatial pesticide decision and application. The spatial and temporal (*e.g.*, the past history) information can also be used to improve the timing of applications. The correct timing of an application is important with either a blanket or spatially variable application.

The following steps describe how spatially variable sprays can be developed for the control of several fruit feeding insect pests of cotton (*e.g.*, tarnished plant bugs and Heliothines). For spray decisions made in July, August, and September, most prescriptions have to be built using remotely sensed images temporally separated by at least two or more weeks. Early and late in the season, this requirement may possibly be relaxed. The general logic and information management pathway (using primarily image processing software) is as follows:

(1) The process first begins with the acquisition of an image, its ortho- and geo-rectification, and, if necessary, the building of a mosaic from two or more frames.

(2) Within the mosaic, geo-referenced field boundaries are used to subset the image information apart from the surrounding landscape (roads, trees, buildings, pastures, rivers, lakes, etc.). The subset of the field is next enhanced to sharpen the contrast in the growth and development among different populations of cotton plants in the field. At least 5 distinct classes within these field polygons should be created and (as much as possible) these classes should be consistent across fields of similar planting dates. Numerous methods exist to create the enhanced map. Experience to date suggests that different processing methods are needed at different times of the season; however, unsupervised classification approaches work well most times.

(3) The next step is to use the proper sampling method for the insect pest and to minimize the sample variance by using the map built in step 2 to define the relevant sampling strata. Avoiding the use of sample unit sizes that are too small can also minimize the sample variance. The simple random sampling estimator can be used to estimate pest abundance in each stratum.

(4) Once scouting information based upon the classed image is accomplished, it is good to question if the map just used to scout the field for insects is congruent with both the scouting data and past experience of the field consultant or producer. Sometimes unusual field conditions exist to cause effects that make the map incorrect for describing the conditions of the crop (A revision may be necessary using recent field information.).

(5) When the map is corroborated it is possible to next create spray 'on' or 'off' zones in correspondence to those areas where insect pests are deemed too high and must be controlled. A GIS is employed to create these various spray zones in the fields. Other software is needed to write the controller specific file so that the sprayer can spatially respond appropriately as it travels across the field.

(6) After the application, it is necessary to evaluate results. The 'as-applied' map generated by the controller on the sprayer can be used to supplement previous information so that the consultant can best evaluate the recent pesticide application. Sometimes, the post-spray scouting information can indicate that the pest still persists (in some places) at a density of concern. If so, the question is, "How can we use the imagery and post-application history to build another map for use in additional sprays?" Additional GIS and RS processing tasks may be necessary.

(7) If an additional application is needed soon after the first, it may be necessary to use imagery from two separate times and at least several weeks apart for the same location. By completing another image processing step known as 'change analysis' one can better determine relevant edges of habitats being heavily colonized by the pest, even though these are not discernable with an image obtained at only one point in time.

(8) Once the refined map is built, re-apply pesticides when and where required. Thus, through an iterative decision making process working with the support of imagery and GIS, it is possible to match the experience and judgement of the field consultant with VRT to conduct site-specific pesticide applications.

A key concept of the above processes is to categorize a field into at least three regions based upon the following question, “Is there a problem ***here***?” Three answers are, “no”, “maybe”, and “yes”. The need for precise, quantitatively based decisions is lessened with the use of imagery because the imagery apportions the field into various habitats relevant to the population biology of the pest.

Collectively, the diverse spatial technologies are very robust in their relevance to site-specific or broadcast applications. The major tasks yet to be resolved before these concepts are available to numerous users is to provide tools which lessen the need for on-site expertise and permit the rapid assimilation and integration of diverse sources of information to generate the map used to apply the pesticide and/or other agronomic inputs. Diverse skills are needed to develop and test this novel approach to cotton pest management which involves many disciplines within public, private and research sectors. This integration strengthens this approach to cotton insect control; however, it demands careful orchestration of information and personnel. It has been frequently observed that the lack of key skills limits the timeliness and effectiveness of this approach to insect control. Before site-specific approaches to cotton insect control can be applied on large acreages, considerable work needs to be accomplished to reduce several labor and time constraints. It is particularly important to maintain clear channels of communication amongst all participants with this approach to cotton insect control.

WEB-BASED YIELD PREDICTION INFORMATION DELIVERY SYSTEM

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The objective of the YieldTracker project is to provide within-season predictions of crop yield in individual fields to farmers over the Internet. YieldTracker uses a combination of crop yield models, regional weather observations, and satellite remote sensing to develop probabilistic predictions of crop yield during the growing season. The region served by YieldTracker comprises the area contained within the intersection of two adjacent Landsat scenes (WRS Path 30, Rows 36 and 37) and the area covered by the Texas Mesonet weather observing system (see figure below).

YieldTracker uses mathematical crop growth models of the form described by Maas (1993), with their distinct capability to use remotely sensed data for within-season calibration of crop growth simulations. Estimates of plant canopy LAI used for model calibration are derived from Landsat TM imagery acquired during the growing season. Versions of the model applicable to the three major warm-season crops in this region (corn, cotton, and sorghum) are being used.

The models in YieldTracker are designed to use observed weather data from the Texas Mesonet and Landsat data from the current growing season to simulate the growth of a crop up to the current date. To simulate the growth of the crop for the remainder of the growing season, the model is run from the current date using synthetic weather data. The WGEN program is used to generate a synthetic "climatology" of 250 years of daily weather data for the YieldTracker region of interest. Based on temperature and rainfall conditions during the current year, a set of synthetic years are selected from the climatology that start out similar to the current year. These are used to complete the model simulation, producing a set of yield estimates that can be statistically analyzed to determine a probabilistic yield prediction. As one progresses through the year, more of the model simulation is based on observed weather and satellite data, so the overall accuracy of the prediction tends to improve with time.

All imagery used in the YieldTracker project is geometrically corrected using known ground points so that corresponding data can be extracted from all images. All images are radiometrically corrected to a relative standard by matching the scatter plots of red versus near-infrared digital counts determined for each image. These scatter plots are also used to estimate plant canopy LAI using an approach similar to the Perpendicular Vegetation Index (PVI). Data for developing and testing the YieldTracker models has been collected on two cooperating farms within the region of interest. Measurements of plant growth during the growing season have been made on a number of the fields on these farms. These data will also be used in developing relationships between plant canopy LAI and remote sensing data.

YieldTracker is intended to be used by individual farmers by access through the Internet. Once logged onto the YieldTracker website, a farmer selects his/her field by progressing through a series of maps and images. Once the field is selected, and some simple information regarding the field is provided (e.g., planting data, crop type), YieldTracker selects the appropriate weather and satellite data for the field. The field is broken down into approximately quarter-acre cells which correspond roughly to the pixels in the satellite imagery. The appropriate crop model is run for each cell, and the resulting yield predictions are assembled into a probabilistic "yield potential map" that is displayed to the farmer. This map can be interpreted similar to a standard yield map, except that it shows the probable distribution of yield across the field.

We are currently in the third year of the YieldTracker project. Years 1 and 2 involved the development of the basic YieldTracker system and collection of field data to support its development. During the growing season of year three, YieldTracker will be operated in a pilot mode, with limited access over the Internet to a group of cooperating farmers. During this pilot test, YieldTracker will be refined, calibrated, and tested. Our intention is that YieldTracker will be generally available to any farmer in the region of interest during the fourth year of the project.

References

Maas, S.J. 1993. Parameterized model of Gramineous crop growth: II. Within-season simulation calibration. Agronomy Journal 85: 354-358.

