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AgClimate: a case study in participatory decision support system development

N. E. Breuer · V. E. Cabrera · K. T. Ingram · K. Broad · P. E. Hildebrand

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Abstract Potential economic benefit exists from the use of seasonal climate forecasts in agriculture. To assess potential end user attitudes toward and interests in climate data, and to provide inputs from users to the development of decision support tools, we conducted a series of surveys. Survey results affected the design, development, and enhancement of *AgClimate*, a web-based decision support system for minimizing climate risks to agriculture. The overall process is an example of how decision makers can participate in the research process, thereby improving the value and relevance of research products such as decision support systems.

1 Introduction

1.1 Climate variability and risk

Climate is defined as the synthesis of weather conditions in an area over a period of 2 weeks or more (e.g. Zaitseva 2005) and is characterized by statistics of meteorological

N. E. Breuer (✉) · K. Broad
Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Gainesville, FL 32611-0570, USA
e-mail: n.breuer@miami.edu

V. E. Cabrera
New Mexico State University, Clovis, NM, USA
e-mail: vcabrera@nmsu.edu

K. T. Ingram
Agricultural and Biological Engineering Department, University of Florida, Gainesville, FL 32611-0570, USA

P. E. Hildebrand
Food and Resource Economics Department, University of Florida, Gainesville, FL 32611, USA

Present address:
N. E. Breuer
PO Box 110570, Gainesville, FL 32611-0570, USA

elements, such as temperature, rainfall, solar radiation, and wind. Thus, climate is long-term whereas weather is near-term. Though climatologists often characterize a region using long-term average conditions, climate is dynamic and variable. This variability exposes many human endeavors to risk. Freezing temperatures in January may damage crops and fisheries, interrupt transportation and power supply. The great variability in August precipitation in the southeast US may result in drought or floods. While we tend to emphasize the negative effects of such extreme events on human enterprises, most natural ecosystems have evolved to adapt to that variability, and may even depend on it. For example, the drought of 2000 thru 2001 in south Florida improved water quality and wild life habitats in Lake Okeechobee, as well as having many other benefits to the natural ecosystems in south Florida (Gray et al. 2002).

1.2 Climate predictability

In some regions of the world, including the southeast USA, variations in seasonal climate conditions are associated with changes in sea surface temperatures (SSTs) in the eastern Pacific Ocean near the equator. In a 2- to 7-year cycle, SSTs in this region rise as much as 8°C above or drop as much below normal. Warm SSTs cause an El Niño event whereas cool SSTs cause a La Niña event, with neutral conditions in between. Because these SSTs change over a large region of the Pacific, they can alter global atmospheric wind patterns, which in turn affect precipitation patterns and temperatures (McPhaden et al. 2006). Principal SST effects on the seasonal climate of the southeastern US have been studied by and are summarized in Table 1 (from Hansen 2002; Neelin et al. 1998; and Mearns et al. 2004). Even within a given SST phase there is climate variability, however, SST phase shifts the probabilities of drought, flood, or freeze, and other events.

Table 1 Summary of typical El Niño Southern Oscillation (ENSO) phase effects on seasonal climate of the southeastern USA

ENSO Phase	Season				
	Region	Oct–Dec	Jan–Mar	Apr–Jun	Jul–Sep
Warm	Peninsular FL	Slightly rainer and cooler	Rainer and cooler	Slightly drier	Slightly drier to no affect
	N FL, S GA, SE AL	Rainer	Rainier	Slightly rainer	No affect
	W FL panhandle	No affect	Rainier	Slightly drier	No affect
	Central and N Al & GA	No affect	No affect	No affect	Slightly drier
Neutral	All	No affect	No affect	No affect	No affect
Cool	Peninsular FL	Drier and slightly warmer	Drier and warmer	Slightly rainer	Slightly cooler
	N FL, S GA, SE AL	Slightly drier	Drier	Drier	No affect
	W FL panhandle	Slightly drier	Drier	Drier	No affect
	Central and N Al & GA	Drier	Dry in south, wet in NW AL	No impact	Wet in NW AL

Source: http://agclimate.org/

A greater understanding of SST effects on climate has allowed researchers to predict seasonal climate probabilities for some regions with a significant lead time (Barnston 1994; Chen et al. 1995). Since 1868, about 21% of years have been classified as El Niño, 52% as Neutral, and 27% as La Niña (COAPS 2005). Extreme warm or cool SST events are relatively rare, though they can have important consequences in the southeastern US. Seasonal rainfall can vary as much as 30% from average, and temperatures can be 2 to 3°C above or below normal (Jones et al. 1999; Winsberg 2003).

1.3 Decision support systems for risk management

Research to estimate the economic value and risks of using ENSO-based climate forecasts in several commodities has shown that there is great potential economic benefit from the use of these forecasts in the management of risk (Messina et al. 1999; Jones et al. 2000; Ferreyra et al. 2001; Letson et al. 2001). In various meetings and interviews, farmers and Florida extension personnel showed strong interest to learn more about climate variability and the use of local climate information to improve their agricultural decisions (Hildebrand et al. 1999; Breuer et al. 2000). On the other hand, simply documenting the effects of climate variability and providing better climate forecasts to potential users are not sufficient for users to benefit fully from this information. Because of the complex interactions among biophysical, social, and institutional factors that affect agricultural systems, clients need decision aids and technical assistance to bridge the gap that still exists between available climate forecasts and their routine applications in agriculture (Podestá et al. 1999). Such decision support systems (DSSs) can help producers to understand better the possible responses to climate forecasts and they must understand the risks associated with alternative responses in order to obtain benefits from a forecast (Jagtap et al. 2002; Letson et al. 2001).

