PROJECT DESCRIPTION

DECISION SUPPORT SYSTEM FOR REDUCING AGRICULTURAL RISKS CAUSED BY CLIMATE VARIABILITY

A proposal Submitted to the USDA-CSREES
for a Federal Administration Research Grant

By Florida State University
on Behalf of the Southeastern Climate Consortium (SECC)
July 1, 2009 to June 30, 2010

OBJECTIVES

Our long-term goal is to design, develop, and implement a prototype comprehensive information and decision support system. The purpose of this system is to inform farmers, ranchers, foresters, water resource managers, industry, and policy makers about climate risks and to identify management practices that can reduce risks and increase benefits by using this climate information. This system has been implemented on the Internet at http://*Agro*Climate.org. The system includes:

- Climate forecasts.
- State and regional outlooks for climate-related risks to agriculture and water resources.
- Commodity-based information and decision support for local users.
- Watershed-based forecast applications to water resources management.
- Feedback and evaluation of forecast tools and information products.

This is a long-term undertaking, which began in 2005. Our initial focus was the design of the system, implementation of a prototype system on the web, development and implementation of example information and decision aids, and evaluation of the overall design and potential value to users in the Southeastern USA. In 2004 we opened AgroClimate to the public and in 2008 we transferred the operational version of the site, now called *Agro*Climate, to the Florida Extension Services, though this project will continue to update the databases and improve the tools on *Agro*Climate

Specific objectives are:

1. Design and develop prototype climate forecast information.
2. Design and develop prototype state and regional agricultural and water resource outlooks.
3. Design and develop prototype commodity-based decision support system.
4. Design and develop prototype watershed-based decision support system.

5. Educate producers and their advisors on the applications of climate–based decision support systems and evaluate the design and potential value of decision support tools and systems.

In 2008 North Carolina State University joined our research and extension consortium so that the Southeast Climate Consortium now includes 7 universities, namely, Florida State University, University of Florida, University of Miami, University of Georgia, Auburn University, University of Alabama-Huntsville, and North Carolina State University. In 2009, Clemson University plans to join the consortium, which will raise our numbers to eight universities.

PROGRESS REPORT – JULY 1, 2008 THROUGH MAY 1, 2009

Here we summarize the important accomplishments and impacts of the past year for the prime, florida state university. More detail is given with the individual institution subcontracts that are attached to the proposal.

Florida State University

Activity 1: Data gathering and analysis.

Raw weather data updated were collected and the database is available to all SECC members and other interested parties at a common ftp site: ftp://secc.coaps.fsu.edu. An important development in 2008 was the establishment of a new method for computing the El Niño Southern Oscillation (ENSO) phase. The traditional approach developed by the Japan Meteorological Association (JMA) established one ENSO phase per year, in October. The new system allows revision of the ENSO phase as sea surface temperatures change during the year, which has greatly enhanced our ability to predict climate trends during the spring and summer.

Activity 2: Outreach and training for extension and other users.

The SECC has a very active outreach and education program, which is critical to our activities. A climate expert has participated in most extension workshops, training sessions, trade shows, etc. Their expertise is needed to give an overview of climate sciences and to field difficult questions on scientific issues. The climate program will continue this level of support for all SECC outreach activities.

Activity 3: Expand efforts in wildfire and forestry.

An improved KBDI forecast format was developed through many discussions with fire weather experts at the Florida Division of Forestry, the Georgia Forestry Commission, USDA Forest Service, and with extension forestry specialists. The final product resulted after several versions and subsequent refinements from user feedback.

Activity 4: Linkage of crop and climate models.

4.1. Develop downscaled ENSO Climate Information and Forecasts for the Southeast USA

Climate information only has value when there is a clearly defined benefit, once the content of the information is applied in the decision making process. *Agro*Climate is a response to the need for information and tools on proactive adaptations to seasonal climate variability forecasts in the southeastern US. Extension agents, agricultural producers, forest managers, crop consultants, and policy makers may use this decision support system to aid in decision making concerning management adjustments in light of climate forecasts. Adaptations include those that might mitigate potential losses as well as maximize yields. The tools section contains two applications that allow a user to examine the climate forecast for his/her county based on the ENSO phase and to evaluate yield potentials for certain crops. AgroClimate is now operational under the Southeast Climate Consortium and several upgrades are under development and consideration.