A DECISION SUPPORT TOOL BASED ON REFERENCE CONDITIONS AND EMPIRICAL DISTRIBUTIONS

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The potential for non point source pollution from agriculturally–related activities is of increasing concern. As a consequence, legislation has been enacted to ensure that the quality of all waters is routinely monitored using chemical, physical, and biological measures. Assessing the biological component is essential for evaluating water quality because it reflects disturbances in both the chemical and physical components; therefore, careful analysis of the biological component may be used as a 'first level' surveillance tool for the ecosystem as a whole.

In streams or *lotic* systems, benthic macroinvertebrates are often used to monitor water quality. Benthic macroinvertebrates are preferred over other biotic indicators because they are differentially sensitive to non–natural disturbances, react to disturbances for an extended period of time, and reflect localized impacts.

Benthic macroinvertebrates are used to assess water quality when regulatory personnel collect a sample and calculate a weighted measure of diversity. Weights often used are pollution tolerance values, functional feeding groups, and selected insect taxa. For the sake of simplicity, we will refer to these as measures of diversity although, technically, they are an *indices of biological integrity*. Nevertheless, those values are then used to assess water quality. This is done in one of two ways. The first is to compare the calculated diversity with a heuristically–derived value or 'threshold'; that threshold serves to separate lower diversity (unacceptable water quality) from higher diversity (acceptable water quality). The second is to compare calculated diversity with 'ranges' of values, thus placing the level of water quality into one of several categories such as 'very good', 'good', 'fair', 'poor' or 'very poor'.

The measures of diversity that are used to assess water quality vary considerably from one regulatory agency to another. Most are composed of calculated entities, referred to as 'metrics'. Metrics are used to create one or more additional measures, the final values of which are used to assess the level of diversity and, hence, water quality. For example, Wyoming uses a set of metrics for its 'Rockies' ecoregion that includes each of the following: 1) number of taxa belonging to the order Ephemeroptera, 2) total number of insect taxa, 3) number of non-insect taxa, 4) percent Ephemeroptera in the sample, 5) percent Oligochaeta in the sample, 6) percent of the top five taxa in the sample, 7) Hilsenhoff Biotic Index, and 8) percent of scrapers in the sample. For the sake of clarification, we will refer to these as the *initial metrics*. Initial metrics are used in a series of intermediate calculations to produce something called metric 'scores'. Once metric scores are calculated, their measure of central tendency (average) is determined. Finally, that average is used to identify a category that describes water quality.

The diversity of benthic macroinvertebrates in lotic systems depends on both non–natural disturbances as well as naturally–occurring factors such as geomorphology, hydrology, and elevation. Assessing benthic macroinvertebrate diversity by ecoregions is an attempt to account for such naturally–occurring influences. However, other naturally–occurring influences do exist, such as seasons, years, and localized spatial variation. Therefore, many sources of naturally–occurring variation are not accounted for when using heuristically–derived threshold values, or ranges of values, for classifying water quality.

Presently, the use of metric scores to assess the diversity of benthic macroinvertebrates fails to incorporate stochasticity into the assessment process. Typically, in other areas of science, stochasticity has been handled by the use of theoretical probability distributions. However, the probability distributions of most initial metrics, and all metric scores, are not known. Further, assumptions must be made before theoretical distributions can be used and, in some cases, those assumptions do not hold.

One way to account for naturally–occurring variation, while using stochasticity in the assessment process, is to use samples that represent *reference conditions*. These must be collected from segments of streams that are not impaired. Such *reference condition samples* are then used to develop *empirical distributions*, using computer-intensive resampling techniques. Use of empirical distributions to identify, for example, the 5th and 95th percentiles, will allow regulatory agencies to determine the likelihood that a calculated level of diversity, from a 'suspect' sample, 'belongs' to the distribution of the reference sample (i.e., represents an acceptable level of water quality). One obvious advantage to using such an approach is the specificity to which assessments are made, as samples representing reference conditions are specific to stream segments, seasons, and types of years (low flow, medium flow, high flow conditions); therefore, naturally–occurring variation is accounted for. Another advantage is that stochasticity is realistically achieved through the construction and use of empirical distributions. One disadvantage to using this approach is that large numbers of reference data sets must be created and stored as computer files. A final disadvantage to using this approach is the obvious need to develop and maintain software that will find and retrieve information, as well as to conduct the resampling efforts, sort the 'resampled' index scores, and find the percentiles that will differentiate unimpaired from impaired water quality conditions.

IMPACTS OF ENVIRONMENTAL CHANGE ON APHIDS THROUGHOUT EUROPE

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Aphids are major pests of most agricultural, horticultural and forest crops throughout the World (Blackman & Eastop, 1994; 2000). Suction traps (Macaulay *et al*., 1988), with an inlet 12.2 m above ground level and an air intake of $0.8 m^3 s^{-1}$ are used throughout Europe to monitor these insects. There are currently 70 traps operating in 19 countries. The first trap began operation at Rothamsted in 1965. There are now 1643 trap years of data available. These data have been brought together in the `EXAMINE' project to provide what is probably the most comprehensive standardised database, in terms of its temporal and spatial scale, for any terrestrial invertebrate group anywhere in the World. The database will be used in fundamental studies of factors influencing aphid dynamics and in applied programmes.

Aphids have amongst the lowest developmental temperature thresholds and highest reproductive rates of the insects and are hence particularly sensitive to changes in temperature (Yamamura & Kiritani, 1998) and other environmental variables. The main objective of the `EXAMINE' project is to look at statistical relationships between aspects of aphid dynamics and environmental variables at a European scale and, given scenarios for environmental change over the next century, use those relationships to predict how aphid dynamics might change. Initially, analyses are being done for 29 key pest species and the following variables.

- Aphid data: dates of first aphid, fifth aphid, first 25%, first 50%, first 75%, last aphid; Log_{10}(number+1) to April 22, July 15, October 7, December 31.
- Site data: latitude; longitude; altitude.
- Climate data (from EU `ATEAM' project): mean temperature of the coldest 30, 60 and 90 day periods; mean temperature of the subsequent 30, 60 and 90 day periods; precipitation for each month of the previous and current year.
- Land-use data in a 75km radius of the traps (these data are from the EU `PELCOM' project and are available for one year only and are hence fixed site-specific variables): area of land: dominated by coniferous trees and shrubs; dominated by deciduous trees and shrubs; dominated by coniferous and deciduous trees and shrubs; with herbaceous cover; with tree and shrub cover of less than 10%; with cultivated areas that have been tilled; with lakes, reservoirs and rivers; with oceans and seas; covered by buildings and other man-made structures; with data gaps or unknown classification.

- Gaseous pollutant data (from UNECE EMEP programme): annual mean concentrations of nitrous oxides, sulphur dioxide and ozone.

Analyses will use Residual Maximum Likelihood (REML) (Patterson and Thompson, 1971) to examine relationships between datasets. REML is a method that combines regression with variance modelling. It is a powerful technique that fits both the fixed effects (regression terms) and random terms (error terms) in a single step. Artificial neural nets and Goldwin correlograms will also be used to look for relationships between the aphid and environmental data.

At the time of writing this abstract, the databases are in place and the data files for analyses prepared, but the analyses remain to be done. Previous analyses using UK aphid and climate data have shown winter temperature to be highly correlated with aphid phenology and early-season abundance (Harrington *et al*., 1995), but only for those aphid species and locations where over-wintering is in the mobile stages as opposed to the egg stage. There is an additional geographical component not related to temperature, or to other meteorological variables tested. The Europe-wide analyses will strengthen understanding of relationships between aphid dynamics and the environment and increase confidence in predictions of the impact of environmental changes on this key pest group.

The EXAMINE consortium is keen that the aphid data are made available to bona fide users. Details of the data access agreement can be found on the project web site.

References

Blackman, R.L. & V.F. Eastop. 1994. *Aphids on the World's Trees.* CAB International, Wallingford.

Blackman, R.L. & V.F. Eastop. 2000. *Aphids on the World's Crops (2nd edition)* John Wiley & Sons, Chichester.