The Southeast Climate Consortium (SECC), a multi-disciplinary, multi-institution research consortium, has as its long-term goal to design, develop, and implement a prototype comprehensive information and decision support system that can inform farmers, ranchers, foresters, water resource managers, industry, and policy makers about climate risks and help these decision makers identify management practices that can reduce risks and increase benefits by using this climate information (http://secc.coaps.fsu.edu). In the fall of 2004, the SECC released *AgClimate* (SECC 2004), a prototype decision support system that provides the first step in meeting this goal. The process of participatory development of the website included regular surveys to assess producer and extension agent awareness of, attitudes toward, and interests in climate data, and to provide feedback to the research developing tools for the DSS. The objective of this paper is to summarize the results of these surveys and to document the value of such iterative inputs of decision makers into the development of a DSS that will meet the needs and interests of decision makers.

In a study on design of agricultural decision support systems, Cox (1996) calls for several steps that must be taken into account for a DSS to be evaluated. The author cites the need for an analytical phase to deconstruct professional (scientific) models, resolution, validation, and appropriateness for the intended purpose. His concern is with the necessary differentiation of DSSs intended for use by scientists and those designed and aimed at directing behavioral change in other groups, such as farmers. Cox also warns that using a DSS creates an intermediary between researchers and farmers that might stifle direct communication. He suggests communication and participation as a more appropriate focus.

2 Materials and methods

This paper will analyze a series of five surveys of agricultural extension agents, agricultural producers, and ranchers in Florida that were conducted from 1999 through 2004. The surveys focused on the following series of topics:

1. Are producers interested in climate information, especially climate forecasts?
2. What level of accuracy in forecasts do decision makers want before using them as decision aids?
3. What are the management options that producers can adopt in light of climate forecasts?
4. How should seasonal climate variability forecasts be presented and delivered?
5. How do potential users evaluate the content and presentation available in *AgClimate*?

Additional details of the survey foci are given in Table 2.

2.1 Survey methodology – the Sondeo

A *Sondeo* is a semi-structured, multi-disciplinary team process that uses discussions rather than formal questionnaires to obtain information about agricultural practices. A key to a successful *Sondeo* is its informal, conversational approach. Researchers do not take notes or refer to a list of questions. While researchers aim to keep the conversation directed toward a general area of interest they encourage respondents to discuss both the specific topic of interest and ancillary issues of concern to the respondents. An important benefit to a conversational approach is that it elicits key issues that the researcher may not have anticipated, issues that would likely have been missed with a standard survey with a pre-established list of questions.

Table 2 Principal questions addressed in each of the five Sondeo surveys

Date	Principal questions
March 1999	How do farmers perceive climate?
	What do farmers understand about El Niño?
	How does climate influence management decisions?
	Where do farmers obtain their forecasts?
Sept. 1999	How can climate forecasts be tailored for agriculture?
	What level of accuracy is needed?
	What are some management options
	What is the value of forecasts
March 2000	Are livestock producers interested in climate forecasts?
	What management strategies would ranchers change in response to forecasts?
	What type of forecast presentation and delivery would be most effective to farmers?
March 2001	What are the perceptions and receptivity of ranchers to climate forecasts?
	Specifically, what management options ranchers would likely adopt?
	What climate accuracy and delivery would you prefer?
March 2004	How user-friendly is the Southeast Climate Consortium's web DSS?
	How good are the content and quality of information provided in the website?
	How useful is the Crop Yield Assessment tool for farmers and extension agents?
	Who are the potential users of the website?

A *Sondeo*-based survey is a multidisciplinary process from planning, through data collection, analysis, and reporting, with each discussion team ideally including people from both social and agricultural sciences. In this case, teams consisted of graduate students from a number of backgrounds including anthropology, agronomy, agricultural extension, natural resource management, forestry, geography, and community development (Table 3). Each team had 2 to 3 members and each survey was conducted by 2 to 4 such multidisciplinary teams. Informal conversations within a *Sondeo* were typically conducted over a 2- to 3-week period. Appointments were scheduled at the convenience of the respondents. For surveys of producers, we enlisted the help of county extension agents to provide contact information for a range of representative producers in their areas. We relied on extension administrators to help us identify county extension agents when they were surveyed. Initial contacts were predominantly made by telephone. Individual conversations lasted from 30 min to 2.5 h, and took place in offices, homes, and fields, wherever was most convenient for the respondent.

Team members met regularly to report and discuss conversational interviews conducted the previous day. General conclusions from these group meetings were recorded and presented as working documents or staff papers. As each team presented its findings, they were discussed to highlight similarities and differences with the results of the other teams. This process of reporting and discussion served as the opportunity to identify trends, gaps in information, and new questions to be pursued.

2.2 Analysis

Data were shared among teams and report writing was done as a group so that observations were confirmed, debated, and analyzed with members of the other teams. Teams collected both qualitative and quantitative data, with validity and results verified through this crosschecking process. Using this process, the final report may be completed within days of the final fieldwork, assuring the timeliness of the results (Hildebrand 1981).

Table 3 Target audience and survey details

Date	Target	Number of discussions	Study area	Team size	Disciplines represented
March 1999	Row crop Farmers	14	Four counties in north-central Florida	11	Forestry, Anthropology, Geography, Economics, Horticulture, Sociology
Sept. 1999	Extension agents	29	All Florida	8	Forestry, Wildlife Ecology, Anthropology, Geography, Economics
March 2000	Livestock ranchers	18	Four counties in north-central Florida	12	Forestry, Agricultural Engineering, Geography, Economics, Interdisciplinary Ecology, Agricultural Education and Communication, Agronomy
March 2001	Livestock ranchers	11	Four counties in north-central Florida	4	Agricultural Education and Communication, Forestry, Ecology, Food and Resources Economics
March 2004	Extension agents and general farmers	9	Eight counties in north and north-central Florida	6	Anthropology, Food and Resources Economics, Interdisciplinary Ecology

3 Results and discussion

Principal findings from each survey are summarized in Table 4.

