An International Sampling of Agricultural Applications of Seasonal Climate Forecasts[1]

James Hansen

International Research Institute for Climate Prediction

Although seasonal forecast applications are still in an early stage of development relative to most areas of agricultural technology, there is now enough collective experience from research efforts around the world to induce some meaningful lessons. In this paper, I use a sampling of several research efforts around the world to illustrate some key lessons that I consider to be relevant to any effort to foster appropriate use of seasonal forecasts. I then propose why there are so few well-documented examples of successful use of seasonal climate forecasts by smallholder farmers in particular. I conclude with a discussion of five areas that must be advanced in parallel if farmers in a particular region are to realize the potential benefits of seasonal forecasts.

WHAT HAS BEEN DONE ELSEWHERE IN THE WORLD?

India is the birthplace of scientific seasonal climate forecasting well over a century ago. Forecasts have been routinely issued to agricultural communities for a little more than a decade in a few countries (e.g., Northeast Brazil, Ethiopia, Australia). Prior to that they were largely the domain of academics and high-level policy makers. The APSRU (Applied Production Systems Research Unit) group in Queensland, Australia, was among the early pioneers of bringing concerted research and systems modeling to bear on use of seasonal forecasts for agricultural decision making. An expanding community of research groups around the world now seeks to build the required foundation of knowledge and methodology, assess the potential for agricultural applications of seasonal forecasts, and in many cases build the necessary institutional support for routine use of forecasts. The partial list below represents a sampling of some of the programs and projects that have a strong research focus.

- In Australia, a strong network of institutions support agricultural application of seasonal forecasts. APSRU and the Queensland Center for Climate Applications (QCCA) are the best known. The proceedings of a conference (Hammer et al., 2000) provide a comprehensive overview of work in Australia through 1998.
- *The Florida Consortium* (University of Florida, Florida State University and University of Miami) first worked in Argentina, then in the Southeast USA. The work has led to the development of a statewide program on climate applications through Florida's agricultural extension service. Overviews of the work in Florida include Hansen (2002) and Jagtap et al. (In press).
- *CLIMAG-West Africa* is a consortium of institutions in West African and Europe that are exploring seasonal forecasts for both farm-level and food insecurity early warning applications in Mali through a project entitled "Climate Prediction for Mitigation of Global Change Impact on Agroecosystems in Sudano-Sahelian West Africa" (Maracchi et al., 2001). The project is one of two "demonstration projects" endorsed by the international CLIMAG program. CLIMAG is a joint initiative of the World Climate Research Program (WCRP),

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International Geosphere-Biosphere Program (IGBP), and International Human Dimensions Program (IHDP), and coordinated by the Global Change System for Analysis, Research and Training (START).

- *Climate Forecasting for Agricultural Resources (CFAR)* is a joint project of the University of Georgia and Tufts University, both in the US, targeting smallholder farmers in Burkina Faso (Ingram et al., In press).

Several other countries (e.g., South Africa, Zimbabwe, Ethiopia, Argentina, Peru, Brazil) have ongoing programs within either their meteorological institutions or agricultural research systems that support use of forecasts by agricultural decision makers.

Besides the many programs that have targeted particular countries, several programs have targeted multiple countries in a manner that allows comparison across countries. For example:

- This conference is sponsored by a project, "Capturing the benefits of seasonal climate forecasts in agricultural management," funded by the Australian Center for International Agricultural Research (ACIAR). The project implemented sub-projects in four countries: India, Indonesia, Zimbabwe and Australia.
- *CLIMAG-Asia.* The initial project, "Management Responses to Seasonal Climate Forecasts in Cropping Systems of South Asia's Semi-arid Tropics," targeted India and Pakistan, with participants from Australia and the US. The next phase, "Applying Climate Information to Enhance the Resilience of Farming System Exposed to Climatic Risk in South and Southeast Asia," adds Indonesia.
- *The Advanced Training Institute on Climate Variability and Food Security*, implemented by the IRI and co-sponsored by START, was designed to equip young agricultural and food security professionals in developing countries to apply advances in seasonal climate forecasting to their home institutions ongoing efforts. The training institute included an intensive three-week training workshop and competitive seed grants for research projects, designed to embed the learning in the participants' home institutions. All nineteen participants in fourteen countries are now managing projects that involve exploration or application of seasonal forecasting.[2]

In Africa and Latin America, periodic Climate Outlook Forums (COF), first initiated in 1997, have built regional capacity and fostered regional collaboration for developing and disseminating seasonal forecasts. They have endeavored to engage various stakeholders, including those in the agricultural sector. A review two years ago of the COF program cited a number of challenges and proposed a number of improvements relative to access and usability of the resulting forecasts (Basher et al., 2001).