Harrington, R., J.S. Bale & G.M. Tatchell. 1995. Aphids in a changing climate. pp 125-155 in : R. Harrington and N.E. Stork (Eds) *Insects in a Changing Environment.* Academic Press, London.

Macaulay, E.D.M., G.M. Tatchell, & L.R. Taylor. 1988. The Rothamsted Insect Survey `12-metre' suction trap. *Bulletin of Entomological Research* **78:** 121-129.

Patterson, H.D. & R. Thompson. 1971. Recovery of interblock information when block sizes are unequal. *Biometrika* **31:** 100-109.

Yamamura, K & K. Kiritani. 1998. A simple method to estimate the potential increase in the number of generations under global warming in temperate zones. *Applied Entomology and Zoology* **33:** 289-298.

KNOWLEDGE ENGINEERING IN A LANDSCAPE ECOLOGICAL CONTEXT: AN APPROACH TO INTEGRATION

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Knowledge engineering is an activity that embraces a set of concepts and methodologies dealing with (i) acquisition of knowledge, (ii) analysis and synthesis of data and information [quantities], (iii) integration and interpretation of knowledge [quantities and qualities], and (iv) application of knowledge. The goal of this activity, in the context of biological integration, is to facilitate the use of the full extent of knowledge available for the purpose of advancing scientific understanding and/or supporting environmental decisionmaking. *Landscape ecology* deals with (i) spatial relationships among landscape elements (ecosystems); (ii) flows of energy, materials, and species among landscape elements, and (iii) change in the configuration of landscape elements in space and time. This discipline addresses the relation of landscape configuration and ecological processes in a spatial context. A suite of tools have been developed to automate knowledge engineering and basic concepts of landscape ecology have solidified to a point were combining the approach and the discipline offers novel ways to examine the interaction of complex ecological and physical systems. Examples to illustrate knowledge engineering and landscape ecology are taken from studies of the impact of agriculture on coastal lagoon systems, the effects of land use change on migratory waterfowl, the interaction of bark beetles and birds in forest landscapes, and the distribution and abundance of feral honey bees in coastal prairie landscapes.

PL-566 RIPARIAN ZONE WATER DYNAMICS FROM HYDROMETRIC AND ISOTOPE MEASUREMENTS

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Small dam PL-566 structures were constructed in the 1950s-70s in Texas and in the U.S. for flood control, sediment loss, and on-farm use. Since then, these structures are either reaching sediment capacity, or are in states of disrepair. The loss of these structures through removal or degradation could have downstream ecological consequences, especially in the riparian zone. To ascertain the ecological consequences, the nature of moisture supply to the riparian vegetation is being determined in a PL-566 riparian zone near Bruceville, Texas in the Cow Bayou watershed. This paper discusses how the stable isotopes in water (^{2}H and ^{18}O) from precipitation, PL-566 lake, stream, sapwood, and bank soils complement on-going hydrometric measurements using stem flow meters, TDR soil moisture sensors, and piezometers.

THE $\delta^{13}C_R$ RESPIRATION SIGNATURE AND CARBON EXCHANGE DYNAMICS IN CENTRAL TEXAS RANGELANDS FROM TALL TOWER MEASUREMENT

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The CO_2 in air has been continuously measured at six different heights from a tall tower near Moody, Texas since January, 2001. Diurnal manual sampling of air for carbon and oxygen isotopes in CO_2 has been done about bi-weekly from the bottom and top levels of the tower. This paper presents the respiration $\delta^{13}C_R$ signature for the mixed C_3/C_4 rangeland systems found in Central Texas using the Keeling plot approach to highlight seasonal, succession, and non-local influences on ecosystem level respiration. The day and nighttime atmospheric CO_2 gradient throughout the year are discussed in terms of regional precipitation and temperature.

Poster Presentations

ENZYME ACTIVITIES IN SEMIARID AGRICULTURAL SOILS

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Over 20 % of the U.S cotton (*Gossypium hirsutum*) crop is produced in the Texas High Plains mostly under monoculture systems that are economically risky and contribute to wind induced erosion. Recent efforts to protect semiarid soils and enhance environmental quality favor conservation tillage practices and crop rotations. We investigated the effect of management practices on β-glucosidase, β-glucosaminidase, arylsulfatase and alkaline phosphatase activities of semiarid soils from West Texas. Surface samples (0-5 cm) were taken from a fine sandy loam, sandy clay loam, and loam that were under continuous cotton (*Gossypium hirsutum L.*) or in cotton rotated with peanut (*Arachis hypogaea L.*), sorghum (*Sorghum bicolor L.*) or wheat (*Triticum aestivum L.*), and had different water management (irrigated or dryland) and tillage (conservation: reduced or no-tillage, or conventional). Among the enzyme activities investigated, β-glucosidase activity was studied because it is involved in the final step of cellulose degradation that provides simple sugars for microorganisms in soils. β-glucosaminidase activity is involved in chitin degradation. Arylsulfatase activity is involved in the mineralization of ester sulfate in soils. Alkaline phosphatase was studied because it catalyzes the hydrolysis of both esters and anhydrides of phosphoric acid, and because semiarid soils have high pH, and thus, this enzyme should play a key role in providing soil P to plants. Soil pH and total nitrogen content in the three surface soils studied were not affected by management. The total C content, however, was affected significantly by the different crop rotations and tillage practices studied, being greatest in soils with crop rotation and conservation tillage practices in comparison to continuous cotton under conventional tillage. In the fine sandy loam, arylsulfatase and alkaline phosphatase activities were significantly ($P<0.05$) higher in wheat-cotton rotation under no-tillage compared to continuous cotton under conventional tillage. In the sandy clay loam, β-glucosaminidase, alkaline phosphatase, and arylsulfatase activities were significantly ($P<0.05$) increased under crop rotations in comparison to continuous cotton. In the loam, the enzyme activities were significantly ($P<0.05$) increased under crop rotations in comparison to continuous cotton when conservation tillage was used. This study demonstrates the impact of crop rotations and conservation tillage on the important soil biochemical reactions studied in comparison to the typical practice of continuous cotton with conventional tillage.

SOIL ENZYME ACTIVITIES IN SEMIARID SYSTEMS: CONSERVATION RESERVE PROGRAM, NATIVE RANGELAND AND CROPLAND

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Knowledge of biochemical processes in low carbon content soils of the semiarid regions in West Texas, USA, in response to different land management is limited. The activities of seven soil enzymes involved in C, N, P, or S cycling were compared in an Olton loam (Fine, mixed, thermic, superactive, Aridic Paleustolls) under the conservation reserve program (CRP), native rangeland (NR), sunflowers (*Eriophyllum ambiguum (Gray)*), continuous cotton (*Gossypium hirsutum L.*), or wheat (*Triticum aestivum L.*)-cotton rotation. Soil samples (0-5, 5-10, 10-15, and 15-30 cm) were taken in January 2001, and analyzed for organic C, total N, pH, and the activities of β-glucosidase, β-glucosaminidase, arylamidase, acid phosphatase, alkaline phosphatase, phosphodiesterase, and arylsulfatase. The soil pH (7.1-8.4), organic C (6.60-13.10 g kg^{-1} soil), and total N (0.55-1.03 g kg^{-1} soil) varied among the management systems. Linear regression analyses indicated that the enzyme activities were positively correlated with organic C (r values up to 0.96, $P<0.01$). There was a trend of positive relationship between the enzyme activities and total N, but soil pH showed the opposite trend. Enzyme activities were significantly intercorrelated with r values up to 0.98 ($P<0.001$). Generally, the enzyme activities (mg product kg^{-1} soil h^{-1}) were significantly ($P<0.05$) lower under continuous cotton in comparison to the other systems. Alkaline phosphatase activity was the most predominant enzyme with values of 251, 238, 174,127, 114, and 93 mg *p*-nitrophenol (PN) kg^{-1} soil h^{-1} in NR, CRP, wheat-cotton rotation, sunflowers, irrigated continuous cotton, and dryland continuous cotton, respectively. The enzyme activities were lower than corresponding values reported for soils from other regions. The specific enzyme activities (mg product g^{-1} organic C) were significantly ($P<0.05$) lower in continuous cotton in comparison to the uncultivated soils (i.e., NR and CRP). The specific activities of β-glucosidase and arylamidase showed a more pronounced decrease with increasing soil depth than the other enzymes. In general, soils under CRP or wheat-cotton rotations revealed higher enzyme activities than soils under the common agricultural practice for these regions, i.e., continuous cotton under conventional tillage.