3.1 Farmer and extension awareness of climate and El Niño phenomena

When survey team members explained it, farmers and extension agents generally understood the difference between longer-term climate phenomena and shorter-term weather phenomena, but few made the distinction before it was explained. As many elements of climate and weather are little more than different portions of the same temporal continuum, it is not surprising that few farmers or extension agents distinguished between them. Moreover, most farmers and extension agents still use the term weather to describe both climate and weather phenomena.

More than 95% of farmers and extension agents were familiar with the term "El Niño," though perhaps only to the point that they associated El Niño with unusual weather patterns. Media reports on severe weather caused by El Niño in the late 1990s engraved the term El Niño in the memories of many farmers. Farmers reported climate patterns of

Table 4 Summary of principal findings from each survey

Sondeo	Principal findings
March 1999	Climate is important. Government regulations and market fluctuations more critical
	Farmers familiar with El Niño but unfamiliar with La Niña
	Little confidence in forecasts and crop models; Farmers felt systems not flexible enough to allow adaptation. Any information on climate is useful
	Weather information obtained from TV, extension agents the internet
Sept. 1999	Farming systems types must be considered when evaluating climate information
	Farm or county scale forecasts preferred. 85% accuracy needed
	Cattle, forestry, and some row crops show greater potential for adaptation
	Management strategies include cropping patterns, pest mgmt., irrigation, herd size, pasture and hay, and fire regimen
March 2000	Ranchers were interested in better climate forecasts
	Ranchers would prepare and adjust winter feeding; also look to mid-west for prices.
	Ranchers preferred bulletins, agent visits, radio, TV, and the Internet, for delivery
	Ranchers preferred distribution functions and temporal sequence graphs
March 2001	All use weather forecasts. Seasonal climate variability forecasts met with skepticism. Older ranchers rely on experiential knowledge. More commercial, technical-minded ranchers welcomed climate forecasts
	Potential adaptations include: plant rye and vary seeding and fertilization rate; Purchase feed ahead of time; ship or sell cattle before winter; stock more over winter
	Forecasts should be 85% accurate. Extension bulletins and Internet are preferred methods of delivery
March 2004	Half found the site easy to use. Specific information needed fast and up-front. Site needs less academic vocabulary and more instructions
	ENSO unknown as term. Farmers want concise information; extension agents want in-depth information or links to it. Dates or timelines needed. Management guidelines deemed good, but more market information is needed
	Crop yield tool has great potential. Needs more instructions. Simpler name. Clarification of axes, dates needed. Extension agents want a page explaining models use

extreme rain from December to March 1998 and drought from April through July 1998 were related to El Niño.

About 60% of farmers had heard the name "La Niña," but none clearly understood its impact. Farmers were able to describe climatic events normally associated with La Niña: very dry, very warm, and a lack of frosts, but did not correlate these events with a climate phase called La Niña; and the term "ENSO" was meaningless to all but a few. Even those farmers and extension agents who were relatively knowledgeable about climate phases tended to confuse the associated weather patterns for the different ENSO phases.

Although most producers remembered the large number of forest fires during 1998, they were unable to relate it to a specific ENSO phase. Causes of severe weather are still in doubt in the minds of most farmers. Several producers speculated that there is a long-term trend toward climate change. Several farmers also commented that bad weather will always exist and little can be done about it.

3.2 Applications and sources of weather and climate information

All farmers reported that short-term weather forecasts have become an essential part f their operations. They adjust their day-to-day plans according to the expected weather conditions. For example, beef cattle ranchers routinely consult weather forecasts when deciding whether it will be dry enough over the next few days to bale hay or if the probability of precipitation warrants fertilizing a field. On the other hand, farmers have not used seasonal climate forecasts because they perceive them to have technological limitations. The issue is not that farmers perceive climate forecasts as being unimportant. Rather, they do not trust climate forecasts because of their low skill.

Farmers of north-central Florida base their decisions on a range of information sources, including weather forecasts, from a range of sources, including their local extension agents, previous farming experiences, and farmer meetings. They also get weather forecast information from television, radio, the Internet, agricultural journals, and evapotranspiration meters. Large-scale farmers and county extension consider the Data Transmission Network, local television, newspapers, extension newsletters, the Farmer's Almanac, trade publications, the Weather Channel, and NOAA as reliable sources of weather forecasts. These sources are free and deal mostly with short-term forecasts. Extension agents reported that farmer meetings serve as an important exchange of weather and climate information. The 2000 survey found that 50% of farmers interviewed were interested in receiving seasonal climate forecasts. Of those showing interest, about half said that they would prefer to receive the information through extension bulletins and half via the Internet. The 2001 survey of livestock producers found that they obtained weather forecasts through the Internet, newspaper, radio, television, and agricultural journals. Of ranchers surveyed, 81% said they would want to receive seasonal climate forecasts, again with half reporting they would prefer receive such forecasts through an extension newsletter and half via an Internet web site.

3.3 Communicating a seasonal climate forecast

According to Hartmann et al. (2002a,b) forecasters and their evaluations typically reflect forecaster, or scientist perspectives, rather than those of users. Often, are not available in forms that users can easily obtain or understand, and this complicates the assessment process. Seasonal climate forecasts are probabilistic rather than deterministic in nature. In other words, a climate forecast is a distribution of probable rainfall amounts rather than a prediction that a specific amount of rain will fall. How to present and explain such forecasts is a challenge to effective communication. During the 2000 survey, farmers were shown samples of various graphical presentations of climate forecast information, included line graphs and histograms for probability distribution functions, cumulative probability functions, and probability of exceedence functions (Fig. 1). About 60% of growers preferred simple cumulative or exceedance functions. In addition to climate forecasts, extension agents were interested in graphs showing historical rainfall and other historical climate data, such as temperatures and dates of first and last frost. The least understood or preferred formats were box and whisker plots and terciles probabilities. Extension agents suggested that such graphic data ought to be presented with specific reference to El Niño–La Niña–Neutral years, and plotted against historical yield data, as opposed to model output data. Farmers tend to think in terms of their past experiences – thus, historical graphs would help them understand the other information presented, and would likely facilitate use of the website.