Due in part to its interdisciplinary nature, the literature on agricultural applications of seasonal forecasts is scattered. A few collected works (Sivakumar, 2000; IRI, 2000; Rosenzweig et al., 2001), including a forthcoming special issue of Agricultural Systems (Hansen, In press b) that provides some of the examples for this paper, cover efforts across countries. Orlove and Tosteson (1999) provide an informative analysis of factors that have influenced the effectiveness of some of these national programs and institutions. Glantz (2001) offers a more recent survey of country-level responses, across a range of sectors, to the 1997-98 El Niño.

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[2] http://iri.columbia.edu/outreach/meeting/ATI2002/index.html

The International Research Institute (IRI) for Climate Prediction has an interest in fostering appropriate use of seasonal forecasts for agricultural decision making throughout the developing world. The IRI's mission is to enhance society's capability to understand, anticipate and manage the impacts of seasonal climate fluctuations, in order to improve human welfare and the environment, especially in developing countries. The IRI accomplishes its mission through strategic and applied research, education and capacity building, and provision of forecast and information products, with an emphasis on practical and verifiable utility and partnerships. In addition to relevant training and capacity building activities, the IRI has participated in collaborative agricultural applications projects in Kenya, Zimbabwe, Uganda, Mali, Argentina, Brazil, India, Pakistan and Indonesia, and has collaborative agreements with advanced programs in Australia and the USA.

WHAT HAVE WE LEARNED?

Collective experience around the world has taught many lessons. I illustrate a few key lessons (Table 1) with vignettes drawn from the activities of some of the research groups who have been working with farmers to evaluate and foster appropriate use of seasonal forecasts.

Queensland, Australia: Discussion Support Systems

Queensland has seen quite a range of research, education and extension activity related to agricultural application of seasonal climate forecasts. One achievement that stands out is their development of quantitative analytical software tools for decision support, and use of these tools to facilitate discussion and learning among farmers and their advisors. "WhopperCropper" is one such tool (Nelson et al., In press). It is built around a data base of APSIM (McCown et al., 1996) crop simulation runs, with several simple graphic formats for presenting probabilistic results and comparing scenarios. It is designed to aid public and private farm advisors in analyzing the potential consequences of risk crop management decisions. WhopperCropper supports analyses of crop management issues, soil conditions, and the use of seasonal climate forecasts based on a five SOI-phase system (Stone et al., 1996). Researchers have concluded that the value of WhopperCropper lies more in fostering dialog and co-learning, than in suggesting particular management decisions. Hence they favor the term "discussion support systems" over the more conventional notion of decision support systems (Nelson et al., In press).

The experience of using WhopperCropper and other computer-based tools with agricultural decision makers illustrates the lesson that quantitative, computer-based analytical tools (i.e., "hard-systems" approaches) can be combined quite effectively with participatory "soft-systems" approaches to facilitate farmer discussion and foster mutual learning (Meinke et al., 2001).

Florida, USA: Institutions and Trust

A consortium of universities (University of Florida, Florida State University, University of Miami) in Florida has been conducting applied research designed 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 in Florida and the surrounding states. Early work focused on building a foundation of understanding of the impacts of the El Niño-Southern Oscillation (ENSO) on the region's climate and agriculture, the perspectives and needs of farmers and their advisors, and decisions that can benefit from forecast information.

Work with farmers revealed strong interest in receiving ENSO-related forecast information, but altitudes ranging from cautious enthusiasm to skepticism, with skepticism more common. They wanted climate information for their particular locations, but were often interested in climate variations in their competitors' regions. For high-value commodities, market risk was of more concern than climate risk. Investigators also learned the importance of channeling information and advice through advisors who the farmers already know and trust. Florida farmers place a great deal of confidence in agricultural extension service personnel with whom they interact routinely, but are cautions of "outside" experts. In a few instances, researchers could not even gain an audience with producers or representatives of the fresh vegetable industry until they approached them through county extension agents.