ESTIMATING CARBON DIOXIDE LEAKAGE RATES IN CONTROLLED ENVIRONMENT CHAMBERS USING NITROUS OXIDE

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Naturally sunlit, outdoor controlled-environment chambers provide an important research tool for studying the effects of environmental variables on crop physiological processes. Typically these types of chambers are semi-closed and are capable of continuously monitoring canopy scale gas exchanges. Accurately determining chamber CO_2 leakage rate is essential for correcting measurements of photosynthesis and respiration in these kinds of chambers. The purpose of this study was to evaluate the ability of a recently installed CO_2 leak quantification system which used N_2O as a tracer gas to estimate chamber CO_2 leakage rates in a recently constructed outdoor, controlled-environment chamber facility at Beltsville, MD. Chamber CO_2 leakage rates as determined by the CO_2 drawdown method (C_L) were compared with CO_2 leakage rates determined using N_2O as a tracer gas (C_{LN}). These two methods of determining leakage rates were compared in two different types of chambers: smaller and more tightly sealed Daylit chambers and larger more leaky SPAR (<u>S</u>oil-<u>P</u>lant-<u>A</u>tmosphere-<u>R</u>esearch) chambers. Comparisons of C_L with C_{LN} indicated that C_{LN} was an excellent predictor of C_L. However, the analysis did show a slight but consistent overestimation of C_L by C_{LN} that averaged 0.3, 1.4 and 1.1 µmols (CO_2) m^{-2} s^{-1} for the Daylit chambers, the SPAR chambers and all data combined, respectively. These results indicate that N_2O can be used as a tracer gas to accurately and reliably estimate chamber CO_2 leakage rates in real time during experiments in the presence of plants and when it is necessary to maintain specific chamber CO_2 treatment set points that make estimation of C_L difficult.

SIMULATING WATER USE OF IRRIGATED CORN ON THE TEXAS HIGH PLAINS

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The crop water supply is the principle factor-driving yield in the U.S. Southern Great Plains. Crop simulation models rely on the calculation of potential evaporation of water (PET) to predict the crop water balance. Several PET equations have been developed, but which equation works best within the framework of a crop model is unknown. We compared the measured yield and seasonal crop water use (e.g., from planting to harvest) of irrigated corn (Zea mays L.) grown in weighing lysimeters at Bushland, TX over 3-years (1989, 1990, and 1994) to the yields and seasonal crop water use predicted with the Environmental Policy Integrated Climate model (EPIC) using the Penman, Penman-Monteith, Priestly Taylor, and Hargreaves PET equations. The mean measured yield and crop water use were 9.7 MT and 785 mm with a SE of 0.9 MT and 53 mm, respectively. Predicted yield and seasonal crop water use with the EPIC model and the four PET equations did not statistically differ from the measured values. These findings suggest that the selection of the PET equation in crop simulation model may not be critically important.

SIMULATION OF BRUSH REMOVAL WITHIN AN URBAN WATERSHED IN TEXAS

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Brush removal has been regarded as one practice to increase water yield (surface runoff and base flow) in semi-arid watersheds. The Soil and Water Assessment Tool (SWAT) model was used to simulate the effects of brush removal on water yield in one urbanized watershed in west central Texas for 1960 through 1999. Landsat7 satellite imagery was used to classify land use, and the 1:24,000 scale digital elevation model (DEM) was used to delineate the watershed boundaries and subbasins. SWAT was calibrated to existing stream gauge flow and reservoir storage. Brush removal was simulated by converting all heavy and moderate categories of brush (except oak) to open range (native grass). Treatment or removal of light brush (<30% cover) was not simulated. Simulated flows at four USGS stream gauge sites were generally within 10% of measured flow. Simulated water yield varied by subbasin from 795 to 2,216 cubic m/(treated ha-yr), but all subbasins showed an increase in water yield as a result of removing brush. This and other similar simulation studies indicated increased water yield was dependent on land use, precipitation, and soil type.

A SIMULATION MODEL OF COMPETITIVE INTERACTIONS AMONG POLYGYNE FIRE ANT COLONIES FOR FORAGING SPACE AND RESOURCES

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A simulation model of polygyne (multiple queens) red imported fire ants, *Solenopsis invicta*, was developed. The foraging component integrated the foraging distributions of ants from several colonies in a population with predictions of colony level numerical dominance on simulated food baits. Foraging parameters included the distance to food resources, colony size (i.e. biomass), and average internidal (between nest) spacing among colonies. The colony with the highest potential of having the largest worker force available at a location was considered to be the numerically dominant colony at that location. Three analyses used independent performance statistics derived from observed data to test model performance. The first analysis showed that the model did a significantly better job of explaining colony numerical dominance on baits than expected from a random assignment of colonies to be numerically dominant on simulated baits. The second analysis showed that the observed and expected frequency distributions of numerical dominance were significantly different when considering numerical dominance as a function of distance from colonies to baits. Food items within 200 cm could be correctly identified as to which colony would be the numerically dominant colony > 80% of time, and declined as the distance between colonies and baits increased. The third analysis showed that the observed and expected frequency distributions of numerical dominance were significantly different when considering numerical dominance as a function of observed ant abundance on baits. The model performed best when there were greater than 50 observed ants on baits.

The second component of the model, food harvesting, relies on parameters from the foraging component coupled with published data on daily energy requirements for colony maintenance and reproduction. The food harvesting component uses predictions of the daily energy (joules per day) requirements for two food types and two physiological processes. Carbohydrates are required for colony maintenance and proteins for colony reproduction. The food harvesting component is presented as a hypothetical scenario that dynamically changes each colonies predicted foraging area based on their food harvesting ability and colony demand for food resources. In the simulation, as colonies harvest food their foraging areas shrink in proportion to how much energy they have acquired in relation to an upper limited defined as their daily maximum energy requirement for reproduction or colony maintenance. Simulations depict changes in colony foraging areas as a result of food harvesting under different patterns of resource distributions. (e.g. regular, random, and clumped).

STABILITY OF RADIATION USE EFFICIENCY OF PEANUTS FOR A DIVERSE SET OF SITES

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A critical value for simulating peanuts is the radiation use efficiency (RUE), which is amount of dry biomass produced per unit of light (PAR) intercepted by the plant. This value can be used in simulation models to predict the dry matter produced in the absence of environmental stress. Daily simulation of water balance and nutrient balances can then predict reductions in the biomass production. For this study, we took measurements on these at the two sites in central Texas in 2001 and one in the southern High Plains of Texas in 2002. The results for RUE were similar to values reported in the literature for Ontario, Canada, in Australia, and in Florida. Thus, in many environmental conditions, one value for RUE appears to be a viable approach to simulating peanut biomass production.

SOIL WATER DYNAMICS, SURFACE ENERGY BALANCE, AND CANOPY MICROCLIMATE IN DRYLAND CROPPING SYSTEMS: THE USDA-ARS FACILITY IN BIG SPRING, TEXAS.