3.4 Potential responses to climate forecasts

It is generally accepted that not all forecast information will necessarily be useful toward the goal of coping with climate variability (Stern and Easterling 1999). Forecast

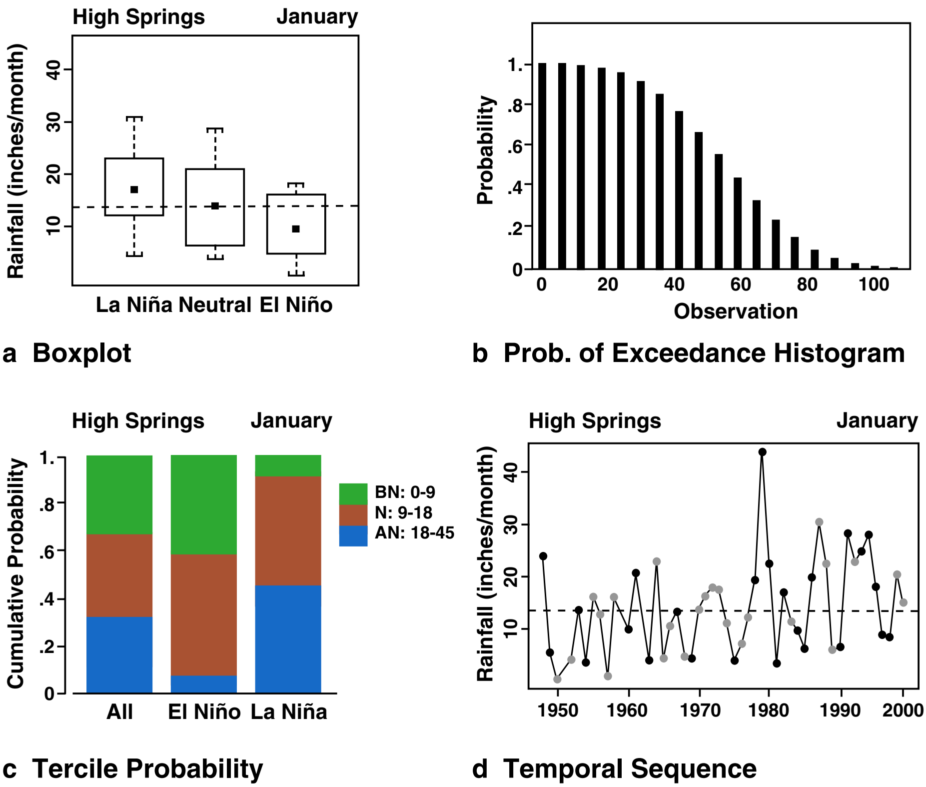

Fig. 1 Examples of graphic data showed to farmers and extension agents in survey: **a** box and whisker plots; **b** probability of exceedance histogram; **c** tercile probabilities; **d** temporal sequence

information can have value only if people can change their actions in beneficial ways based on the content of the information (Letson et al. 2005; Stern and Easterling 1999).

Surveys of extension agents, farmers and ranchers revealed that improved forecasts might help guide decisions about what crops and varieties to plant, where on the property a crop should be planted, and when to plant. Because of diversity in farming operations, however, not all types of operations will benefit from forecasts. Climate factors of importance in relation to these decisions include temperature, rainfall, humidity, and sunlight. Interviewees stressed the importance of extreme events such as storms, floods, droughts, frosts, freezes, and hail. Some extension agents felt that management practices would not change regardless of the climate predictions. They suggested that decisions are more weather than climate-based. Areas of potential application mentioned during conversations include pest and disease management, irrigation, marketing, and land allocation to different crops as summarized in Table 5.

Table 5 Other potential users of climate information and potential applications of climate information identified

User	Potential Uses
Agricultural producers	
Vegetable growers	Melons, watermelon, lettuce.
Forage	Perennial peanut. Important during first years when roots are being established.
Horse farmers	Encephalitis mosquito more abundant in wetter seasons. Bahiagrass develops bacteria that cause abortions when rainier.
Forestry	Dry: delay planting. Wet: plant earlier. Harvest: if wetter season predicted, may log early or to postpone because of difficulty of operating in wet conditions.
Hobby Farmers	Hobby farmers who produce for market are flexible enough to change crops or varieties in response to climate forecasts.
Non-agricultural producers	
USDARMA	Reduce risk
Banks	Reduce risk
Insurance companies	Reduce risk
Tourism fishing	Reduce risk Anticipation of stormier seasons
Tourism general	Weather or climate extremes could seriously damage this industry.
	Precipitation prediction valuable for golf courses, fertilizer applications, and algal blooms
Disaster prevention and aid	Anticipation of storms. Bad climate season prediction can help long-term preparation to minimize negative effects
Urban planners	Storm and hurricane prediction for building construction and homeowner protection, including protecting ornamental vegetation. Fire and flood planning
Water management districts	Water management districts already have excellent information. Information is not always shared freely with the extension offices. Urban water supply, wetlands restoration, and aquifer management
Marine management	Possible climate effects on access to fishing and on algal blooms
Agrochemical and insurance industries	Already use climate forecasts to maximize profits. Open access to climate prediction information might affect both providers and users of agrochemicals and insurance services
Florida citizens	Exotic Plant Species, Diseases, and Insects. In the Florida Keys, low-pressure systems have introduced non-native insects and associated diseases

3.5 Trustworthiness of climate forecasts

Many farmers were unsure about the validity and reliability of seasonal climate forecasts. An important source of farmer uncertainty with respect to forecasts was whether the technology could predict *local* variations. Farmers were very conscious of spatial variability in weather because weather conditions often vary from field to field, with significant production differences among fields that result from spatial weather variations. Many farmers said that any trustworthy forecast would be useful. Farmers were interested in knowing the level of precision obtainable from the climate models.