The work led to a joint research-extension program on climate prediction applications. An existing web-based weather information extension program (FAWN) provided an entry point for a pilot climate information system. The next, ongoing phase is the development of a Statewide Major Program (SMP) in the application of climate information. The SMP provides sustained state funds, supports ongoing training of extension personnel, justifies climate-related extension activities and materials development, and provides a mechanism for evaluating impacts. Importantly, extension ownership through the SMP gives seasonal forecast application legitimacy in eyes of stakeholders.

Our experience in Florida illustrates the lesson that farmers tend to evaluate the credibility of information or advice based on its source. Climate information is likely to have greatest value if communicated through advisors who farmer already know and trust. Sustained benefit requires commitment of relevant, trusted institutions. Any new initiative must either work through existing trusted institutions and advisory networks, or invest considerable time and effort to establish trust and credibility with the farming community.

Zimbabwe: Individual vs. Societal Goals

A study by Cane et al. (1994) that showed a strong correlation between ENSO-related SSTs and national maize yields, prompted considerable interest in seasonal forecast applications in Zimbabwe. Phillips et al. (2001) conducted household surveys among communal farmers for three years, beginning in 1997. The surveys were designed to determine to what extent the farmers received and trusted seasonal forecasts, and how they modified farm management in response. As in many places in the world, the highly-publicized 1997 El Niño was the first time that seasonal forecasts were widely distributed in rural Zimbabwe.

Prior to the 1997/98 and 1998/99 seasons, communal farmers expressed plans to modify several decisions, including total area planted (Table 2) – decreasing total area during the 1997/98 El Niño, and increasing area during the 1998/99 La Niña. The study was not designed to measure actual farmer decisions. However, aggregate statistics show that area under cereal crops decreased in 1997/98 and increased in 1998/99, consistent with elicited farmer plans.

To consider how widespread availability of forecasts might impact aggregate food production, Phillips and her colleagues projected proportional shifts in area under cereals observed in the 1997/98 El Niño and 1998/99 La Niña to past El Niño and La Niña years. Extrapolating 97/98 and 98/99 area changes to past Niño and Niña years suggests that widespread forecast use could increase mean production, but also increase its variability from year to year and decrease production during El Niño years. Philips et al. speculated that widely-publicized predictions of drought in 1997 may have contributed to expectations of food aid and disincentive to expand cultivation to meet household food needs. Regardless of the reasons, increased production volatility would complicate management of markets, food stocks and imports at a national level.

The key lesson that this study illustrates is that forecast information may results in both "winners" and "losers." Responses that are optimal for farmers may not be optimal for other segments of society. Policy (e.g., safety nets) may contribute to unintended responses and impacts of forecast use. Achieving desired societal outcomes may therefore require targeted changes to existing policy.

Argentina: Preserve Probabilities

Initial meetings between Florida Consortium investigators and Argentina's agricultural sector (early 1997) revealed skepticism about ENSO-based forecasts, and little apparent flexibility to alter management in response. However, participants did suggest shifting farm land allocation among crops as a possible farmer response.

As in many parts of the world, the 1997-98 El Niño received widespread attention and media coverage in Argentina. Some farmers responded to expected rainfall enhancement by planting more maize. By the end of the summer growing season, their highly-visible success led to widespread enthusiasm. According to a report conveyed to a colleague working in the region (F. Royce, personal communication), as the 1998-99 crop season approached, a cooperative of eager farmers invited meteorologists to discuss implications of the developing La Niña and recommend management responses. One gave a probabilistic assessment and urged appropriate caution. Apparently dissatisfied, they invited another, who confidently predicted that the rains that had just passed (October) would be the last, and recommended only drought-tolerant crops. Precipitation was only slightly below average, and its timing quite favorable for maize. Farmers who minimized maize area in response to La Niña watched their "uninformed" neighbors prosper. Enthusiasm turned to disillusionment. What went wrong?

Messina et al. (1999) conducted an economic optimization study to explore the opportunity to improve farm income in the Pampas region of Argentina by adjusting farm land allocation in response to ENSO-based forecasts. I extended the study to consider the economic implications of ignoring the uncertainty of ENSO-based forecasts, to illustrate what may have gone wrong in the particular case of the farmer cooperative described above (Hansen, 2001). For a 600 ha case-study farm in Santa Rosa, in the dryer western Pampas, I determined optimal land allocation among crops for all years (1931-1997) and separately for, La Niña, neutral and El Niño years.