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Two identical facilities have been constructed at the USDA-ARS Big Spring Field Station to study the Soil Water Dynamics (SWD) of dryland cropping systems. One of the facilities was constructed on a field of Acuff loam that has been in continuous cultivation since 1915 and the other was constructed on an adjacent field of Acuff loam that has been in native and improved range grasses from 1950 - 2000 and in high residue rotations since being broken out in 2000 and is representative of long-term conservation tillage management. The in-field SWD facilities consist of four transects of soil water and temperature sensors placed at depths of 0.3, 0.6, 0.9, 1.35, and 1.8 m depths. At both the 0.3 and 0.6 m depths, 16 TDR probes measuring soil water storage are spaced .25 m apart, 8 thermal dissipation type matric potential sensors are placed at alternate TDR probe locations, and 8 thermocouples are placed at TDR locations alternating with the matric potential sensors. At the 0.9 m depth TDR probes and matric potential sensors are spaced as at the 0.3 and 0.6 m depths, but thermocouples are absent. At the 1.35 m depth, 9 TDR probes are placed at 0.5 m intervals and 4 matric potential sensors are placed with the 3rd, 4th, 6th, and 7th TDR probes. At the 1.8 m depth, 7 TDR probes are placed at 0.5 m intervals (starting directly under the 2nd probe at the 1.35 m depth) with matric potential sensors located directly beneath those at the 1.35 m depth. The soil water and temperature probes will be automatically read at least twice daily (06:00 and 18:00 initially) in order to determine diurnal water uptake and use patterns and seasonal development of the rooting pattern. The addition of instrumentation in the 2003 field season will allow closure of the surface energy balance equation and allow the comparison of canopy microclimate between cropping systems. The additional instrumentation includes soil heat flux plates, infrared thermocouples for measurement of soil surface and canopy temperatures, split-band net radiometers, aspirated fine wire thermocouples, light interception measurements of Photosynthetically Active Radiation (PAR), and water vapor and carbon dioxide analyzers sampling through selectable-port valves. Plant measurements to be taken will include stem flow, stomatal conductance, and carbon dioxide assimilation.

WEDNESDAY – APRIL 16, 2003

8:00 AM	**Session I**	**Program Chair: Jeff Baker**
9:00 AM	**Session II**	**Program Chair: Ken Boote**
10:25 AM	**Session III**	**Discussion Leaders: Jeff Willers, Robert Lascano, Bob Coulson, Ted Wilson**
1:30 PM	**Session IV**	**Program Chair: Ted Wilson**
2:15 PM	**Session V**	**Business Meeting**

SIMULATION OF LEAF AND CANOPY PHOTOSYNTHESIS OF MAIZE UNDER ELEVATED CO_2 AND VARIOUS TEMPERATURES

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A coupled model of photosynthesis, leaf conductance, and transpiration was developed for maize leaves. The model was based on a biochemical model of C_4 photosynthesis, the Ball, Woodrow, and Berry's model of stomatal conductance and the energy balance model. The model was calibrated using maize plants grown at two $[CO_2]$ and five temperature regimes in Soil-Plant-Atmosphere-Research (SPAR) chambers. This leaf model was extended to predict whole-canopy photosynthesis and transpiration by combining with a radiative transfer model inside the canopy. The whole-canopy gas exchange simulations were compared with whole-canopy gas exchange measurements. Effects of elevated CO_2 and increased temperature on photosynthesis and water use were evaluated using the canopy gas exchange model. Effect of shade curtains surrounding the canopy in the SPAR chambers was demonstrated using the model. Incorporation of the gas exchange model into a crop simulation model including carbon and water balances, and phenology is discussed.

DELAYED SENESCENCE AND REDUCED DISEASE SEVERITY IN COVER CROP MULCH-CULTIVATED TOMATO PLANTS IS LINKED TO ACCUMULATION OF SPECIFIC GENE PRODUCTS

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The conventional fresh market vegetable production heavily depends on materials that are synthesized off the farm. These include plastic mulch, nitrogen fertilizer and pesticides. Such farming practices contribute to the unintentional introduction of agrochemicals into non-farm environments. This raises serious environmental concerns for human and animal health. The integration of on-farm biological inputs into vegetable production system is one potential means of reducing the dependence on off-farm inputs. In recent years, alternative agriculture practices have tested cover crops such as hairy vetch (*Vicia villosa*) as an on-farm biological input that has the potential to reduce soil erosion with lesser reliance on agrochemicals without impacting the yield or quality of the produce. Field-grown, fresh market tomato (*Lycopersicon esculentum* L.) plants cultivated in hairy vetch mulch display tolerance to disease and have reduced defoliation as compared to plants cultivated in the plastic mulch. We used a molecular approach to test whether these beneficial attributes are linked to changes in the expression profiles of one or more specific gene products. A large number of antibodies and PCR-derived gene-specific probes were used to quantify the levels of proteins and transcripts implicated in senescence and disease tolerance. The data indicated that vetch-grown tomato plants have increased accumulation of transcripts and proteins that are central to disease suppression and delayed senescence.

SOIL PHYSICAL PROPERTIES, CROP WATER AVAILABILITY, CANOPY TEMPERATURE, AND INCIDENCE OF GREEN BUGS AND MAIZE DWARF MOSAIC VIRUS IN A HETEROGENEOUS DRYLAND SORGHUM FIELD

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Five years of yield data from a dryland wheat and sorghum cropping system have consistently shown that the northwest and far east portions of the field are less productive than the north central area, and that sorghum yield appears to be more sensitive to these differences than wheat. Measurements along an east-west transect have revealed gradients for soil textural properties, depth and, for most of the season, moisture storage. These gradients are consistent with those for yield and leaf area. In 2002, we installed mast-mounted infrared thermometers along the same transect to continuously monitor sorghum canopy temperature. Leaf temperature increased as soil water availability decreased. We then hypothesized that greenbug populations, which are known to respond to temperature, would reflect canopy temperature data. Mummy counts taken in the fall decreased with canopy temperature. Finally, since greenbugs are known to vector maize dwarf mosaic virus (MDMV), we hypothesized that MDMV incidence would reflect temperature-induced changes in greenbugs. Results indicate that percent MDMV was well correlated with mummy counts. Although we have only one year's data, to our knowledge this is a unique data set that relates the complex processes of soil hydrology, microclimatology, insect population dynamics, and plant virology within one agro-ecological system. We believe that it may provide new opportunities for greater understanding of how these processes interact, and potentially for the identification localized pest and disease given sufficient weather and soil data.

RICE SYSTEMS RESEARCH:
FROM CULTIVAR DEVELOPMENT TO INTEGRATED SYSTEMS MANAGEMENT

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This presentation describes the development and evolution of a rice simulation model. The model was developed for the purpose of defining which combination of primary plant traits, and therefore genes, to select when breeding for higher grain yield. The advantage of this approach is that it provides greater focus to the Texas rice breeding program over what is achievable using either a conventional plant breeding program or a marker-assisted breeding program, both of which are limited in their ability to identify the "best" genetic or phenotypic combination when the primary focus is yield enhancement.

The rice-breeding program at Beaumont evaluates 20,000 to 30,000 selections each year, with about 25 to 30 new pure lines also evaluated in regional trials for their potential as cultivar releases. At different stages of the selection process, measurements are taken of a limited number of phenotypic traits. The culmination of this process is the release of a new cultivar 7 to 12 years after an initial cross. Numerous lines possessing desirable genes are discarded during the repeated selections because they are not recognized as being desirable within their existing phenotypic background. Similarly, numerous lines possessing undesirable genes are maintained long after considerable investment has been expended on the selection process. A pressing need is technology that would enable a major increase in the speed with which desirable lines can be identified. The merging of marker-assisted selection with phenotype modeling has the potential to allow rapid definition and selection of rice genotypes with the greatest economic benefit to the Texas rice industry.