4.2. Dynamically downscaled regional forecasts for agriculture

In order to build a firm bridge between the numerical climate model and crop simulation model, the following details must be studied. First, we investigated the performance of the Community Land Model 2 in the seasonal dynamical downscaling of surface fields (maximum and minimum temperatures, precipitation, and solar radiation) through the FSU regional climate model (Shin et al. 2005) and explored the suitability of these surface fields for crop yield estimations using a state-of-the-art process-based crop model (e.g., DSSAT 4.0 family of crop models). These models are able to simulate between 2.5 and 10% of the observed yields when accurate data for crops, soils, and weather are available (Mavromatis et al. 2002). Preliminary finding indicate a skillful prediction of peanut yield was achieved using a crop model forced with ten years of daily data from the FSU model. The average rainfall amount was similar to that observed, resulting in similar water stresses during the reproductive phases of peanut growth.

University of Florida

Objective 1: Develop drought index forecasts
- 1.1. Finalize LGMI forecast for release on AgroClimate
- 1.2. Comparing WDI with other drought indices

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Objective 2: Characterize uncertainty associated with predicted agricultural responses using climate forecast information.
- 2.1. Uncertainties in cotton model parameters and associated uncertainty in yield predictions.
- 2.2. Modification and release of improved crop models
  - *2.2.1. Improved soil evaporation model*
  - *2.2.2. Improved organic carbon model*

Objective 3: Integrate agricultural and hydrological models
- 3.1. Nutrient flow analysis of Little River watershed
  - *3.1.1. Spectral time series model prediction of water quality in the Little River watershed.*
  - *3.1.2. Link and apply WAM and DSSAT models.*
- 3.2. Exploring annual to decadal climate forecast use in water resources management in South Florida
- 3.3. Simulating water resources management under variable and changing climate in the Apalachicola-Chattahoochee-Flint (ACF) River basin

Objective 4: Enhance climate risk analysis products
- 4.1. New crops

4.2. Translating climate forecasts into crop yield forecasts using a geospatial-temporal weather generator

4.3. Coupling crop and land surface models for the FSU regional climate model

*4.3.1. C*ouple DSSAT 4.5 with CLM2

4.3.2. Assessing the influence of land development patterns on regional climate using regional circulation models

4.4. Evaluate use of ocean/climate indices to forecast agricultural variables

4.4.1. Use of Atlantic and Pacific sea surface temperatures to forecast corn yields in the southeast USA

4.4.2. Evaluate use of ocean/climate indices to forecast agricultural variables

Objective 5: Transition of *AgroClimate* from Research to Extension

Objective 6: Developing methods for use of the new monthly ENSO classification scheme in crop yield tools

6.1. Evaluate the use of weather generator data parameterized using the new ENSO classification scheme

University of Georgia

Activity 1: Design and Develop Prototype Climate Forecast Information.

1.1. ENSO Climate Outlooks and Forestry

1.2. Climate Sensitivity Analysis of Georgia Winter Fruit and Vegetables

Activity 2: Evaluation and application of the peanut, cotton and other crop simulation models for climate forecast applications and risk management in Georgia, Alabama, and Florida.

2.1. Crop model calibration and evaluation

2.2. Weather data generation

Activity 3: Design and develop prototype state and regional agricultural and water resource outlooks

Activity 4: Design and develop prototype commodity-based decision support system

4.1 Calibration and evaluation of the cropping system model CROPGRO-Peanut

4.2 Evaluation of the cropping system model CROPGRO-Cotton

4.3 Prototype irrigation decision support system

Activity 5: Design and develop prototype watershed-based decision support system.

5.1 Integrating agricultural and hydrological models

5.2 Streamflow analysis

University of Miami

Activity 1: Climate information and income

Activity 2: Assessment and evaluation

Activity 3: Influence of persistent SST forcing on precipitation in the southeastern USA
Activity 4: Factors influencing the incorporation of climate into water resource management in Florida

Auburn University

Activity 1: Economic modeling of implications of climate and yield forecasts on agriculture and user education program
Activity 2: Economic modeling of climate information on crop insurance
Activity 3: Bio-economic modeling.

