Understanding Farmers' Forecast Use from Their Beliefs, Values, Social Norms, and Perceived Obstacles*

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ABSTRACT

Although the accuracy of weather and climate forecasts is continuously improving and new information retrieved from climate data is adding to the understanding of climate variation, use of the forecasts and climate information by farmers in farming decisions has changed little. This lack of change may result from knowledge barriers and psychological, social, and economic factors that undermine farmer motivation to use forecasts and climate information. According to the theory of planned behavior (TPB), the motivation to use forecasts may arise from personal attitudes, social norms, and perceived control or ability to use forecasts in specific decisions. These attributes are examined using data from a survey designed around the TPB and conducted among farming communities in the region of eastern Nebraska and the western U.S. Corn Belt. There were three major findings: 1) the utility and value of the forecasts for farming decisions as perceived by farmers are, on average, around 3.0 on a 0–7 scale, indicating much room to improve attitudes toward the forecast value. 2) The use of forecasts by farmers to influence decisions is likely affected by several social groups that can provide "expert viewpoints" on forecast use. 3) A major obstacle, next to forecast accuracy, is the perceived identity and reliability of the forecast makers. Given the rapidly increasing number of forecasts in this growing service business, the ambiguous identity of forecast providers may have left farmers confused and may have prevented them from developing both trust in forecasts and skills to use them. These findings shed light on productive avenues for increasing the influence of forecasts, which may lead to greater farming productivity. In addition, this study establishes a set of reference points that can be used for comparisons with future studies to quantify changes in forecast use and influence.

1. Introduction

Previous studies that examined how farmers use weather and climate forecasts have focused primarily on the specific needs of the farmers, based on the assumption that "forecasts . . . are likely to have value to decision makers [and thus potential for use] if the characteristics of those forecasts are consistent with decision maker needs" (Sonka et al. 1987). Farmer needs may be divided into 1) more accurate and relevant forecasts and easier formats for comprehending them and 2) information or training concerning the correct use of forecasts in specific decisions. For example, Easterling (1986) indicated that forecasts with longer lead time and forecasts pertaining to extreme weather events were most relevant for farmers. Some also have argued that modifying forecast formats and graphics may make forecasts more appealing and may help users to understand them better. In addition, various prerequisites have been proposed for forecasts to increase their usefulness and use in certain farming decisions (Lamb 1981; Sonka et al. 1987; Easterling 1986; Barrett 1998;

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Hansen 2002). Those prerequisites have been primarily defined with the expectation that more task-specific and easy-to-use forecasts would attract more attention of certain users and result in effective use of the forecasts.

The results of these studies may have helped forecasts to fit some specific needs better, but forecast use in farming decisions has changed little over time. The current situation is that seasonal and longer-term forecasts of precipitation and temperature typically are not adopted, nor are they used effectively when they are adopted in very limited cases (e.g., Changnon et al. 1995; Pielke and Sarewitz 2002). This lack of effective use of forecasts in farming decisions is apparently not due to the lack of traditional education and outreach efforts. For example, a series of workshops were held by the National Weather Service in cooperation with the regional climate centers in late 1994 to inform potential users, including farmers, of the nature of the "climate outlook" and related forecasts and to explain their scientific basis (HPRCC 1994). Various presentations also have been made at numerous conferences and in other venues thereafter.

The lack of change in forecast use by farmers contradicts the notion suggesting that the route to improved forecast use is primarily via forecast improvement: Forecasts have improved, but the extent to which and manner in which farmers use them have not changed. Furthermore, low use of forecasts makes it difficult to evaluate the effect/usefulness of certain changes and improvements in weather and climate forecasts. For example, improved accuracy in prediction of rain might result in more efficient use of irrigation, but only if farmers allow the forecast to influence their irrigation decisions. Furthermore, truly effective use of existing and new forecasts will certainly take some experimentation and practice. Regardless of how advanced the forecasts are in accuracy and formatting, farmers cannot develop and improve their forecast-use skills if they do not use forecasts and reflect upon the outcomes of their forecast use.

With respect to the issue of low use and influence of forecasts, it may be that many farmers have tried using forecasts in the past and reflected upon that use, yet determined that the outcomes were not favorable. This process could result in farmers forming generally negative attitudes that prevent them from using and being influenced by forecasts in the future, even though the forecasts are changing to become more useful. Thus, one set of possible explanations for the lack of change in forecast use among farmers may be rooted in farmer attitudes and motivations.