Economists define the value of forecast information as the difference between expected outcomes from the best decisions using the forecasts and expected outcomes from the best decisions without the forecasts. It is useful to differentiate between "objective" value based on difference in expected returns, and subjective value based on difference in certainty equivalent returns, which penalize for the degree of risk and farmer risk tolerance. I considered three scenarios: (a) a risk-neutral farmer, (b) a risk-averse farmer with forecast uncertainty preserved, and (c) a risk-averse farmer, with the forecast unbiased with respect to mean predicted crop response but with the variability lost in El Niño and La Niña years. The third scenario is a simplistic representation of the apparent deterministic interpretation of the expected impacts of the 1998-99 La Niña. As expected, use of ENSO information increased both expected and certainty-equivalent income for the two scenarios in which forecast uncertainty was preserved, as indicated by positive objective and subjective value (Table 3). However, the subjective value of optimal use of the forecast became strongly negative when information about the uncertainty of the outcomes in El Niño and La Niña years was lost. We can speculate that loss of information about variability among La Niña years and the associated recommendation to plant fewer types of crops led some farmers to abandon risk-reducing crop diversification strategies in the above example. Disillusion resulted because land allocation decisions that might have been beneficial in an "average" La Niña led to missed opportunity and resulting income loss in the particular conditions of 1998-99.

The key lesson that this analytical exercise illustrates is that overconfidence due to miscommunication or distortion of uncertainty can negate the value of forecast use, leading farmers to make decisions that are inconsistent with their risk tolerance, thereby exposing them to unacceptable downside risk. If they are to benefit risk-averse farmers, seasonal forecasts must be communicated and understood in probabilistic terms.

Burkina Faso: Need a Holistic Approach

The CFAR project has worked with smallholder farmers in three zones in Burkina Faso: the Southwest Sudan dominated by commercial cotton, the Sudan of the Central plateau dominated by subsistence sorghum and millet, and the Northern Sahel with pastoralism and agro-pastoralism (Ingram et al., In press). The project used a range of methods to elicit farmer decision options and information needs relative to seasonal forecasts. They also sought to understand institutional requirements and capacity to support forecast applications.

Farmer flexibility and the management responses to forecasts available to farmers differed greatly among the three zones. Decisions that farmers in the Southwest would consider modifying in response to forecasts include furrow orientation (for water retention or drainage) and the proportions of area under cotton and maize. The farmers of the Central plateau have the greatest flexibility to respond to forecasts. Options include field selection (upland vs. depressional) and crop and cultivar selection. In the Northern Sahel, pastoralists have few if any viable forecast-sensitive options. Agro-pastoralists have options that are similar to farmers in the Central plateau, but tend to be highly constrained by availability of land due to competition with pastoralists.

The nature of the forecasts also influences the ability of farmers to respond. Farmers were more concerned about within-season characteristics (onset, termination, and likelihood and severity of mid-season dry spells) of rain than season total amounts. The value of forecasts diminishes if information is received after late April or early May, when a number of pre-planting decisions must be made. Contrary to popular belief, the probabilistic nature of forecasts is not a serious constraint as long as the probabilities are explained. Although farmers do not want to be told what to do, they do want forecasts packaged with access to technical expertise.

The team found that a number of barriers currently restrict the use farmers make of seasonal forecasts, including: shortage of labor at critical periods; competition for fields; debt burden; limited access to credit, inputs and markets; disruptions to traditional lines of authority; and the content, timing and scale of available forecasts. The relative importance of these barriers varies with location. Importantly, these are the same challenges that confront the farmers in the absence of forecasts. With the exception of the nature and content of forecasts, all of these challenges are targets of ongoing development efforts. None are insurmountable in the face of concerted, holistic development effort.

The key lesson that the CFAR experience in Burkina Faso illustrates is that many different factors determine farmers' ability to change decisions in response to forecasts. Taking a holistic approach and engaging all relevant stakeholders in the process may overcome many apparent barriers. Such a holistic approach may require forecast information to be packaged with other information, inputs, technological innovations and institutional support.

How Can We Advance in the Future?

