Responding to stakeholder’s demands for climate information: from research to applications in Florida


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Abstract

Previous research shows that Florida’s climate and agricultural production are influenced by the El Niño-Southern Oscillation, suggesting that farmers and ranchers might use new methods of climate forecasting to modify management, increase profits and reduce economic risks. The purposes of this paper are to describe the framework used by a Florida Consortium (FC) of researchers to assess the potential use of climate forecasts in agricultural decision-making and to summarize what was learned in the research process. The framework includes components for generation, communication and use of climate information as well as an implementation and evaluation component. Results showed that winter months are affected most by ENSO phase (higher rainfall and lower temperatures in El Niño years and the opposite during La Niña years). Yields of most crops were significantly associated with ENSO phase as were prices of some commodities. Through various mechanisms of interacting with farmers, ranchers, and extension faculty, we learned that interest in climate forecasts varied widely from highly optimistic to skeptical, and that these clients had good ideas of how to vary management if they have good forecasts. Case studies aimed at understanding potential value and risks associated with use of climate forecasts were conducted for winter fresh market tomato, cow-calf operations, and peanut production. Analytical results, confirmed by interactions with clients, showed significant value in using climate forecasts to alter specific decisions. Risks of using climate information varied among commodities, with considerable
risk found in tomato due to the strong link between production and price. Perhaps the most important lesson learned was the importance of engaging trusted advisors in research and outreach efforts. A major output of the project was the close cooperation established between the FC and the Florida Cooperative Extension Service. Prospects for sustaining a climate information program in Florida are high due to joint research and extension initiatives. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The El Niño-Southern Oscillation (ENSO) is the strongest driver of interannual climate variability around the world (Ropelewski and Halpert, 1996) and its impact on climate of the southeast (SE) USA is well-documented (Ropelewski and Halpert, 1986; Rogers, 1988; Sittel, 1994a; Green et al., 1997). Through its influence on climate, ENSO affects crop yields in many parts of the world (Nichols, 1985; Handler, 1990; Garnet and Khandekar, 1992; Cane et al., 1994; Rosenzweig, 1994; Carlson et al., 1996; Rao et al., 1997; Hansen et al., 1999, 2001; Podestá et al., 1999), soybean futures prices in the USA (Keppenne, 1995), and the gross value of Australian crops (Nicholls, 1985). Along with increased understanding and predictability of ENSO (Latif et al., 1994, 1998; National Research Council, 1996), has come increased awareness of potential opportunities to utilize forecasts (Adams et al., 1995; Jones et al., 2000; Mavromatis et al., 2002) either to increase food production and profit or reduce risks. Achieving this potential requires significant dialog between, and amongst, the science community and the existing and potential users of climate information (Hammer et al., 2001). Current experience is limited when it comes to applying imperfect climate forecast skill to management issues. Agricultural decision makers need to understand these uncertainties, in terms of their own production systems and other sources of risks, before they can effectively use them (Sonka et al., 1986, 1987, 1992; Podestá et al., 1999).

Agriculture is one of the most important sectors in the southeastern United States (SE USA), contributing about $33 billion in 1997 to the economy, with crop production valued at about $14 billion (USDA, 1997). Climate variability is a major source of risk to farmers and ranchers in this region. Vulnerability of Florida’s agriculture to climate fluctuations and weather extremes and demand for climate information from stakeholders (farmers, ranchers, agribusiness managers, extension advisors and others in the agricultural sector) contributed to the formation of the Florida Consortium (FC) to capitalize on the potential predictability of climate. The FC consists of an interdisciplinary team of researchers from three universities in Florida: Florida State University, University of Florida and University of Miami. The goal of this consortium is to reduce economic risks and improve social and economic well being by facilitating the routine and effective use of climate forecasts for agricultural decision-making. The FC objectives aim to bridge the gap between those who supply climate forecasts and those who make agricultural decisions or policies. They are to: (1) characterize stakeholder needs, uses and perceptions of
climate forecasts to guide product design and approaches for routine agricultural uses, (2) adapt and enhance research tools, methods, and data products for translating climate forecasts into information required to support agricultural decision making, (3) evaluate the usefulness and limitations of climate forecasts to help stakeholders understand risks for specific applications and gain confidence in their use, and (4) build mechanisms for developing and delivering useful climate forecast applications.