Livestock producers expressed considerable skepticism towards the reliability of forecasts. Long-time ranchers rely heavily upon a long history of experience to influence their decisions. They stated that the climate-forecasting model was unproven. Typically, they avoid risk by managing for adverse climate years as was noted by Thornton et al. (2004). Ranchers who responded positively to the possibility of receiving seasonal climate forecasts tended to be receptive to any new information that could lead to improving the productivity or efficiency of their operations. Ranchers with larger than average herds stated that climate prediction information 3 to 6 months in advance could affect their decisions, if they proved over time to be trustworthy. Though in a strict sense, a probabilistic climate forecast can be neither correct nor incorrect, farmers reported that a forecast would be trustworthy if it were correct 80 to 85% of the time.

Farmers also referred to the spatial trustworthiness of the forecasts. To be useable, forecasts must be given at a fine spatial resolution. That is, farmers insisted that for a forecast to be of value it must be at a level of sufficient resolution that it relate to their personal farm or county rather than for a region. Several ranchers identified within season distribution of rainfall as more important than seasonal total, which is particularly important in areas of sandy soils having low water retention capacity (Breuer et al. 2000).

3.6 Ability to respond to a climate forecast

The 1999 surveys found that the importance of climate and producer ability to adjust their operations to forecasts varied geographically. Diversity of agro-ecological conditions and farming systems directly influenced the importance placed upon seasonal climate variability and decision-making by extension agents and farmers (Table 6). In general, because they have smaller and more highly diversified operations, farmers in central and northern Florida appear to be better positioned to respond to seasonal climate predictions than those in the south. Among extension agents, attitudes toward climate forecasts and their willingness to recommend strategies often depended on whether climate predictions were easy to access and understand. Most extension agents expressed a lack of confidence regarding forecast reliability and the ability of producers to respond to such information. Several farmers stated that other stakeholders, such as chemical suppliers, insurance companies, brokers, relief agencies, and banks, might benefit more from climate forecasts than would agricultural producers. From perceptions gathered, a table was constructed analyzing how several variables might affect the ability of different types of producers to benefit from climate forecasts (Table 6).

Farmers were curious about the specific kinds of information they might be given in relation to optimizing their management practices. Decisions regarding management practices depend on many factors, not just climate. Many farmers expressed that they were “locked in” to what they could grow and when. They expressed concern that changing practices has a cost and that any recommendation should take the whole production system

Table 6 Analysis of the relationship among farm size, crops, production system, and farmer characteristics on potential for use of seasonal climate forecasts, derived from conversational surveys

Criterion	Description	Potential for use of seasonal climate forecasts
Farm Size	Small (<4 ha)	Low
	Medium (4–40 ha)	Medium
	Large (>40 ha)	High
Crop	Pasture	High
	Vegetables	Low
	Corn	Medium
	Soybeans	Medium
	Peanut	Medium
	Tomato	Low
Production System	Family-organic	Medium
	Large-scale, multi-crop, irrigated	Low
	Large-scale, multi-crop, rain fed	High
	Large-scale single crop, fixed market	High
	Large-scale, single crop, variable market	Medium
Age of Farmer	Younger (<54)	High
	Older (>54)	Medium
Gender of Farmer	Male	Medium
	Female	High

into account. If the potential benefits of responding to a climate forecast are relatively small per unit area, or if costs of implementing recommendations are high, then only farmers with plentiful resources on large farms might profitably use such recommendations. For these farmers, planting dates and rotations were on a rigid schedule and it would be difficult to alter the schedule based on climate prediction. Farmers in north-central Florida wanted to receive recommendations for management of crops such as tobacco and vegetables, not just grains.

Larger specialized farmers that require specialized equipment are less flexible in responding to climate predictions than are others. Equipment investments for such mono-crop systems could be important barriers to diversifying their crops based on climate forecasts. On the other hand, wealthier farmers, even though they may have large equipment investments generally have more leeway to make changes according to forecasts.

Farmers mentioned that they weigh market demand more heavily than planting dates in relation to climate forecasts. Market is the primary factor that affects agricultural decisions, not climate. Therefore, even if a recommendation based on a seasonal climate forecast is against early planting, farmers may still plant early and get lower yields in anticipation that an early crop would bring a higher price. Small farmers were less interested in variety or crop recommendations than were larger farmers because small farmers tended to mix crops and varieties in order to diversify and minimize risk whereas larger farmers grew fewer crops and varieties in order to achieve economies of scale. Small farmers reported an interest in getting recommendations for pest and disease management practices that depend on climate, and in detailed frost information.

Surveys revealed the importance of climate predictions to farmers as being secondary. Many other constraints limit agricultural production. Asked about the importance of climate on their crop production, farmers said it was an important factor, but one farmer added: “We have been battling climate ever since the beginning.” Most of the farmers said that what impacts them most are government regulations and market fluctuations. Farmers also mentioned concern regarding availability of labor; free trade agreements and the inability to compete with large agricultural corporations were also constraints that limited the profitability of their products. Some farmers expressed concern about the loss of land due to urbanization. To round off the list of worries, fewer young people were involved in farming and high energy costs were impacting management activities as a result of high fertilizer costs.