University of Alabama -- Huntsville

Activity 1: Analysis of future climate projections on southeast agriculture
Activity 2: Engineering analysis of on-farm storage ponds
Activity 3: Expansion of surface moisture indices
Activity 4: Water policy

North Carolina State University

Activity 1: SECC CRONOS enhancement
Activity 2: High spatial resolution soil moisture maps for *Agro*Climate decision support
Activity 3: New and improved *Agro*Climate tools for crop and pest management
Activity 4: Precollege education

Clemson University

Activity 1: Climate risk and county yield database in *Agro*Climate for South Carolina
Activity 2: Collect climate data from appropriate weather stations and evaluate data quality
Activity 3: Collect soil and crop data needed to run crop simulation models
Activity 4: Collaborate in application of these data to climate and crop yield tools for South Carolina

PROCEDURES

1. Climate Forecasts

This component of the project has developed prototype climate forecast products that are updated quarterly, including a tutorial that explains the different forms of climate forecasts. The tutorial prototype is written at the level of the lay user and emphasizes the uncertainty associated with the different forecast products.

2. Water Resources

This component produce interpreted maps and text of variables important to decision makers in agriculture, forestry, and water resource management in the Southeast. Outlooks emphasize drought, freeze, and other extreme events. Feedback from users suggests that they have difficulty understanding data presented in the form of probabilities, so we will continue to explore alternative formats for communicating this probabilistic information. In addition to probability distributions, some textual information is provided specific to the coming season, ENSO phase, commodity, and watershed

3. Commodity-based Information and Decision Support Systems for Local Users

The SECC has created *Agro*Climate, a web site that includes climate and commodity information for agricultural decision makers.

4. Watershed-based Forecast Applications to Water Resources Management

For this component, we will focus on watersheds that include both agricultural and municipal water users and for which other projects have already conducted appropriate hydrological studies.

5. Education, Feedback, and Evaluation of Forecast Tools and Information Products

This component of the project had two broad objectives: 1) to education stakeholders and users about climate information and products; and 2) to inform SECC members, sponsors, and other stakeholders about the user responses to and use of other project components, as well as the potential economic value of each component.

Objectives, Progress Reports, and Work Plans for Participating Institutions

Specific objectives and work plans for each institution are attached as appendices.

JUSTIFICATION

Climate variability causes considerable economic risk to the agricultural, forest, and water resources in the southeastern USA. In the southeastern USA, estimates of crop losses during a single drought year exceed $1 billion. The hurricanes of 2004 caused about $38 billion in losses and losses from hurricanes in 2005 exceeded this amount. The multi-year drought in the northern part of our region during 2006 through 2009 has led to continuing friction among the different states and sectors that depend on water flowing through the major hydrological basins of the region. One late frost event in Georgia caused a loss of $250,000 on one blueberry farm alone. Climate extremes associated with drought, floods, freezing temperatures, and hurricanes can be predicted with increasing levels of skill. If decision makers were aware of probable climate conditions several months in advance, they could adjust their resource management practices to reduce risks of crop losses, forest fires, or water shortages that arise from extreme variation in climate. Our research team has developed considerable information on impacts of climate variability on agriculture and forests in the southeast USA, as well as identifying management options that reducing risk from climate stresses or taking advantage of anticipated favorable climate conditions.

The Southeastern Climate Consortium (SECC) now includes seven member institutions in three states – Florida, Georgia, Alabama, and North Carolina – and we anticipate adding Clemson University in South Carolina during 2009. The SECC mission is to provide scientifically based climate, climate impact, and response option information to appropriate decision makers that are responsible for managing land, water, and air resources. Our target user groups include farmers, ranchers, foresters, and reservoir managers. The SECC has its major activities in research, but also has established strong partnerships with outreach entities to ensure that research is relevant to users and that the products of our research reach users through equitably and reliably. The SECC research aims to strengthen decision-making, knowledge application, economic security, and environmental stewardship in the Southeast USA.

A grant from the USDA-Risk Management Agency (RMA) allowed the SECC to add Auburn University and the University of Alabama-Huntsville to its membership and to increase the level of participation for the University of Georgia. This award also allowed the SECC to increase its effort in extension. This 2-year grant from RMA was extended for 18 months from September 2005 through March 2007 to support additional extension and education efforts. A second continuation of this project allowed us to add North Carolina State University to our consortium in 2008. The SECC actively promotes collaboration among members through regular meeting or research teams as well as annual program review and planning meetings.