Learning how to use climate prediction to make better decisions is an evolutionary process with potentially major impacts. To have lasting impact, this new technology must be integrated into existing institutions. The purposes of this paper are to (1) describe the approach that FC is using to address the four objectives above, (2) discuss important lessons that were learnt from stakeholders, including their perceptions about the use of climate information, and (3) explain how activities are evolving from research to applications of climate information in Florida in partnership with the Florida Cooperative Extension Service.

2. Framework for a climate information system

There have been significant and increasing efforts devoted in various parts of the world to applying climate information to improve agricultural systems (Mavromatis et al., 2002; Hammer et al., 2000; Jones et al., 2000; Messina et al., 1999; Phillip et al., 1999; Podestá et al., 1999; Meinke and Hammer, 1995). This research has identified key issues and resulted in considerable understanding of the process. The complexities of the problem call for a concerted research effort, integrated across the physical, biological and social sciences, to bridge the gap between current climate forecast capabilities and the information needs of stakeholders. Much of the FCs early effort was devoted to developing, implementing and testing tools and methodology, including methods for processing and analyzing time-series data; use of weather sensitive crop models, weather generators, optimization procedures, economic and risk analysis; and interactions with stakeholders. These activities were guided by a framework (Fig. 1) that has four integrated components that encapsulate: (1) the generation of climate information; (2) the communication of climate information, (3) the use of climate information, and (4) the implementation and evaluation of these first three components (Jones et al., 2001b; Hook and Pielke Jr., 2000). The FC had parallel activities in each of these components and the feedback received contributed to their efficient functioning. The following sections briefly describe what was done in each of these components, and relevant findings.

2.1. The generation of climate information

The generation of climate information focused on diagnostic analysis of historical climate and agricultural data and the role of ENSO in shaping up climate and eventual impact on agriculture using models to create advisories for stakeholders.
2.1.1. ENSO and Florida’s climate

The dynamic interplay between atmosphere and ocean causes variability of different magnitudes in climate regimes ranging from tropical in south Florida to more temperate in north Florida. In a statewide study, monthly averages of temperature and precipitation were computed for El Niño, La Niña and Neutral years (JMA, 1991) at a network of 88 cooperative weather stations in Florida for the period 1948–1998. Sittel (1994b) showed that rainfall is highly sensitive to ENSO phases, with an average excess of about 40% of the normal rainfall across most of the state during an El Niño winter (October–December). La Niña has the opposite effect, with deficits of about 30% lasting from fall through spring (July–April). During the summer crop production season, rainfall is erratic and lower (higher) during El Niño (La Niña). Florida gets few Atlantic hurricane landfalls during El Niño years (O’Brien et al., 1996).

The monthly deviations from average daily maximum or minimum temperatures associated with El Niño or La Niña are much smaller than the average differences between seasons. However, departures from normal are substantial in Florida, especially during winter months. Florida can expect to see average temperatures 1–2 °C below normal during El Niño years. La Niña has the opposite effect, with temperatures 1–2 °C above normal during winter months. In the winter and spring months, average daily maximum temperatures are higher than normal in La Niña years, and lower than normal in El Niño years. Martzolf (2002) identified 12 major winter freezes in central Florida through the last century, 11 of which were during Neutral phases. Additional analysis by the FC showed that in parts of northeast, central, and south Florida, nights with freezing minimum temperatures below −7 °C are up to three times more likely to occur in Neutral years than during El Niño or

Fig. 1. A conceptual framework for the effective use of climate information, including ENSO related forecasts (adapted from a framework presented in Jones et al., 2001a; Hook and Pielke Jr., 2000).
La Niña events, with freezes in La Niña years being the least likely (Fig. 2). For example in white areas of northern Florida, freezes of different thresholds are relatively common in all years. In the hatched areas of south Florida, freeze events are rare in all years. The probabilities are expressed in terms of Neutral vs. El Niño and La Niña years because of the greater occurrence of freeze events during both previous El Niño and La Niña years. At the request of a tropical aquatic specialist, the analysis and forecast was expanded to include extended freeze events of three days or longer.