Insurance coverage was another factor that farmers consider when responding to a forecast. Several farmers said that they were certain that the insurance companies had good weather and forecast information for the regions in which they were selling their insurance. At the same time that farmers expressed doubt that they could use a climate forecast to their benefit, they wanted to receive any available climate information that insurance companies or other agribusinesses might be receiving in order to increase their competitiveness.

3.7 Assessments and revisions of AgClimate web site

The Internet has emerged as an accessible and increasingly used information medium for agriculture. All extension agencies have Internet access and web pages. Many extension agents currently use the Internet to obtain and deliver weather and climate information. A newsletter survey (Cabrera et al. 1999) revealed that 54% of the farmers in Citrus County, Florida prefer to get data about weather on the Internet, which agrees with our findings indicating that about half of farmers regularly access the Internet.

Extension agents interviewed mentioned potential differences in the use of the Internet among different segments of the farmer population. For example, large farmers and hobby farmers use the web more frequently than medium size farmers. Also, since extension agents consider women and children to be more likely to use the Internet, they could be targeted as users of the website and tool. This focus could be especially important, as wives of male farmers tend to handle many of the logistical details involved in the operation of the farm. Older farmers with less computer experience may not be comfortable using web-based technology.

3.7.1 Decision support system for use of climate information

In an important early article the importance of a three step process was highlighted. These steps are, “identifying weather-sensitive economic sectors, documenting the flexibility of these sectors with respect to likely forecast information, and the development of accordingly focused forecast capabilities (Sonka et al. 1982). Our study follows this framework, especially steps one and two. We have identified agriculture as a climate sensitive sector, have sought to understand their farming systems and decision-making processes, and have shown farmers and extensionists some prototype versions of forecasts tailored to their particular needs.

Based on farmer and rancher interests in receiving seasonal climate forecasts, the SECC moved forward with the development of a decision support system (DSS) to help them use climate forecasts and other climate information to reduce climate related risks to agriculture. Although only about half of producers interviewed said they preferred receiving information through the Internet, because we felt that this fraction was likely to increase, the SECC planned to disseminate this DSS through a web site, *AgClimate* (http://AgClimate.org). Development of the *AgClimate* began in 2003 and a prototype DSS was available in mid-2004, which provided climate information, forecasts, and tools to support decisions based on seasonal climate forecasts.

The 2004 survey focused on *AgClimate* and its tools. In general, extension agents found the prototype to be informative and user-friendly. They raised questions regarding the applicability of the website to farmer needs and concerns. Particular questions referred to the accuracy and historical reliability of forecasts, where the site would be located on the web, and frequency of updating.

All extension agents surveyed emphasized the need to keep *AgClimate* operations simple if farmers are to use the site. They explained that most farmers want specific information quickly. Producers have no desire to dig through layers of extraneous information or to browse through various pages of the site.

Initially, farmers and extension agents mentioned that information presented on the website needs to be more explicit, to use less academic language, and to provide better instructions for users. Also, the *AgClimate* homepage should state how this website differs from others. If not, farmers might conclude that it is “just another website” despite containing potentially useful information.

There was a dichotomy between what farmers and extension agents would want in a web-based DSS. Farmers want specific and concise information, whereas extension agents would also like access to additional detailed information, perhaps through link to other sites.

3.7.2 Increased forecast detail required

A prominent concern among interviewees was the perception that weather descriptions corresponding to the three ENSO phases were ambiguous and sketchy. Farmers wanted much greater detail in terms of the intensity of expected rain or temperature levels for a particular forecasted phase. The most importation information for them is the expected ranges of rainfall and temperature, and information about late freezes. Many respondents discussed the importance of frost/freeze information and the necessity of having the website display this for planning purposes. One agent stated such information would be extremely useful, but was concerned that this website offered little reliability with regard to freeze forecasting at this point in time. Exactly when an ENSO phase begins and ends was unclear to all interviewees. A need was expressed to have explicit dates attached to both the current phase and to the next forecasted phase. Farmers and extension agents said that a timeline would be a useful visual on the page. In addition, to facilitate the understanding of how management practices differ between the phases of ENSO, it was suggested that recommendations for all ENSO phases be contained in one table, with the current phase highlighted. In addition, the skill of the forecast is something almost all interviewees would like to be prominently shown on the page. Also, producers and extension agents would like to be able to read how the skill of the forecast progresses over time.

3.7.3 Additional information needed

Several participants mentioned the lack of price information for commodity crops and timber. Several extension agents stressed that because markets, as opposed to climate, tend to drive production decisions there should be links to market information for the southeast, as well as other regions. Farmers were interested in climate information for other regions that may affect crop and livestock market prices, or costs for inputs.

3.7.4 Crop yield risk assessment tool

The SECC developed a yield risk assessment tool that uses crop model outputs to estimate yield distributions based on climate forecasts. Assumptions that computerized decision support systems would become standard tools in farm management once computers became commonplace have not always proved right. Use of DSSs in agricultural management has not grown at pace with computer ownership (Hayman and Easdown 2002; Ascough et al. 1999; Parker 1999). Many agricultural decision support packages are readily available and affordable (Hayman and Easdown 2002). However, contrary to expectations, use of the DSS in management has not grown at pace with computer ownership. (Parker and Ascough 1999).

Many DSSs such as FARMSCAPE, PCYield, CottonPro, WHEATMAN and others, have had limited adoption (McCown et al. 2002; Cash and Buzier 2005). The Decision Support System for Transfer of Technology (DSSAT; Jones et al. 2003) has been more widely adopted, however, its use remains mostly in the realm of researchers and consultants with high levels of education and training. Some reasons for non-adoption or short-term use are high levels of expectations on the part of farmers, lack of user friendliness, the deterministic nature of outputs, and problems with up-scaling (McCown et al. 2002). Substantial changes must be incorporated into all phases of development if past deficiencies with regard to end-user utilization are to be overcome. One of the most important aspects required may be intensive and effective participation and continuous feedback from all stakeholders involved.