To devise a strategy to advance future applications, it is useful to first ask, "What conditions must be in place before farmers can benefit from seasonal climate forecasts?" The short answer is that benefit arises when *prediction* of climate fluctuations leads to *decisions* that reduce human *vulnerability* to impacts of climate variability. Recognizing that the improved decisions depend on communication, and that the process depends on institutional support in an appropriate policy environment, Hansen (In press a) proposed five preconditions to successful forecast application. These five conditions correspond to five areas that any holistic effort to foster appropriate seasonal forecast use needs to address:

- *Decision maker vulnerability and motivation*. Forecast information is useful only when it addresses need that is real and perceived. Decision makers must be aware of climate risk and its impacts, and motivated to use forecasts to manage that risk.
- *Viable forecast-sensitive decision options*. Benefits are conditioned on existence and understanding of decision options that are sensitive to incremental information in forecasts, and compatible with goals and constraints.
- *Predictability of climate fluctuations*. Relevant components of climate variability must be predictable in relevant periods, at an appropriate scale, with sufficient skill and lead time for decisions.
- *Communication*. Use of climate forecasts requires that the right audience receives, understands, and correctly interprets the right information at the right time, in a form that can be applied to the decision problem(s).
- *Institutions and policy*. Sustained operational use of forecasts requires institutional commitment institutions to provide forecast information and other support, and policies that support provision and use of climate forecasts.

As agricultural applications of seasonal climate prediction move increasingly beyond exploratory efforts of the climate community into mainstream agricultural research, credible demonstration of farmer use and benefit is likely to become increasingly important. Skeptics rightly point out that there are not very many clear, well-documented examples of forecast use particularly by resource-poor farmers in less-developed countries. I propose that this may have more to do with the nature of past studies than the fit between forecasts and the needs and abilities of farmers. First, few studies have attempted to use the best possible forecast methods and tailor forecast products to the expressed needs of farmers and the scale of farm decision making. Second, while studies have identified barriers related particularly to resource availability, few have attempted to involve relevant actors, such as suppliers of agricultural inputs or credit, sufficiently to address these apparent barriers. Third, few have allowed sufficient time for farmer learning, often due to the constraints of project funding cycles. Finally, few studies that have taken a holistic approach have been designed explicitly to evaluate adoption and impact. Wherever resources allow, a holistic approach that attempts to put the necessary conditions in place, and concerted efforts to demonstrate and quantify use and benefits, will benefit the cause of seasonal forecast applications and the farmers whom we serve.

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Table 1. Key lessons from international experience with agricultural application of seasonal forecasts.

- Quantitative, computer-based analytical tools can be combined quite effectively with participatory approaches to facilitate farmer discussion and foster mutual learning.
- Climate information is likely to have greatest value if communicated through advisors who farmer already know and trust. Any initiative must either work through existing trusted institutions and advisory networks, or invest considerable time and effort to establish trust and credibility.
- Responses that are optimal for farmers may not be optimal for society. Policy (e.g., safety nets) may contribute to unintended responses and impacts of forecast use. Achieving desired societal outcomes may require targeted changes to policy incentives.
- Overconfidence due to miscommunication or distortion of uncertainty can negate the value of forecast use, leading farmers to make decisions that are inconsistent with their risk tolerance. Seasonal forecasts must be communicated and understood in probabilistic terms.
- Many different factors determine farmers' ability to change decisions in response to forecasts. Many apparent barriers can be overcome by taking a holistic approach and engaging all relevant stakeholders in the process.

Table 2. Pre-season elicited management responses of survey respondents who had heard the seasonal forecast or expected below normal rainfall in 1997/98 or above normal rainfall in 1998/99 (Phillips et al., In press).

Response strategy	1997/98 El Niño	1998/99 La Niña
Change total area planted	49%	47%
Change crop or cultivar	46%	17%
Change planting date	51%	21%
Change plant spacing	2%	0%

Table 3. Value of ENSO-based climate forecasts, expressed on an objective (expected value) and subjective (certainty-equivalent) basis, for farm land allocation under three scenarios (Hansen, 2001).

Decision scenario		**Forecast value**			
Risk	**Forecast**	**Objective**		**Subjective**	
preference	**uncertainty**	**Total**	**ha^{-1}**	**Total**	**ha^{-1}**
Neutral	Preserved	$5,108	$8.51	$5,108	$8.51
Averse	Preserved	$4,490	$7.48	$2,441	$4.07
Averse	Distorted	$8,289	$13.82	$-4,044	$-6.74