2.1.2. ENSO influence on Florida’s agriculture

El Niño and La Niña, through their relatively predictable influence on the climate of Florida, exert considerable influence on agricultural production. Hansen et al. (1998, 1999) found that ENSO influenced high value crops in Florida, such as citrus, tomato, bell pepper, snap beans, and sweet corn. During El Niño years, mean winter yields decreased (relative to long-term average in Neutral years) to 77% for tomatoes, 77% bell pepper, 83% sweet corn, and 83% snap beans. El Niño events increased mean sugarcane yields to 107% following La Niña years, and increased yields of grapefruit 109% and tangerines 116% but decreased lime yields to 86% in harvests following El Niño events. During El Niño years prices of bell pepper and snap beans increased by 31%. These effects extend to several neighboring states of the SE USA (Hansen et al., 2001).

2.2. Communication of climate information

The communication process has been identified as a challenge to the effective use of climate information (Hammer et al., 2001; Jagtap et al., 2001; Keating and
McCown, 2001). For this reason, the FC team devoted a great deal of time and effort in distributing climate information and maintaining interactions with various groups of stakeholders (i.e. extension specialists and agents, growers and ranchers) to learn about existing decision-making processes, institutions that influence them, and how weather and climate information could be used to improve decisions. Several mechanisms were used to engage stakeholders. These interactions with stakeholders inspired research and showed that there is a considerable diversity among farmers in the lead-time requirements of climatic forecasts and perceived flexibility to adjust management in response to forecasts. Given that farmers have not had enough experience or learning time to evaluate alternatives, actual flexibility for altering decisions may increase with incentive and understanding.

2.2.1. Internet presence on the Florida Automated Weather Network (FAWN)

The FC delivers both prognostic and diagnostic climate information via FAWN. The Florida Cooperative Extension Services (FCES) of the University of Florida developed and operates FAWN (http://www.fawn.ifas.ufl.edu). FAWN was created at the request of various grower organizations in 1998 after the National Weather Service stopped providing specialized frost and freeze warnings. Subsequently, a devastating freeze in January 1997 caused over $300 million damage to the citrus crop. FAWN provides up to date weather information through a series of about 22 automated weather stations distributed throughout the state of Florida. FAWN provides real-time weather data collected at 15-min intervals, weather data archive, management aids, educational materials and training programs. FAWN design provided an ideal framework for incorporating climate information and management aids targeted for specific commodities or clientele. Because of cooperative efforts with the FC, FAWN now includes a new Internet home page designed to provide climate forecast information to the agricultural community in Florida. The website is designed to produce graphs of mean monthly temperature and precipitation anomalies associated with El Niño and La Niña on demand. Monthly graphs show the patterns of mean monthly anomalies for each ENSO phase for any of the 88 sites selected by the user. FAWN also provides users with probabilistic presentations of monthly climate variables, expressed as smoothed histograms or time series plots, segregated by ENSO phase.

In October 2001, based on the forecast for neutral ENSO phase during the winter of 2001–2002, the freeze forecast was posted on FAWN, and circulated to Extension offices in every county, and the Florida Department of Agriculture. This advisory included color-coded maps showing the risk for freeze events (Fig. 2) of varying thresholds, a short discussion of the forecast and the general winter jet stream patterns associated with the different ENSO phases. The form of the forecast was based on input from extension advisors and growers on what information is useful and easily understood. By March 2002, north Florida and central Florida experienced 3 and 1 nights, respectively, with temperatures of $-7 \degree C$ ($20 \degree F$) or lower. The freeze forecast helped increase the visibility of the FC in the agricultural community.
2.2.2. The Florida Cooperative Extension Service (FCES)

Any effort to build a climate information system in Florida would be naïve and possibly counter productive without effective cooperation from the FCES. FCES is a statewide institution with offices in every county to provide specific information for use in agriculture and natural resource management. In cooperation with the FCES and FAWN, the FC presented information on climate variability and prediction, agro-meteorology and weather-driven crop models to extension advisors through an in-service training program. The course was held live, and broadcast via closed-circuit television to several locations across the state. The purpose was to provide extension specialists and county advisors with background information and tools necessary to help growers take advantage of climate information. Similar efforts were made to inform the County Extension Directors and solicit feedback to guide research and outreach efforts. There was a strong desire and interest among extension administrators and faculties in cooperating with the FC in learning what types of information are needed and then in providing it to the different geographic and program areas in extension.