Generally speaking, extension agents found the yield risk assessment tool to have great potential both for use by extension as well as for farmers (Barham et al. 2004). With the understanding that this tool is still under construction, agents made suggestions concerning how both the user-friendliness and content of the tool could be improved. The most common criticism of the yield tool is that there were no clear instructions on how to use it. Once survey members explained how to use the tool, most extension agents were able to grasp the utility of the tool and how they and farmers could effectively use it.

3.8 Iterative contribution of surveys to participatory DSS development

While there has been much discussion of the need for user participation in the development of DSSs, there are few viable examples in agriculture. One notable example is FARMSCAPE. Australian and other researchers have used participatory approaches in developing and disseminating their products to farmers. Notable among these studies is that by Carberry et al. (2002). FARMSCAPE is in a participatory research process piloted community of northeast Australia. Their research explored if and how farmers and their advisers could benefit from tools including climate forecasts and simulation modeling. They found that direct engagement of farmers enabled a limited number of beneficiaries. However, the work led to the realization that a commercial market existed for these types of decision support tools, and that a significant sector of the farm population would be willing to use them. They have since shifter their focus to training, support and accreditation of farm consultants and the system is being tested nationally and internationally.

We have used surveys following the *Sondeo* methodology (Hildebrand 1981) as the principal means for farmer and extension agent participation in assessing the potential need and value of a DSS for climate risks, and the development of the *AgClimate* DSS. Initial surveys assessed the potential value of climate information to agricultural producers in the southeast USA. Subsequent surveys addressed needs for specific climate information, means of disseminating and presenting that information, and trustworthiness of climate information, all of which led to the development of prototype tools for *AgClimate*. Following the 2004 survey, *AgClimate* was revised according to the survey results and officially announced in the fall of 2004. In contrast to the findings of Carberry et al. (2002), who found that commercial consultants would be the best intermediaries for reaching large numbers of farmers, we have found that working with the Cooperative Extension Service as a boundary organization is a valuable means to reach diverse farmers while maintaining a free and open source of public utility.

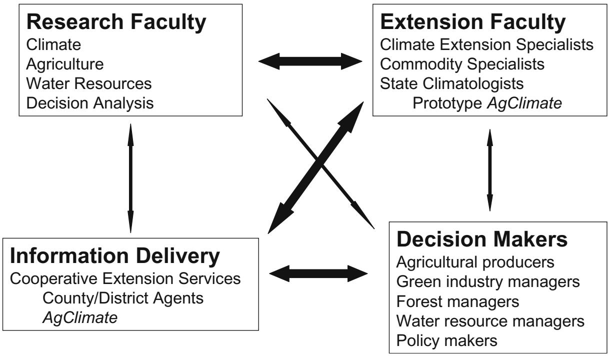

Fig. 2 Relationships among the various components needed to develop, disseminate, and apply climate information to agriculture. *Arrow thickness* is relative to the proportion of interaction between elements

Participation of farmers and extension agents throughout the entire process of developing *AgClimate* has been essential (Fig. 2). How researchers have responded to comments and suggestions are summarized in Table 7. In addition to assessing the need for climate information and guiding the development of the DSS, the involvement of farmers and extension agents has: (1) increased their awareness of and interest in seasonal climate forecasts and other climate information; (2) earned trust in DSS products, especially as farmers and extension agents have been able to observe their feedback contributing to DSS development; and (3) increased the value of the DSS by meeting specific needs and interests of the users.

While the SECC still considers *AgClimate* as a prototype DSS with continuing need for user inputs to guide improvements, following the 2004 survey to assess *AgClimate* efforts to solicit these inputs shifted from *Sondeo* survey methods to farmer advisory panels, questionnaires from workshops, on-line feed back, and other means. Based on these user inputs, the SECC continues to add new tools, new information, and to modify presentation formats in *AgClimate*.

Table 7 How the SECC has responded to feedback from farmers and producers

Requested by Farmers	Response
Freeze and frost forecast	In conjunction with Florida Agricultural Weather Network (FAWN), this service is now offered
Validation of model results through field trials	Unnecessary. Field data already incorporated in crop model
Develop models for melons, perennial peanut, cotton, strawberry, etc.	A cotton model is being developed. Other crops may be in the future
Location-specific forecasts	Farmers can obtain county level forecasts
Monthly outlooks	Researchers at FSU and UF are working on a global model to produce these
Use of simple graphs	The website and tools use bar graphs and exceedence probabilities
Graphs showing historical data	Incorporated into tools
Wildfire forecast	Developed for the SE USA and available through SECC and Forest Service
More explicit instructions on website and tools	Development underway
Timeline for ENSO phases	Currently being considered. Information overload per page is a problem

As for the on-going debate as to whether a site and crop-specific approach versus a generic plant and broad zone approach may be the most useful and lead to wider adoption and adaptations, the SECC experience suggest a combination of both is necessary. Crop specificity can best be achieved through the use of crop models. Because crop models are available for a limited number of crops, and the development of new models is expensive and time consuming, the prospect for having a climate sensitive, physiological model of every crop is unlikely. Generic tools based on phenology – or development stages of crops – can be used by a wide range of producers for different crops. However, the tools should always be as site specific as possible, the County level being a good standard. More generic tools such as growing degree days and chill unit accumulation tools are being incorporated into AgClimate. These tools can be used for most crops, and have special default temperatures for temperate, tropical, or sub-tropical fruits. Still, the meteorological inputs yield the best results when they are County specific.