The SECC first received funding through a Federal Administration Research Grant (FARG) in 2003. We now propose activities for July 1, 2009 through June 30, 2010 in a renewal of this research project. This new project builds directly on the progress of activities conducted in the initial phases of the FARG, as well as on project activities funded by NOAA, RMA, and other agencies. The requested funds will allow us to increase the numbers of crops included in the prototype agriculture and forestry decision support systems, to implement the prototypes as an operational web site, to develop additional information and tools as requested by agricultural and other users, to develop new prototype decision support systems for water resource management, to provide additional training for county agents and to further interact with our stakeholders to help identify their needs.

LITERATURE REVIEW

Climate forecasts

The central hypothesis of this proposal is that access to improved climate and weather information will enable agricultural and water resource managers to make better decisions and to reduce risks and insurance payments for crop losses. Climate variability is a major source of risk to farmers, ranchers, foresters, and water resource managers in the Southeastern USA. In each of two recent years of extreme climate events, 1995 and 1999, insurance claims paid for crop losses exceeded $150 million in the three states of Florida, Georgia, and Alabama (USDA, 1995, 1999). The Florida Department of Agriculture and Consumer Services estimated that losses to crops, livestock, and forests caused by the strong 1997-1998 El Niño event exceeded $650 million (FL DACS, 1999).

Newly developed capabilities for forecasting climate several months into the future have major financial implications for agriculture. Most of these climate forecasts are based on the El Niño Southern Oscillation (ENSO) phenomenon, which is related to changing sea surface temperatures off the western coast of South America. These ENSO events have clear influences on the climate of the Southeast USA (Ropelewski and Halpert, 1986, 1987; Rogers, 1988), varying both in magnitude and spatial distribution (Sittel, 1994; Green et al., 1997). In the Southeast, El Niño events typically cause lower winter temperatures than those associated with neutral or La Niña events. During El Niño events, precipitation is higher in the Gulf Coast states in the winter and is higher during the spring throughout the region. In summer, climate impacts of El Niño events are more localized, including drier conditions along the Atlantic Coast and from north Texas to northern Alabama. With a few exceptions, La Niña events show the reverse trends to the climate anomalies associated with El Niño events.

Simulating weather associated with ENSO phases

A challenge to the application of crop simulation models to help identify crop management strategies appropriate under different climate forecasts is the need to simulate weather variables in a way that is statistically consistent with historical records. As part of work sponsored by USDA-RMA, we implemented an innovative non-parametric weather generator based on a direct resampling of historical weather data using a conditional bootstrap based on nearest neighbor probability density estimation (Rajagopalan and Lall, 1999).

Recent developments of stochastic nonparametric weather generators and their successful applications (Rajagopalan and Lall, 1999; Yates et al., 2003; Clark et al., 2003) are attractive alternatives to traditional parametric approaches. Nonparametric methods avoid subjective judgments about appropriate model forms and probability distributions, which are rarely tested formally. Furthermore, as data-driven methods, they can capture deviations from theoretical probability distributions and nonlinearities in the associations among variables (Rajagopalan and Lall, 1999). As the number of weather variables and desired periods increases, more parameters must be estimated; with short historical records, this can lead to unstable parametric models. In contrast, nonparametric methods are more parsimonious.

For most agricultural applications, stochastic weather series can be generated on a site-by-site basis. In contrast, many hydrological applications require that weather sequences be generated simultaneously for multiple sites, that is, for several meteorological stations inside a watershed, while preserving the spatial correlation among stations. Various methods have been proposed to extend single-site methods to the generation of weather at multiple sites (Wilks, 1998; Qian et al., 2002; Kottegoda et al., 2003; Wilby et al., 2003). The K-NN generator of Rajagopalan and Lall (1999) has been adapted to simulate weather variables in various locations simultaneously (Buishand and Brandsma, 2001) and may be suited to watersheds of the southeastern USA.