2.2.3. Agricultural weather schools for stakeholders

FAWN organizes a series of weather schools throughout the state of Florida specifically tailored to local needs. The objective of these schools is to show growers how weather data can be incorporated into management tools that can help them with day-to-day decisions. Weather schools provide an excellent forum for exchange of ideas among growers and local climate and weather service providers on various issues including access, relevance and their operational use. The FC provided information on ENSO, the reliability of long-range forecasts, and how ENSO-related climate variability affects agricultural production. In the year 2000, about 160 growers and ranchers attended these weather schools. Discussions confirmed that the FCES is a highly trusted source of technical recommendations and information. Growers producing different commodities generally raised the same issues and indicated a need for similar information before they would use climate forecasts. Corn and soybean growers indicated, for example, that if dry weather is expected, they might not plant as extensively. Late spring freezes are a threat to tobacco, watermelon and corn. With reliable forecasts, farmers could push back the planting date of these commodities, but they expressed fear that they would then lose market windows and risk harvesting during hurricane season.

2.2.4. Rapid rural surveys of stakeholders

Rapid rural surveys were conducted to gather information from extension advisors, farmers and ranchers about agricultural production systems and about decisions that could potentially benefit from climate information (Hildebrand et al., 1999). Surveys of extension personnel proved to be particularly effective in determining farmers’ perspectives and opportunities for using climate prediction within agricultural production. Growers already use weather forecasts (1 day–2 weeks) for farm management. Growers and extension personnel indicated that they would consider changing field preparation, marketing, livestock stocking rates, crop choice
or area of each crop, choice of crop varieties, and crop management, if credible climate forecasts were available. Many growers were sensitive to price impacts of increasing globalization, and wanted forecasts for their competitors’ regions. While growers of rainfed crops were concerned about climate fluctuations, market variations tended to dominate decisions of high value crops.

Ranchers expressed strong interest in climate forecasts, and indicated that there were several decisions that they might change if they had climate forecasts. Ranchers with stocker steer operations might expand the herd if wet weather (El Niño) and thus good forage production were expected. Cow-calf ranchers could cull cows more heavily in a La Niña year. Farmers producing hay were most interested as climate forecasts would allow them to make decisions about how much hay they can grow, how much fertilizer to use, and how much hay they need to stock. Thus, indirectly they could also affect fertilizer use. Ranchers said that the warm and dry winters brought by La Niña are unfavorable for planting winter rye as forage. With reliable climate predictions, cattle farmers can decide whether it is profitable to plant winter forage in a given year.

2.3. Use of climate information

It has long been recognized that if society could have advance information on weather, the adverse effects associated with it could be minimized. For climate information to benefit climate-sensitive sectors and society in general, it must induce changes in the decision-making process and in the actions taken by stakeholders (Sonka et al., 1992). However realizing these opportunities is not straightforward since forecasting skill is imperfect, and approaches to applying the existing skill to manage issues have not been developed and tested extensively (Meinke et al., 2001; Hammer et al., 2001). To understand how climate information could potentially be used, we developed three case studies focused on tomato, cow-calf livestock ranch management, and peanut production. Each of these studies originated directly from our interactions with farmers and extension advisors, and built on information from our earlier assessments of ENSO impacts on agriculture in Florida. Progress in each of the case studies is summarized below.

2.3.1. Improving peanut production

Government assisted price support programs have partially isolated peanut farmers from the need to produce as efficiently as possible. Growers in north Florida mentioned of a likely change in such programs and inquired whether they could use climate prediction technology to increase yields and improve peanut quality (Jagtap et al., 2001). Little if any was known about how either planting date or irrigation practices based on ENSO may improve yield. Mavromatis et al. (2002) used the CROGRO-Peanut model (Boote et al., 1998) to investigate the potential effects of modifying planting date and irrigation management on yields under different ENSO phases at four locations in north Florida and south Georgia. Daily weather data from 1947 to 1998 were used. The period included 12 El Niño (1952, 58, 64, 66, 70,
and 11 La Niña events (1950, 55, 56, 57, 65, 68, 71, 72, 74, 76 and 1989). The remaining 28 years were neutral.