The quadrupling of Texas rice yields over the last 60 years is a strong indication of the genetic variability that is available within the rice genome. There is ample data to suggest that further increases of a major nature are probable. The Chinese hybrid rice-breeding program suggests that yields can be increased by at least 30% over the best existing cultivars (Yuan 1996). Xiao et al. (1996a, b) presented data suggesting that the introgression of genetic material from a wild rice progenitor species has the potential to increase yield by 35% over the best Chinese hybrids. A six year study of recombinant inbred lines from a cross of a high yielding Texas semidwarf cultivar with an extremely high yielding Chinese semidwarf suggests that Texas main crop yields can be increased by at least 40% (Wilson, unpublished data). The significance of these examples is that they strongly demonstrate the potential for greatly increasing current commercial yields. However, they do not clearly identify how to focus selections so as to maximize the rate of cultivar improvement.

Two recent technologies show considerable promise for speeding the rate of rice cultivar development. The first involves the use of genetic markers to assist selection. The second involves the use of mechanistic crop simulation models to define the "best" combination of traits for a given set of environmental conditions.

Marker-assisted selection was used by Drs. McClung and Park as part of the USDA/ARS-Texas A&M University rice plant-breeding program to develop Jacinto and Cadet, the first two commercial rice cultivars containing genes that afford resistance to all major US rice blast races. However, marker-assisted selection has not proven as useful when selecting for improved yields.

In a few studies, quantitative trait loci (QTL) analyses have identified one or a few loci that explain a substantial proportion of grain yield variability (Xiao et al. 1996a). But typically there is poor correspondence between QTLs identified for "yield components" and those identified for grain yield (e.g. Xiao et al. 1996b). This reflects the fact that yield genes per se do not exist. Crop yield, unlike disease resistance is influenced by a large number of interacting plant traits. As a result, it is unlikely that marker-assisted selection, as currently practiced, will significantly improve the speed with which yield enhancing genes are pyramided to produce desirable genotypes. The difficulty lies with the current poor understanding of which genes control which plant traits, and an even weaker understanding of how phenotypic traits interact to affect yield.

Our research has partially addressed this problem by focusing on identifying yield related "primary phenotypic traits", traits which are to a large degree environmentally invariant (Wu and Wilson 1997, 1998, Wu et al. 1998, Samonte et al. 1998, 2000, 2001); traits for which we have an increasing body of evidence to suggest are each controlled by a few genes or a single gene. Twenty-eight primary traits have been identified; fourteen of which appear to be invariant across genotypes. Of the remaining 14, variability across genotypes is moderate to considerable. Preliminary model-based analysis of data from a detailed study of 17 genotypes suggests that nine of the primary traits may be responsible for the majority of yield variability.

Gene identification advances our scientific knowledge base, but presents a major challenge when addressing yield, due to yield being affected by several genes interacting via primary phenotypic traits. Our research team has developed a mechanistic rice population simulation model whose structure is based on primary traits, which allows a direct link to the gene(s) that are responsible for each trait. This structure provides a means to forecast a genotype's yield performance for an environment, and to estimate the result of incorporating one or more putative advantageous traits. By contrasting simulated results with results from independent field experiments, we have verified that the model accurately predicts the growth, development, and yield of each of the 17 genotypes (R^2 = 0.85-0.93). In contrast, rice simulation models have historically been based largely on secondary plant traits and explain less than 60% of the variability (see Wu and Wilson, 1998). The model's accuracy at predicting the yield of a wide range of genotypes for a number of years (1988 to 1995) is encouraging.

Our research focuses on two areas. The first focuses on incorporating the rice simulation model into the Texas A&M University rice varietal development program. The model has been now been used for two years, on about 30% of the varietal development program, to identify which crosses to make and which recombinant inbred lines to select. The second focuses on converting the rice simulation model to an individual-based structure. This structure allows the model to focus on physiological processes responsible for each primary plant trait. This structure also allows for incorporation of spatially implicit variables, such as site-specific soil characteristics and insect, disease, and weed pressures. Individual-based modeling is a major step towards capturing biological and spatial detail, a necessary step for developing truly integrated site-specific management systems. But a limitation is the number of objects that can be simulated. Our previous research on individual-based modeling of Africanized honeybee colony gene flow and regional population dynamics suggests that up to several thousand objects can be simulated, while maintaining a fairly high degree of behavior and genetic complexity (Makela et al. 1993a, b, Rowell et al. 1993). To capture the biological detail required to simulate the population dynamics of millions of individual arthropods (or plant pathogens), and their interactions with host crops growing in thousands of spatially distinct locations each with potential unique edaphic and agronomic conditions, is presently beyond the ability of most complex plant-herbivore-parasitoid models. The model structure needed to address the site-specific management of a crop, its agronomic inputs, and its main herbivores requires integration not readily accomplished with most cropping systems modeling efforts. While too much detail can limit the tactical use of biological simulation models, too little detail adds little to increasing knowledge of interactions inherent to biological systems. A compromise obviously exists between structuring a modelling such that it requires excessively detailed data, and structuring one that is devoid of sufficient mechanistic realism.

Our long-term goal is the integration of the model into a web-based decision system for both strategic and tactical management. Web-based delivery affords several advantages, not least, of which is greater control over application updates and the potential for greater integration of management information across time and space.

References

Makela, M. E., G. A. Rowell, L. Erickson, and L. T. Wilson. 1993. AHB resource availability across Texas. American Bee Journal 132: 811.

Makela, M. E., G A. Rowell, W. J. Sames, and L. T. Wilson. 1993. An object-oriented intracolonial and population level model of honeybees based on behaviors of European and Africanized subspecies. Ecological Modelling 67 (2-4): 259-284.

Rowell, G. A., M. E. Makela, and L. T. Wilson. 1993. BeeMig: A population growth and migration model of AHB across Texas. American Bee Journal 132: 813-814.

Samonte, S. O. PB., L. T. Wilson, and A. M. McClung. 1998. Path analysis of yield and yield-related traits of fifteen diverse rice genotypes. Crop Sciences 38: 1130-1136.

Samonte, S. O. PB., L. T. Wilson, A. M. McClung, and L. Tarpley. 2001. Seasonal dynamics of nonstructural carbohydrate partitioning in fifteen diverse rice (Oryza sativa L.) genotypes. Crop Sci. 41: 902-909.

Wu, G. W., and L. T. Wilson. 1997. Growth and development response of rice to rice water weevil injury. Environmental Entomology 26: 1191-1201.

Wu, G. W., and L. T. Wilson. 1998. Parameterization, verification, and validation of a physiologically complex age-structured rice simulation model. Agricultural Systems 56: 483-511.

Wu, G., L. T. Wilson, and A. M. McClung. 1998. Contribution of rice tillers to dry matter accumulation and yield. Agronomy Journal 90 (3): 317-323.

Xiao, J., S. Grandillo, S. N. Ahn, S. R. McCouch, S. D. Tanksley, J. Li & L. Yuan. 1996a. Genes from wild rice improve yield. Nature 384: 223-224.

Xiao, J., J. Li, L. Yuan & S. D. Tanksley. 1996b. Identification of QTLs affecting traits of agronomic importance in a recombinant inbred population derived from a subspecific rice cross. Theoretical Applied Genetics 92: 230-244.

Yuan, L. P. 1996. Current status of hybrid rice in China and future strategies for the 21st century. Proceedings 26th Rice Technical Working Group, Texas Agricultural Experiment Station, College Station, Texas, p. 45.