ENSO effects on crop productivity

Previous SECC research shows that ENSO has strong effects on most crops in the Southeast (Hansen et al., 1988a, b; Hansen et al., 2001). This relationship suggests that crop producers may benefit if they use climate forecasts to alter management of field crops or the mix of crops planted (Jones et al., 2000). Analysis of historical crop yields shows that ENSO significantly influenced productivity of maize, wheat, cotton, tomato, rice, sugarcane, and hay in eight southeastern states (Hansen et al., 1998s). The ENSO phase explained a shift of $212 million, or 26% of the long-term average, inflation adjusted value of maize, and $133 million, or 18%, for soybean in a four-state region (Hansen et al., 1988a). Analyses also show that ENSO influenced high value specialty crops in Florida, such as citrus, tomato, bell pepper, snap beans, and sweet corn (Hansen et al., 1998b).

CURRENT WORK

Members of the Southeastern Climate Consortium are actively engaged in research on risks to agricultural and water resources from climate variability. Research and extension activities were initiated with funding from NOAA, followed by additional funding from USDA RMA. The activities described in this program are a direct evolution from these ongoing collaborative efforts among the consortium members as they identify potential users of climate information, including climate forecasts, and create tools that allow users to apply climate forecasts to their own situation. This work includes data collection, generation of forecasts, developing and using simulation models to link climate, agriculture, and water resource systems, as well as understanding the economic and policy environments that affect how farmers and other climate information users apply that information. More details on current activities germane to this proposal are given in the progress report above.

FACILITIES AND EQUIPMENT

Florida State University

Computer Equipment: COAPS has more than 60 computer workstations, which include PC clones, Macintosh computers, and numerous Silicon Graphics (SGI) workstations. COAPS SGI computing resources include: an Origin 2000 with 24 250-MHz CPUs and 6 GB memory, a second Origin 2000 with 4 195-MHz CPUs and 2.5 GB memory, an Origin 3400 with 8 40-MHz CPUs and 2 GB memory, two Origin 200s, two ONYX computers, and three OCTANE (3-D visualization) workstations for high performance computing and scientific visualization..

FSU Supercomputers: COAPS personnel have free access to FSU supercomputers, including one 168 CPU IBM SP Power 3 supercomputer and one 512 CPU IBM Power 4 supercomputer. The latter has 1GB of memory per processor and is one of the most powerful computers nationwide. This places FSU near the top of universities as far as computational resources.

University of Miami

The Rosensteil School of Marine and Atmospheric Science includes the new Center for Southeastern Tropical Advanced Remote Sensing (CTARS) a new facility for conducting research with remotely sensed data received from earth-orbiting satellite systems.

University of Florida

Researchers at the University of Florida have access to extensive computer and technology facilities.

University of Georgia

UGA-Athens: Houses the Office of the State Climatologist, with all computer and communications equipment needed.

UGA-Griffin: The Department of Biological and Agricultural Engineering currently has an Agrometeorology Laboratory that is equipped with several computers systems for interrogating automated weather stations via dedicated telephone lines, data processing and dissemination of information via the internet (www.Georgiaweather.net).

University of Alabama-Huntsville

All work by UAH will be performed at the National Space Science and Technology Center, a consortium of university, NASA, and NOAA scientists. The center includes the Office of the State Climatologist will all equipment and facilities needed to forecast daily SE weather, collect and process remotely sensing data, and provide logistical support for project scientists, so this location does not ask for any infrastructure to be purchased under the grant.

Auburn University

Research to be conducted at Auburn will be primarily economic analyses, for which all computational and other equipment are already available.

North Carolina State University

The state climatologist for North Carolina, Dr. Ryan Boyles, is located at NCSU and has begun to collaborate actively in the area of database development. Dr. Boyles is assembling all available daily data to be made available to other SECC researchers to allow daily or weekly updating or our climate products.