When peanuts were planted as usual in El Niño years, simulated yields were low and highly variable compared to La Niña years. During El Niño years, a combination of warmer than normal temperatures and lower than normal rainfall result in higher drought stress. Simulated results indicate that tailoring planting dates to ENSO phases has potential to reduce the coefficient of variability of yields (2–12%) and increase mean yields by 1–8%. Tailored management calls for later planting during a Niño, and earlier planting in a Niña.

Highly productive but relatively small farms, and high levels of inputs dominate peanut production at these sites. Although peanut is not fertilized with nitrogen, it symbiotically fixes large quantities of nitrogen that are left behind in residues after harvest. When decomposed, these residues release nitrogen that may leach into the ground water, creating adverse off-site effects. As there is substantial rainfall during and after harvesting peanuts in Florida and Georgia, there are concerns about the environmental and health impacts of nitrate from agricultural fields. When planting dates were tailored to ENSO phases, simulation showed at least 10% lower nitrogen leaching in about 70% of the years. Among ENSO phases, La Niña seasons were shown to have greater nitrogen leaching, with little response to management changes relative to El Niño seasons. Tailored management may be most advantageous in El Niño seasons as a result of higher yields and lower N-leaching.

This case study showed potential for enhancing peanut yields and reducing yield variability by tailoring management to expected climate conditions, while at the same time reducing potential environmental damages from nitrogen leaching. Growers and extension advisors have yet to verify results of this study. Based on observations following the 1998 El Niño, Letson et al. (2001) reported that farmers who delayed planting avoided catastrophic losses experienced by those who planted at the usual time.

2.3.2. Winter tomato production

Winter tomato production in Florida generates $460 million in annual sales and supplies 95% of the US winter fresh tomato market. Historical data suggest that yields are about 20% lower than average during El Niño years and about 8% higher during La Niña years (Hansen et al., 1999). Using historical weather data and the CROPGRO-Tomato model Messina et al. (2001) analyzed the potential benefits and risks of tailoring transplanting date to ENSO-based climate forecasts. ENSO effects on tomato yield varied with transplant date. Transplanting 4–5 weeks earlier than normal, increased yields during El Niño years by about 10% on average. Delaying transplanting by about 5–6 weeks during La Niña years also increased simulated yields by about 10%. Optimizing for yield, however, is neither practical nor acceptable to tomato producers. If all tomatoes are transplanted during a short period, they will also have to be harvested during a short interval. Labor constraints will not allow this to happen. Furthermore, a high production level in a particular month would drive prices down. Results from our economic model (which accounts for these effects) indicated that if only one grower with 500 ha adopted the optimal
transplanting dates, she or he could expect to benefit by an average of 892 $ ha^{-1} year^{-1}. However, if all producers in the region adopted the same optimal practice, each producer and the industry as a whole would lose money. When all tomato growers in the region were included in our economic model, we found an expected annual value of $1.7 million to the tomato industry by following an ENSO-based transplanting schedule.

This study suggests considerable potential value for winter tomato producers in south Florida from the use of ENSO-based climate forecasts. The information can be used to plan the size of areas to plant and where to plant tomatoes. However, our results showed that there are risks associated with overproduction due to the strong influence of monthly production on tomato prices. This poses a challenge for the extension service as it aims to assure the improvement of social and economic well-being. Our results indicate the need for cooperation among growers for societal benefits of climate forecasting to accrue. Plans are underway to further interact with growers to present and validate the methods and results for applying climate forecasts, and to investigate potential actions that can be taken to stimulate cooperation among growers in order to minimize the risks associated with overproduction in response to climate forecasts.