4 Conclusions

With AgClimate, using the interactive research methodologies described in this article, we have successfully completed several of the steps Cox (1996) lists as prerequisites to successful DSS development and assessment. We began with an analytical phase that explored end users need for climate information. This analysis led to the development of methods for translating model outputs into understandable formats. We validated forecast models and output displays, crop model outputs and displays, and management recommendations through direct consultation with farmers and extension agents. Furthermore, we continuously exposed our DSS to criticism and feedback to insure the appropriateness of tools and qualitative information to a diverse community of farmers and extension agents. Finally, we used a high degree of communication and participation in all phases of DSS development and implementation.

Our research agrees with a fundamental precept espoused by Mjelde et al. (1988), that forecasts are useful if they permit *ex ante* actions, such as altered choice of crop species and cultivars and shifting planting dates. Our surveys have shown that farmers believe that if they can anticipate higher than normal precipitation they can likely improve their profits by adopting appropriate varieties or stocking more cattle. In addition, our interviewees agree with Stern and Easterling (1999) that forecasts are helpful only if they arrive before planting or stocking decisions are made. In the words of farmers interviewed "timing of forecast availability may be more important than forecast accuracy." Furthermore, site specificity or regional conditions are necessary and positively affect the usefulness of forecasts. Interviewees noted that the spatial distribution of climate forecasts, which are regional rather than local, may be favor decisions of insurance companies and traders more than growers and producers. Stern and Easterling (1999), who anticipated this situation, warned that if the overall benefits of climate forecasts are distributed so that some groups gain greatly while others do not benefit at all, enthusiasm for climate forecasting might be greatly reduced. Farmers and agents in this study confirm this suspicion.

Understanding how people make decisions is relevant to designing methods of conveying the information in climate forecasts, which will have uncertainty attached (Stern and Easterling 1999). Although this aspect of climate science is crucial in designing useable decision support systems, our research in this area is just underway and much more work is needed. The extension agents and farmers interviewed for this study noted that the forecasts would have to be correct, that is, outcomes would need to agree with the probabilities of the forecast, for several years before they would make a management decision based on them. The climate community widely knows that trust in institutions and information sources affects people's perceptions of technological and environmental risks and that such trust is easier to destroy than to build (Slovic 1993; Slovic et al. 1991). Our interviewees, though enthusiastic about seasonal climate forecasts, will likely follow the dictum "once burned, twice shy" (Glantz 2000).

Our methods and results also agree with Stern and Easterling (1999) in that the AgClimate DSS is intended not only to inform but to benefit the users; the DSS is based on scientific techniques that few of the recipients understand; the DSS provides forecasts several months in the future and these forecasts are probabilistic; the probabilities given contain inherent uncertainties; the forecasts have a limited track record and thus their credibility is difficult to determine; and the predictions are in great measure relevant to the users' decisions because they are interpreted or translated into appropriate formats supplied by the users themselves.

Cash and Buzier (2005) state that "effective knowledge-action systems support processes for the production of useful knowledge through collaboration between knowledge users and knowledge producers." The extension service and its agents fit well with what Cash and Buzier call "users," who, in turn, become "producers" as they translate, repackage, or further analyze information. We noted that members of this boundary organization have been fundamental in our understanding of farmer needs and adjustable management practices. In several instances they have taken information from AgClimate and sent out more specific information, for example the notion that it is a good idea to plant ryegrass for winter pasture in El Niño years in monthly bulletins. Furthermore, the "user-driven paradigm" as defined by Cash and Buzier (2005), in which the "agendas of analysts, forecasters, scientists, and other researchers are at least to some degree set by the potential users of forecasts," was followed by SECC researchers. We attempted to avoid having the dialog of interviews being driven by our knowledge of ENSO and instead have focused on end-user needs and potential adaptations. We focused on developing a system that promotes user-driven risk-management objectives. Our objective of achieving farmers' goals of better risk management is currently under evaluation. Cash and Buzier (2005) go on to suggest that a collaborative, user-driven decision support system might even enable such a system to better withstand a "failed" forecast. Although our study did not collect data to test this hypothesis, it is likely that benefits such as higher adoption rates, more varied adaptation strategies, and user trust in the provider institution is being enhanced by the collaborative research and development process.

For those trying to link seasonal climate forecasts to decision making, it may be noted that our methodology closely parallels that proposed by Cash and Buzier (2005). Namely, we went into the field and learned about end users' perspectives, problems, and needs. We have used feedback obtained through conversational surveys to design or redesign and implement information packages and tools that respond to particular needs. We have used lessons learned about farmer goals to provide a range of risk management tools that are interactive and site specific. We have initiated conversations with leaders in the farm community and the Extension Service, which has been described as one of the keys to success. It is hoped these leaders will lay the groundwork for broader participation of other users. We have tailored our climate forecasts and converted or translated when necessary to a language or visual format chosen by end users. An example is the choice to present information as simple bar graph probabilities and probability of exceedance graphs that were preferred by our interviewees. Most importantly, we continue to maintain the dialogues over the long term, though this paper covers only 1999–2005; the work continues in order to successfully link knowledge with action. We are working to develop a trust relationship through time between users and producers of climate knowledge. The method of constant iteration of these interactions increases the probability salience, credibility, and legitimacy, are likely to be achieved (Cash and Buzier 2005).

By providing interactive tools and quarterly outlooks we provide information at critical times when decision needs to be made. We attempt to communicate forecasts that are not static, as was also recommended by Cash and Buzier (2005). We show trends and recent conditions as well as probabilities or upcoming conditions. We have a strong agricultural focus so that the forecast is not the end point, or final product, but rather its links to decision making for risk management by farmers is the key end result of the decision support system. Finally, we maintain an outreach effort through the hire of Climate Extension Specialists and our constant interaction with a very effective boundary organization, the Cooperative Extension Service.

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