In general, human motivation cannot be discussed without reference to both internal (e.g., psychological and social) and external (e.g., technological and situational) factors. Many studies have examined the external factors, by investigating how forecast type, accuracy, format, and timeliness affect forecast use in farming decisions (e.g., Easterling 1986; Sonka et al. 1987; Barrett 1998; Mjelde et al. 1998). Although these properties and formats of the forecasts do affect their usage, forecast use likely is strongly affected by a host of *internal* psychological and social factors (as suggested by Glantz 1977) that have not been fully explored. The fact that the features of forecasts *have changed* over time but that the use of forecasts by farmers *has not changed* suggests the need to focus on the internal factors and reevaluate the forecast use and influence from the perspective of farmers, asking the questions concerning not only how farmers perceive forecasts, but also how farmers value those perceptions. That is, what are the attitudes and other psychological, social, and economic influences that enhance or hinder farmer motivation to consider forecasts in their farming decisions? Examining such internal motivational factors and their role and influence in decision making related to using or not using forecasts is essential to a more complete understanding of farmer forecast use. This understanding may help to inform and improve weather and climate forecasts and, eventually, the effectiveness of their use in, and the extent of their influence on, farming decisions.

Note that we do not propose that more use of all forecasts in all decisions will necessarily lead to better farming outcomes. We believe, however, that more and effective use of certain accurate forecasts for certain farming decisions can lead to better results for certain outcomes (including not only increasing profitability, but also helping farmers and rural communities to achieve other substantive goals). The current situation is that too few (not too many) forecasts have been considered by farmers in relevant farming decisions. Given the amount of effort and investment currently dedicated to developing and improving the forecasts, it is important to investigate and understand why the extent of their use and influence has not changed.

To understand the internal factors affecting farmer forecast use in farming decisions, we can use tools and perspectives from the social sciences, such as those discussed in Ajzen and Fishbein (1980), Ajzen (1985, 1991), Stewart (1991, 2001), Stewart et al. (1992, 2004), Stewart and Lusk (1994), and Nicholls (1999). This current study uses the theory of planned behavior (TPB), which originates in social psychology (Ajzen 1985, 1991), and enhances it by adding a financial variable suggested by the theory of derived demand (TDD), which originates in economics (e.g., Varian 1992). The TPB has been used in many other areas to identify successfully the motivational factors that underlie decisions, and accumulating evidence supports the TPB for describing decision behavior in natural resource conservation and behavior of farmers (Beedell and Rehman 1999, 2000; Trumbo and O'Keefe 2001). Integrating the TPB with main ideas from the TDD gives the TPB even greater explanatory power, as demonstrated in Lynne and Rola (1988), Lynne (1995), and Lynne et al. (1995); in the latter study, the enhanced version of the theory is referred to as the theory of planned demand (TPD). The TPB and TPD can provide a useful framework for understanding farmer motivation and intentions to use or not to use the forecasts in farming decisions.

The TPB predicts three kinds of factors likely to affect forecast-use behavior: 1) attitudes reflecting expectancies and values associated with forecast use, 2) social influences stemming from expectancies about local norms concerning forecast use and extent of personal desire to comply with those social norms, and 3) perceived control over one's forecast-use behavior (e.g., one's self-perceived technical and economical ability to use forecasts). These three terms affect the motivation and intentions as depicted in the following TPB model (Ajzen 1985):

$$A \approx I = f(\text{attitude, social norms, perceived control}), \tag{1}$$

where A is action, I is intention, and both are influenced by the causal factors through function f. The TPB framework points toward identifying the influences of attitudes, social norms, and control variables on specific decision making. Thus, within this framework, we can examine the specific content of farmers' motivation and intention and how that motivation forms and drives forecast use in specific environmental and social settings.

In this paper, we report the descriptive findings from a survey designed consistent with the TPB approach. In a companion paper (Artikov et al. 2006) we report the findings that arise from the enhanced TPB model as represented in the integrated TPD model, focusing on causal factors. We focus here on describing the current farmer attitudes, social norms, and perceived control factors affecting forecast use. That is, we report the current "mean states" of those aspects affecting farmer motivation. These descriptions will provide a reference point for measuring changes that may correspond with future forecast-use improvements, and they provide a detailed definition of the broader constructs, which are then actually modeled in the companion paper by Artikov et al. (2006). In the next section, examples will be presented to show how the survey questions were designed to extract the information and to identify those mean states. Major results are presented and discussed in section 3. Section 4 discusses the results and considers whether the attitudes and motivations that were uncovered are indicative of inherent limitations in the utility of forecasts or are indicative of changes that might be made in either the forecasts or their presentations to help to advance informational and educational efforts to improve effective use of forecasts in farming decisions and thereby to increase the value of forecasts to farmers.