PROJECT TIMETABLE

Component/Activity	Year 1				Year 2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Climate forecast component								
Database updating and analysis	X	X	X	X	X	X	X	X
ENSO phase assessment			X				X	
Simulating weather data for climate scenarios	X	X	X	X				
Experimental down-scaled forecast		X		X		X		X
2. Regional Component								
Wild fire forecast			X	X			X	X
Freeze forecast		X	X			X	X	
Assess format for ARID drought index	X	X	X	X				
Support national integrated drought information system	X	X	X	X	X	X	X	X
Transfer special climate products	X	X	X					
3. Local commodity component								
Link crop and climate models	X	X	X	X	X	X	X	X
Evaluate and apply new crop simulation models	X	X	X	X	X	X	X	X
Develop methods for dynamic updating of *AgroClimate*	X		X		X		X	
Expand climate risk anal. to new crops/locations	X	X	X	X	X	X	X	X
Develop new decision support tools	X	X			X	X		
Characterize ag. model uncertainty	X	X	X	X	X	X	X	X
Economic models of climate effects on agric.	X	X	X	X	X	X	X	X
Economics of crop insurance *vis a vis* climate risk	X	X	X	X				
Using crop and climate insurance to reduce risk	X	X	X	X	X	X		
Outreach and training for extension, users			X	X			X	X
Expand crops in *AgroClimate*								
Pasture	X	X	X	X				
Maize					X	X	X	X
Train additional forestry extension agents	X	X	X	X				
Economic implications of climate forecasts	X	X	X	X	X	X	X	X
Simulate rainfed/irrig. ag. at different times, AL	X	X	X	X				
Strategies for on-site seasonal storage ponds		X	X	X	X	X	X	

Component/Activity	Year 1				Year 1			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
4. Watershed component								
Integrate agric and hydrologic models	X	X	X	X	X	X	X	X
Simulate watershed responses to climate	X	X						
Assess water and land management options			X	X	X			
Transfer methods to Flint River watershed	X	X	X	X	X			
Assess value of climate information to water policy	X	X	X	X	X			
Impact of hydro-climatology on agriculture	X	X	X	X				
Simulate effects of irrigated ag. on stream flows					X	X	X	X
Stakeholder assessment for water resources	X	X	X	X				
Assess value & needs for water management DSS	X	X	X	X	X	X	X	X
5. Education and Evaluation component								
Meet regularly with advisory panels to evaluate SECC products	X		X		X		X	
Data gathering and evaluation	X	X	X	X	X	X	X	X
Survey and interview of clientele	X	X			X	X		

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KEY PERSONNEL

Key project personnel are listed below. The curriculum for Dr. J.J. O'Brien follows, whereas curricula vita for all others accompany the work plans for the sub-grants.

1. Dr. James J. O'Brien, Project Director and Director, COAPS, Florida State University
2. Dr. James W. Jones, Institutional P.I., Agricultural & Biological Engineering Department, University of Florida
3. Dr. David Letson, Institutional P.I., Rosenstiel School of Marine & Atmospheric Sciences, University of Miami
4. Dr. Gerrit Hoogenboom, Institutional P.I., Biological & Agricultural Engineering Department, The University of Georgia
5. Dr. J. Novak, Institutional P.I., Dep. of Agricultural Economics & Rural Sociology, Auburn University
6. Dr. Puneet Srivastava, Co-P.I. Department of Biosystems Engineering, Auburn University
7. Dr. John R. Christy, Institutional P.I., Earth Systems Science Center, University of Alabama-Huntsville
8. Dr. Keith T. Ingram, SECC Coordinator and Co-PI, Agricultural & Biological Eng. Department, Univ. of Florida
9. Dr. David Stooksbury, Co-PI, Biological & Agricultural Engineering Department, The University of Georgia
10. Dr. Gail Wilkerson, Institutional P.I., Crop Science Department, North Carolina State University.

COLLABORATIVE ARRANGEMENTS

PROJECT MANAGEMENT

Dr. J.J. O'Brien, Florida State University, will be responsible for the overall project, including coordination of work performed in subcontracts, coordinating meetings, and reporting findings to USDA-CSREES. Dr. K.T. Ingram, University of Florida, will support project coordination as part of his responsibility for coordination of the SECC, including facilitating collaboration and communication among institutions, writing reports, and serving as liaison among investigators, the CSREES project manager, and other regional climate research teams. Florida State University will serve as host institution, with the other five universities linked via subcontracts. Key personnel on the proposed project have extensive experience in research on climate variability, its affects on agricultural systems, and on the potential value of climate forecasts to reduce economic risks to producers in the Southeastern USA. The team includes experts in climate modeling, crop modeling, agricultural systems, hydrologic modeling, meteorology, and economics, and includes State Climatologists from three states. In addition, the investigators have developed close cooperation with Extension Services and are involved in training activities aimed at providing Extension Agents with the understanding of climate and weather impacts on agricultural systems that these agents will need in order to effectively teach client groups how to use the climate forecast tools developed in the project.

SUBCONTRACTS

Work to be done within each subcontract is explained in the appendices to the project description.