AN INDIVIDIUAL-BASED RICE CROPPING SYSTEM MODEL

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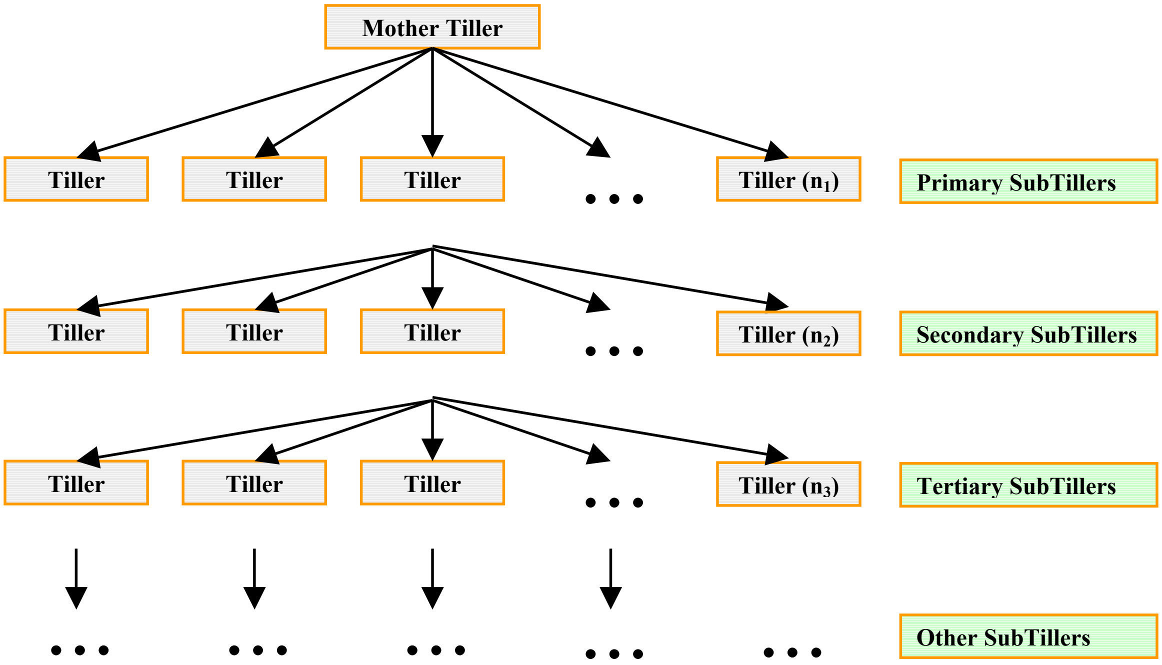
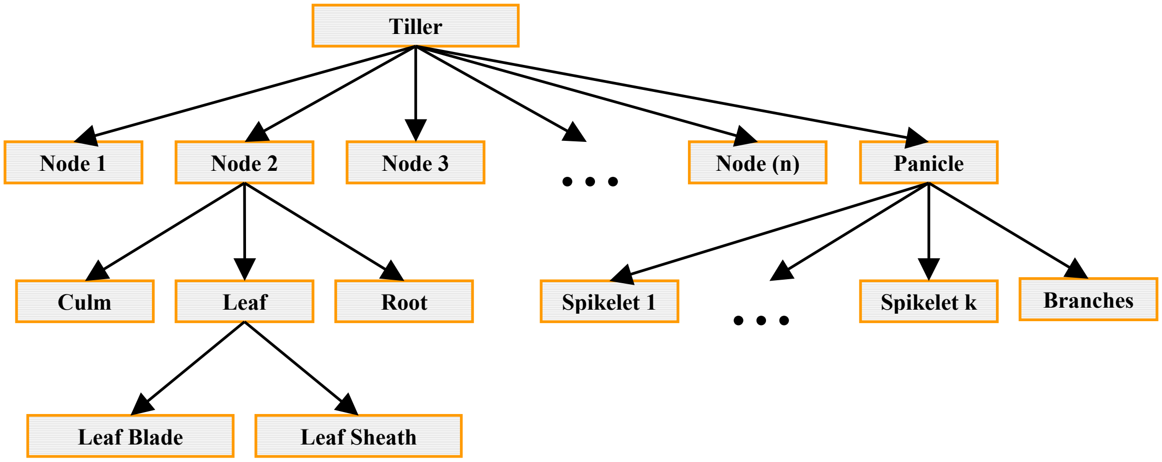
An individual-based rice cropping system model was developed to simulate the temporal and spatial dynamics of rice plant growth as affected by biotic and abiotic environmental variables, and agronomic practices. The rice cropping system is subdivided into four modular components: rice, field, agronomy, and weather. The rice component represents the rice plant and its temporal and spatial dynamics. The field component represents the soil in 3-dimensional space. The agronomy component represents the agronomic practices. The weather component represents the weather variables.

Each rice plant starts with a rice seed, and is identified by its spatial location in the field. Each rice plant is represented by the mother tiller and its subtillers, and subtillers of the subtillers (see the following figure).

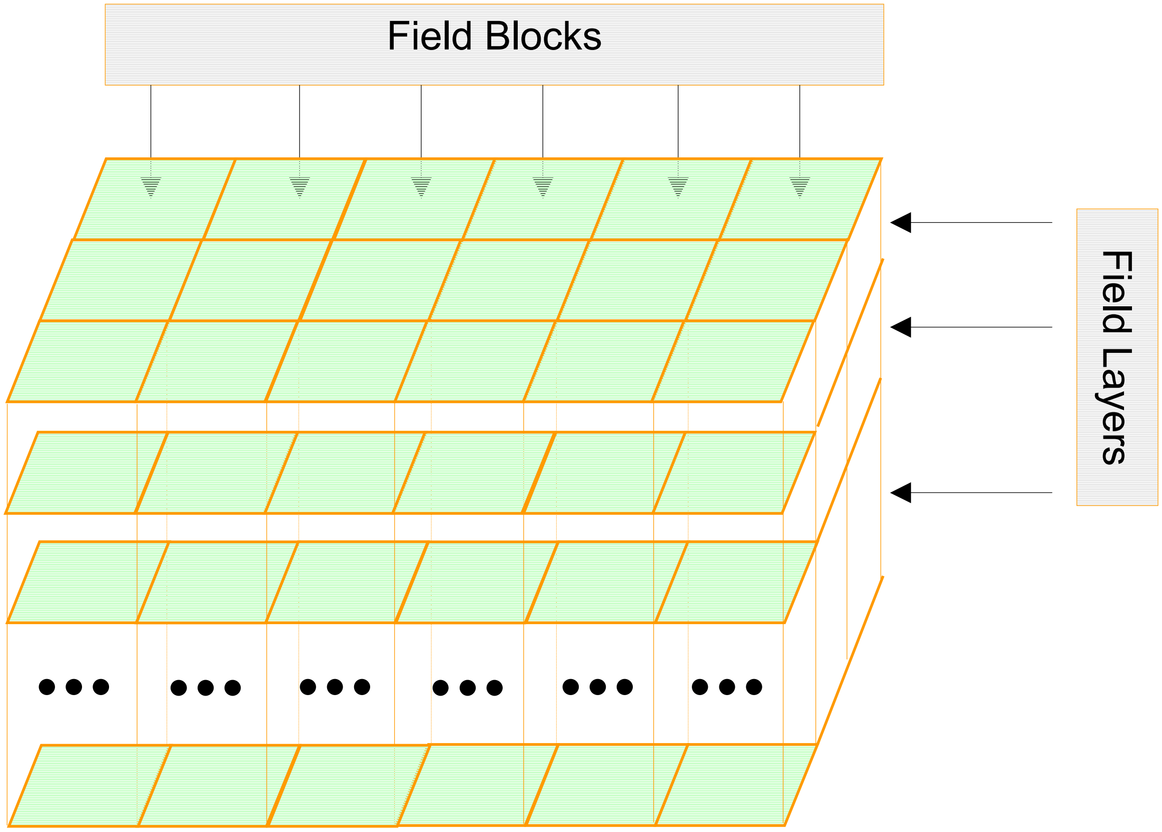


Each tiller is represented by its nodes and panicle. Each node is represented by a leaf blade, a leaf sheath, a culm, and root (see the following figure).