2.3.3. Livestock production

Livestock production in Florida generates about $500 million in annual revenues. One of the most important livestock systems in Florida is the cow-calf operation. In these ranches, cows are managed to produce calves, which are kept until they are weaned or held over winter and then sold, usually to feedlots in the midwest USA. In order to minimize production costs, most ranchers in north central Florida prefer to produce enough feed on their own landholdings to feed their herds throughout the year, and would not expect to alter stocking rates based on climate forecasts. Ranchers believed that there were potential benefits of using climate forecasts to estimate hay requirement and anticipate marketing conditions. Potential decisions included when to plant hay, rate of seeding, fertilizer application, whether to purchase bulk feeds and nutritional supplements, when or if to ship cattle to another region, and adjusting stocking levels during the winter and spring months. A linear programming model evaluated optimal management practices based on ENSO phases on a hypothetical 150 ha farm (Breuer et al., submitted for publication). To assess the effects of uncertainty of climate forecast given for a particular ENSO phase, the results were compared to using optimal ENSO management in each year, thus taking into account the variations that occur in each ENSO phase. Results showed that the optimal management of cow calf operations varied with ENSO phase. Ranchers were not likely to plant winter rye grass if a La Niña event is forecast, due to expected lower rainfall that reduces pasture production. Consequently, more hay would need to be purchased during the summer in La Niña (at a lower price than in winter) to offset the decision not to plant winter rye grass, and maintain about 50 fewer head of livestock. Expected profits were lower in La Niña events than in other phases. In contrast, if an El Niño or Neutral event is forecast, planting winter rye grass was advantageous. Climate variability within an ENSO
phase affected costs. When management is not based on ENSO phase, there was an increased cost of purchasing hay during the winter months, especially in La Niña years (increasing costs an average of about $4500). Additional studies are investigating the impacts of incorrect forecasts of ENSO phase.

Findings suggest that ranchers would make different decisions depending on ENSO phase. The results suggest practical options for tailoring management to ENSO phase forecasts, which are consistent with decisions that ranchers thought that they might alter if they have a reliable climate forecast. Ranches vary considerably in their size and management. The linear program is currently being used to mimic variations in ranches for use as a discussion support tool with ranchers.

2.4. Implementation and evaluation

The FC has invested significant efforts in establishing mechanisms in the FCES to ensure sustainability by implementing research findings and evaluating the use of climate information. Working with the FCES serves three essential purposes. First, extension serves as a highly successful resource for transferring research findings into practical technologies and could serve an analog model to suggest how climate information can be disseminated effectively. Second, extension provides an infrastructure for information delivery and for evaluating the effectiveness of such transfer. Third, interactions with extension provide the iterative bridging process between forecast producers and users. Through this partner, impacts of research are likely to greatly amplify, leading towards sustained delivery and use of climate information and decision aids in the future. Three major mechanisms are especially relevant for long-term effective implementation and evaluation: FAWN, State Major Program (SMP), and in-service training programs for Extension specialists and county agents who advise farmers throughout the state.

Given the lack of distinction in the minds of area farmers between weather and climate, FC found that a climate prediction information system could complement the state’s existing FAWN weather. Growers are looking to FAWN as a source of reliable information not only for cold protection, but also for new technologies in pest control, irrigation scheduling and other management programs. In addition to providing climate information, FAWN will ultimately have tactical and strategic decision aids that use climate forecast information as well as real time weather from the FAWN weather station network for use by farmers and their advisors.

The FC has worked closely with Extension administration in order to establish a process to implement and evaluate climate forecast program. Consequently, a climate and weather SMP has been organized within the FCES. The SMP is coordinated by a design team that sets the goals, overall objectives, and boundaries of a program. The SMP team includes members of the FC as well as key extension specialists and FAWN representatives. This mechanism provides a way of accounting for effort expended in each program, and measures of impact are requested as well. To our knowledge, this is the first partnership of its kind in the USA. The design team is responsible for conducting in-service training programs for extension advisors so that they can effectively develop and carry out programs under the respective
SMP; advisors get credit for continuing education in such programs. Extension specialists work with county advisors as needed, and the advisors report their activities under these programs. The formalization of this SMP clearly confirms the importance of this technology by extension and provides a high probability of a sustainable climate information program in Florida.

3. Lessons learned

Researchers from the FC have collaborated over the past 3 years with stakeholders to develop a framework for sustainable applications of climate information to support decision making in Florida. A number of different mechanisms have been used to gain insight into how research and applications of climate information could be tailored to meet the demands of stakeholders in the agricultural sector while at the same time attempting to understand the sector itself. Whereas this is still a work in progress, these mechanisms have provided us with a rich set of experiences; some reinforce successful approaches already tested elsewhere in the world whereas others have been unique lessons on what not to do or how not to do it. These lessons guide current research efforts and provide a vision for sustainable applications of climate information in agriculture.

