Cover Sheet
Agronomy Endowment Initiative Project Report

Project Title: An Agroecosystem Water Management Model: Coupling of Plant, Soil, and Climate Components

Year funding began: July, 2001

Principal Investigators: Robert Horton, Zaitao Pan, and William Batchelor

Collaborators: Ray Arritt, Fred Blackmer, William Gutowski, Mark Person, John Prueger, Moti Segal, Dennis Todey

Percentage of proposed work that is completed as of this date circle one):

10% 20% 33% 40% 60% 80% 100%

R. Horton/Z. Pan October 7, 2002

PI submitting report **Date**

1. Goals and Objectives of the project

The overall goal of this project is to create a coupled agroecosystem modeling system that allows crop producers to inventory, update, and project seasonal soil water availability at field scale for planning strategies on cropping, seed selection, chemical application, planting, harvest, and marketing. It also pursues the understanding of nonlinear interactions among individual components within the whole agroecosystems. The specific objectives of the project are:

- to couple best available crop, soil, and atmospheric models using telescoping two-way nesting,
- to gain insight into important feedback processes and fundamental science by conducting sensitivity simulations with the coupled model, and
- to forecast sub-seasonal to seasonal crop-available water over field to regional scales, and thereby allowing evaluation of alternative cropping strategies.

2. Describe briefly (not more than two paragraphs) how your project is contributing or will contribute to meeting the mission of one or more of the Initiatives.

This project brings together the best available tools and understanding of plant physiology, soil physics and chemistry, microclimatology, surface hydrology, regional climate projection, and data analysis and display. It forms an integrated modeling system for seasonal prediction of soil water availability at specific sites, as envisioned by the *Integrated Studies of Agroecosystems Initiative*. The developed modeling tool directly helps evaluate management strategies to optimize system performance by providing seasonal soil moisture forecasts and water stewardship. Adopting ensemble soil moisture simulations also directly depicts temporal and spatial heterogeneity of the agroecosystems, another sub-program under the Initiative. This project will interact closely with the soil measurement project and those CO_2 sequestration projects proposed under the Initiative.

While falling directly under the core programs of the *Integrated Studies of Agroecosystems*, this project is also closely related to the other three initiatives. For instance, predicted soil moisture along with climate change information can help policy makers involved in the *Agricultural Science and Policy Initiative*. The developed modeling tool can be configured as various class materials, promoting the *Education and Extension Initiative*.

3. What successes, expected or unexpected, have resulted from this project?

2002 quasi real-time prediction. We have set up an agroecosystem modeling system for quasi real-time seasonal prediction of soil moisture, precipitation, temperature, and other variables by nesting a regional model into a global forecast through lateral boundary conditions. The weekly model runs predict mean weather and soil conditions over Iowa 16 weeks in advance. The forecast products are displayed at http://www.pircs.iastate.edu/Endowment which will be linked to the Experimental Climate Prediction Center at Scripps Oceanographic Institution. These 16-week forecasts are one of the first regionally specific seasonal forecasts in the U.S. Current research here and elsewhere suggests that the use of ensembles would likely provide more reliable guidance than typical single-member runs. A six-member 16-week forecast of soil moisture showed a surprisingly good agreement with observations, given the length of forecast and high variability of soil moisture. All individual member forecasts captured the dry period in June and wet period in early July although they failed to capture the August soil moisture increase (Fig. 1). The model predicted trends very well although it has a systematic dry bias that can be manually corrected if it further persists in tests.

Direct input for soil moisture is precipitation. The temporal variation of precipitation was simulated reasonably well, reproducing the June dry period as indicated by the flat curves in Fig. 2 although forecasts underpredicted rainfall in all but one member of ensemble forecasts.

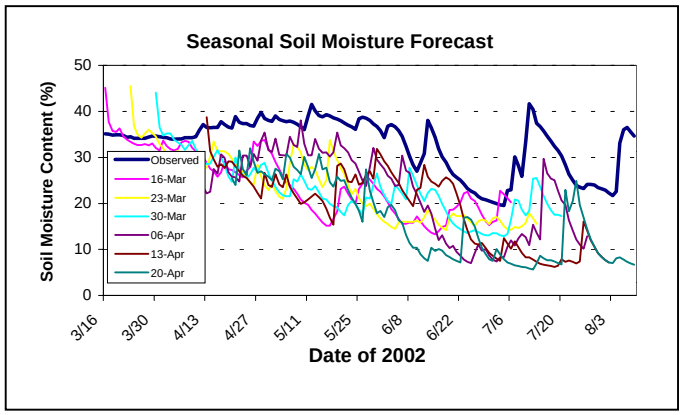

Fig. 1. Sixteen week-forecast of soil moisture at Ames, Iowa. Different lines represent ensemble members with varying starting week. Note all forecasts captured the June dry and early July wet periods.

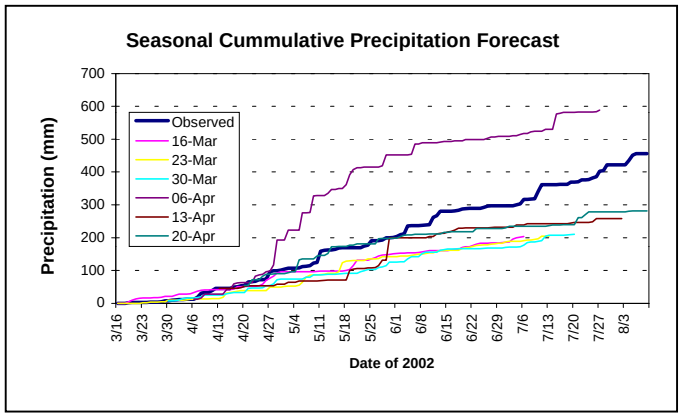

Fig. 2. Sixteen-week forecast of Iowa cumulative precipitation. Different lines represent ensemble members with varying starting week. Note all the forecasts captured the June dry period.