Each panicle is represented by its panicle branches and the spikelets. The growth and development of each rice plant, each tiller and its components is individually simulated, and is affected by the biotic and abiotic environmental variables local to the specific plant, and tillers. A tillering algorithm was developed to simulate the tillering pattern of a rice plant starting with a seedling. Light interception of a rice plant is calculated based the leaf area of the plant and on the plant density local to the specific plant. The intercepted light is then distributed to each tiller and to each leaf of a tiller based on the vertical position of each leaf and its leaf area. Photosynthesis is simulated for each leaf of a tiller, and is affected by light interception and area of the leaf, CO_2 concentration, temperature, and nitrogen content. Growth respiration and maintenance respiration are also simulated for each tiller components (leaf blade, leaf sheath, culm, and root). Carbohydrate supply from each leaf is first allocated to the panicle and each node of a tiller depending on demand and allocation priorities of the panicle and the node. The allocated carbohydrate for each node is then further allocated to each component of the node (leaf blade, leaf sheath, culm, and root) depending on its demand and allocation priority. Nitrogen demand for a specific component is based on the component's carbohydrate demand and its potential maximum nitrogen ratio.

The simulated rice field is divided vertically into a number of layers, and each layer is divided into rectangular grid blocks of equal size (see the following figure).



Each rice plant and its tillers are identified by their coordinates in the field. The root mass of a tiller is first distributed vertically into each layer using a gamma distribution function, and the root mass in each layer is further distributed into adjacent grid blocks using an exponential distribution function. The nitrogen uptake from each involved grid block in each involved layer is then calculated based on the root surface area.

The system also simulates the processes which affect soil nitrogen supply, including nitrogen application, mineralization, nitrogen fixation and release, nitrogen nitrification and denitrification, and nitrogen volatilization and diffusion. Soil nitrogen diffusion in 3-D space is simulated using a modified gradient transfer theory model (McCartney et al. 1985, Yang et al. 1998). The variation in nitrogen concentration (C) in time and three-dimensional space is described in Cartesian coordinates by

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}(K_x \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial C}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial C}{\partial z}) - S(x,y,z) + R(x,y,z)$$

where C is the nitrogen concentration at the Cartesian coordinate [x, y, z]; K_x, K_y and K_z are the diffusion coefficients of soil nitrogen in the x, y and z directions, respectively; $S(x,y,z)$ is a sink term, representing nitrogen loss rate; $R(x,y,z)$ is a source term, representing nitrogen production rate. The equation states that the rate of increase in nitrogen concentration in a small volume $dxdydz$ equals the rate of nitrogen diffusion into the volume, $\frac{\partial}{\partial x}(K_x \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial C}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial C}{\partial z})$; minus the rate of nitrogen loss, $-S(x, y, z)$; plus the rate of nitrogen production, $R(x, y, z)$.

Because the individual-based approach deals directly with individual plant, tillers and tiller components, and the state (e.g. growth stage, mass, age) of each individual and its components is already built into the system, it does not depend on the traditional concepts of cohorts, age classes, and distributed delay process (Wu & Wilson 1998). The cohorts, the age classes, and the distributed delay processes are no longer the mechanisms which drive the system. Rather, they are the end results of the individual-based system. Because the individual-based approach works at a level of resolution much closer to physiological processes and to its physical environments, it offers a strong capability to incorporate into the system genetic variability, detailed physiological processes, and microenvironments, and it offers a promising opportunity for maximizing the integration of scientific knowledge across different disciplines and different levels of abstraction.

References

McCartney, H. A., and B. D. L. Fitt. 1985. Construction of dispersal models. p. 107-143. In: C. A. Gilligan (ed.) Advances in plant pathology: mathematical modelling of crop disease. Academic Press Inc., London, Orlando, San Diego, New York.

Wu, G. W., and L. T. Wilson. 1998. Parameterization, verification, and validation of a physiologically complex age-structured rice simulation model. Agricultural Systems 56: 483-511.

Yang, Y., L. T. Wilson, M. E. Makela & M. A. Marchetti. 1998. Accuracy of numerical methods in solving the advection-diffusion equation as applied to the study of spore and insect dispersal. Ecological Modelling, 109: 1-24.

2DSPUD, A TWO-DIMENSIONAL MODEL OF POTATO GROWTH AND DEVELOPMENT

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Potato is an intensively managed crop that requires large amounts of nutrients and water. Potato is also planted on hills or ridges which imposes a strong two-dimensional structure to infiltration and runoff. Our goal is to develop a mechanistic simulator of potato growth and development that is coupled with comprehensive two dimensional models of soil and atmospheric processes. The model calculates two-dimensional fluxes of water and movement of chemicals between rows and within the soil profile to simulate row position effects. The purpose of the model is to provide information on crop development stage, irrigation timing and amount, nitrogen fertilizer requirements and timing, and expected time to harvest.

There are a number of useful computer programs for the simulation of soil and atmospheric processes, and potato growth and development. Much of the modeling code that is currently available has also seen extensive use and testing. The ability to re-use code is a critical requirement to make full use of our investments. The use of a modular structure can facilitate the ability to choose the best tested and most appropriate code from an existing model and incorporate it into a new model. This will also allow us to match the level of detail between the plant and soil components. We have developed 2DSOIL, a modular two dimensional simulation model of soil and atmospheric processes, to be used for soil processes simulation in crop models. 2DSOIL is modular in the sense that components of the model can be added or removed with only minor modifications to the existing computer code. This model uses a finite element description of solute and water flow. Much of the code was adapted from SWMS_2D (water, solute and heat movement), SOIL-N (nitrogen dynamics), and GLYCIM (atmospheric and root processes). For potato growth and development we chose the model SIMPOTATO (Hodges, 1992). The model SIMPOTATO uses a daily time step and models photosynthesis on a canopy level using a parameter to model daily carbon assimilation as a function of the daily solar radiation integral. Temperature, nitrogen and water stresses are modeled using stress indices. The 2DSOIL model was incorporated into the potato simulation model, SIMPOTATO, (Hodges, 1992) to build the new model, 2DSPUD.

In order to simulate photosynthesis on a more mechanistic level, we added a coupled, leaf level model of photosynthesis, stomatal conductance, and transpiration (Kim, 2001). This allows a coupling of the supply function of diffusion of CO_2 through the stomata (as controlled by stomatal resistance) to the demand function of the CO_2 fixation reaction. Recent advances in gas-exchange systems greatly simplify the parameterization of the model. The model was parameterized using data from leaf level photosynthesis measurements. Canopy level photosynthesis measurements from the Alternate Crops and Systems Laboratory's SPAR (Soil Plant Atmosphere Research) chambers were used to evaluate the performance of the photosynthesis model. Simulated photosynthesis values did follow the measured data at the extremes of the temperature ranges. However, uncertainties in leaf age and canopy light interception were sources of error.

The use of a more detailed model of photosynthesis will allow us to model the effects of environmental stresses with less dependence on stress factors and provide a more realistic method to model the effects of climate change. The results suggest that a good canopy radiative transfer model is important to be able to scale leaf level photosynthesis to the canopy level. Future work will be directed toward this area. The addition of a more mechanistic model of photosynthesis will help us better understand the photosynthetic process in potatoes and the effects of environmental variables.

References

Hodges, T. 1992. A modular structure for crop simulation models: implemented in the SIMPOTATO model. Agron. J. 84:911-915

Kim, S. H. 2001. Photosynthesis models and canopy management optimization in cut-flower roses. Ph.D., University of California, Davis.

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