Farmers require local climate information and knowledge of how probabilistic forecasts might affect their risks if they use them for making decisions. Farmers generally do not fully understand probabilistic climate forecasts, although farmers always have to consider uncertainties in climate and markets when making decisions. In many cases, farmers are more vulnerable to market fluctuations than they are to climate variability as Podesta et al. (1999) and Messina et al. (1999) found in Argentina. Many make their decisions to minimize or manage risks as opposed to maximizing profits. Nevertheless, many farmers have indicated that they would consider using climate forecasts in their decisions, but they want forecasts specific for their localities and in their competitors’ areas.

End-users trust information communicated by a trusted source. Feedback obtained via interactions with farmers and agribusinesses overwhelmingly indicated that they had strong relationships with extension and that they trusted their extension contacts to provide sound information to them. We concluded that the FCES is the institution in Florida that has mechanisms to deliver climate information and applications in agriculture.

Interest in using climate forecast varied considerably among growers, ranging from no confidence to a high level of optimism but most growers have ideas about how they would change their management if they had a reliable climate forecast for their specific situations. Whereas most farmers and ranchers routinely use weather forecasts to adjust management schedules, we found only a few cases where farmers have already been using climate forecasts in their decisions. There seems to be a varying flexibility to adjust management using climate forecasts among sizes and types of farmers depending upon their specific situations. In high value crops, such as
Active and early involvement of agencies with strong established relationships and trust with end-users is required to improve chances of delivering operational applications of climate information. One of the biggest achievements of the FC in implementing and evaluating applications of climate information has been its partnership with extension, which has both legitimized its efforts in the eyes of growers and provided the infrastructure to interact with them. This relationship enables our research to find operational uses among end-users of climate information. Extension personnel develop their own programs based on their understanding of farmer needs and of technology that would serve these needs. This was made clear by extension administration as well as from interactions with extension faculty that a successful program must attract the interest of and engage specialists and advisors in the field. In our early attempts to engage growers and industry representatives in one commodity, we asked extension for names of people with whom to interact. After a number of attempts by members of our research team to schedule interviews with them failed, the extension specialist made the contacts and successfully scheduled visits. This was a valuable lesson on the importance of established relationships and trust; in this case the strong relationships between the agricultural sector and Extension Service. In another case, we began work on a decision aid for one commodity after discussions with the extension specialist in that commodity. After considerable work, the decision aid was finished, but the specialist did not approve putting it on FAWN. In this case, the specialist did not completely buy into the effort, and without his feeling of ownership or his intention of using the product at the end of the day, we should not have embarked on this effort. Both of these examples of what not to do highlight the necessity of complete engagement and ownership of an effort by extension if it is to succeed and be sustainable. A number of examples from elsewhere (Keating and McCown, 2001; Hammer et al., 2000) illustrate that this engagement must be at an early stage to ensure success.

4. The challenge ahead

The strategy of our research team has been first to develop an application program in Florida, and then expand into other southeastern states progressively, taking into account lessons learned. There is a growing interest in climate in this region, partly due to the extreme drought during winter and spring of 2000 and 2001. Time is required to understand mechanisms of predictability of climate fluctuations and impacts on agricultural systems, to identify and evaluate opportunities to use that information to improve decisions, to understand decision maker perspectives, and to understand the roles of institutions that influence those decision makers. In addition to the efforts of a research team, successful and sustained application of climate prediction requires both the interest of individual beneficiaries and a commitment on the part of relevant institutions. Cooperation with the FCES, and the improved access to individual decision makers it provides, helps inform our research priorities...
and improves our understanding of decision makers perspectives and of institutions that influence them. User demand for information and decision aids from an agricultural climate information system requires expertise and resources beyond our Consortium research team. Research aimed at delivering information to clients must be balanced with research that investigates innovative methods and approaches. Nevertheless, we have learned that this “research on demand” is essential for bridging the gap between our specific studies and the needs of the agricultural community. By combining our knowledge and methods with the resources of the extension service, considerably more impact can be realized.

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