Component coupling. Currently the model has only crude parameterizations of surface hydrology and crop presentation. We are coupling crop model (CERES) and hydrological model (SWAT) to the modeling system. It is expected that the fully coupled model should further improve forecast skills.

4. List or describe the disciplines or subdisciplines involved in your project. Indicate those that are in the ISU Department of Agronomy

- Disciplines in Department of Agronomy
  - Agricultural climatology – precipitation, evapotranspiration, daily maximum/minimum temperatures, extreme/erratic weather events.
  - Soil physics – soil water, heat and nutrient transfer, soil carbon storage, root water extraction.
  - Crop modeling - yields dependence on climate, water usage efficiency, heat and water stress.
  - Agriculture system – agroecosystem modeling, landscape and landuse ecology, agricultural sustainability.
- Disciplines outside the Department

- Atmospheric science – El Nino/La Nino, convective storms, climate change.
- Water resources – stream flow contamination, soil erosion.
- Remote sensing – satellite observed NDVI, surface temperature.

5. List members PIs or collaborators on your project that you had collaborated with in this research/teaching/extension area before the endowment project.

William Batchelor, Dept. of Agricultural and Biosystems Engineering, ISU.
Ray Arritt, Dept. of Agronomy, ISU.
William Gutowski, Dept. of Geological and Atmospheric Sciences, ISU.
Moti Segal, Dept. of Agronomy, ISU.
Dennis Todey, Dept. of Agronomy, ISU.

6. List proposals have been submitted as an outgrowth of your endowment funded grant? Indicate the source of funding (e.g., USDA-SARE, NRI) and the current status of any proposals (funded, declined, pending).

- Pan, Z., E. Takle, and W. Batchelor: Test and evaluation of climate-ecosystem models, DOE National Institute for Global Environmental Change, $253,604, 7/2002-6/2005, funded.
- Takle, E. and Z. Pan: Basin scale water quality change and uncertainty under global climate change, Center for Global and Regional Environmental Research, Seed Grant Program, $19,500, 08/2001-07/2003, funded.
- Evaluating agricultural sustainability under future warm climate using climate-crop coupled models, to be submitted to NRI.

7. What personnel outside the Agronomy Department or ISU have been engaged in your endowment-funded research? Indicate the affiliation and position of each (e.g., faculty, student).

- William Batchelor, Assoc. Prof., Dept. of Agrcultral and Biosystems Engineering, ISU.
- Roy Gu, Assoc. Prof., Dept of Civil and Construction Engineering, ISU.
- Manoj Jha, Graduate student, Dept. of Civil and Construction Engineering, ISU.
- Dave Flory, Graduate student, Dept. of Geological and Atmospheric Sciences and Dept. of physics, ISU.
- John Roads, Director, Experimental Climate Prediction Center, Scripps Oceanographic Institution, CA.

8. Timeline for completion of work (may be revised from original):

- 12/31/02 - Analyzed 2002 growing season model forecasts
- 03/30/03 - Coupled climate-crop model; ready for real-time, interactive growing season prediction.
- 08/31/03 - Validated model; written manuscript on 2003 growing season forecast for publication.
- 06/30/04 - Fully coupled agroecosystem modeling system that can interactively forecast soil moisture and water resource management; written papers on the model along its forecast for publication.

9. **How will results of your work be made known to others (scientific publication, conference proceedings, workshop report, CD ROM, etc.)?**

Our major scientific findings are being and will continue to be published in peer reviewed journals. Technical details are presented at conferences. The seasonal forecast products are updated on the web, as following:

http://www.pircs.iastate.edu/Endowment, the website displaying seasonal forecasts that are updated weekly.

Segal, M., Z. Pan, and R. Arritt, 2002: On the effect of relative timing of diurnal and large-scale forcing as summer extreme rainfall characteristics over the central U.S. *Monthly Weather Review*, 130, 1442-1450.

Pan, Z., E. Takle, R. Horton, and M. Segal, 2002, Warm-seasonal soil moisture prediction using a coupled regional climate model. Preprint, 16th Conference on Hydrology, American Meteorological Society, Orlando, FL, Jan. 13-17, 2002.

Pan, Z. R. Horton, M. Segal, E. Takle, D. Herzmann, D. Todey, and J. Roads, 2003: Seasonal mositure preidiction using a climate-plat-soil coupled agroecosystem water management model, Prepint, 17th Conference on Hydrology, American Meteorological Society, Long Beach, CA, Feb. 9-13, 2003.

Pan, Z., 2002, Intercomparison of precipitation and forcing in simulating 1993 central U.S. flood, Presented at the International Severe Storm Workshop, Chinese Academy of Sciences, Chengdu, China, June 15-17, 2002.

Takle, E., Z. Pan, and D. Miller, 2003: Impacts assessment confidence based on uncertainty propagation from a regional climate model to a crop yield model, presented at 2nd ICTP Conference on Detection and Modeling of Regional Climate Change, Trieste, Italy, Sept. 30 – Oct. 4, 2002.