2. The survey

Because very little is known about the motivations underlying farmer decisions to use or not to use weather and climate forecasts, we designed and conducted a survey based on the TPB and the TPD to gather such information from farmers in eastern Nebraska. To guide survey development, focus groups were conducted in three eastern Nebraska counties: Otoe, Seward, and Fillmore. These counties were chosen to represent dryland, mixed dryland and irrigated, and mostly irrigated cropping systems typical in western U.S. Corn Belt region. Farmers attending focus groups described their farming decisions, their knowledge of weather and climate forecasts, and their experiences with and concerns about using those forecasts. Findings from the focus groups helped to identify common farming decisions and the climate predictions/information that farmers accessed and assisted us in designing questions to assess the attitudes, social norms, and components of perceived controls, as well as financial variables that also affect farmer use of the forecasts and information in farming decisions.

Because the extent of "use of forecast information in farming decisions" is unknown, it would have been ideal to ask very detailed questions about how specific forecasts were used for particular decisions and how various psychological and social factors influenced the use of the forecasts and aided those decisions (e.g., the influence of drought forecasts on seed choices). However, a complete set of such detailed questions would have resulted in an unmanageably long survey. Given that this was the first study of its kind, we designed the survey questions to focus at an intermediate level of detail that would assess the universe of decision–forecast combinations relatively completely without over-

TABLE 1. Data products and forecasts in the CRPC, STF, and LTF groups.

Climate information and forecasts
Current and recent-past conditions
Current drought conditions
2001 growing-season rainfall in your area
2001–02 winter recharge and precipitation
Crop water use estimates
Current soil temperature
Other current forecasts
2001–02 snowpack in Rocky Mountains
Short-term forecasts
1–2-day rainfall and temperature
3–7-day rainfall and temperature
8–14-day rainfall and temperature
1–2-day wind
Other short-term forecasts
Long-term forecasts
Seasonal forecasts
One-month rainfall and temperature
Other long-term forecasts

whelming the participants with the number of questions.

Results from the focus groups suggested that farmers tended to distinguish between three broad categories of climate information: current and recent-past weather/climate conditions (CRPC), short-term forecasts (STF), and long-term forecasts (LTF). The specific forecasts and data products in each category, which are primarily from the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center, are listed in Table 1. Focus groups also suggested that farming decisions could be categorized into five groups corresponding to different stages of crop production: 1) agronomic decisions through planting (including choice of crop type, seed variety, tillage method, planting density, and date), 2) summer growing-season decisions (including applications of pesticides, herbicides, fertilizers, and irrigation), 3) harvest and postharvest decisions (including harvest date, autumn irrigation, and tillage), 4) crop insurance, purchased before the 15 March federal deadline of each year, and 5) marketing choices made throughout the year.

When making these decisions, farmers have a variety of goals in mind, and they try to use available information to make the decisions and achieve those goals. Forecasts are one type of such information. According to the TPB, attitudes toward forecasts predict use of the forecasts, and attitudes are determined by expectancies (beliefs) and values. Thus, to examine farmer attitudes toward forecast use in making those decisions we asked farmers to rate on a given scale (ranging from 0 to 7[1]) their expectancies, in 2002, that specific forecasts are useful to achieve particular outcomes/goals, for example, the expected likelihood that CRPC can help to determine buying the right amount of crop insurance (see question A in the appendix). To assess the value component of attitudes, the survey also included a question asking farmers to rate the *outcome value,* or importance of the various goals (question B in the appendix; again measured on the 0–7 scale). According to the TPB (Ajzen 1988), the product of the expectancy and the outcome value of a decision from these two questions measures farmer attitudes toward the forecast use. This product is a proxy for the (subjective) utility gained from forecast use in that decision.

In our survey, the social norms affecting forecast use [the second causal factor on the right-hand side of Eq. (1)] was probed with two questions suggested by the TPB. The first question asked farmers their *expectancy* (i.e., how likely it was—again a kind of belief) that various persons/groups (spouse, children, neighbors, landlord, bankers and lending agencies, government agencies, crop consultants and extension educators, as well as news media and Internet services) believed that forecasts and weather information should influence farming decisions. The second question asked how much farmers *valued* the forecast-use views of each of those persons/groups. The more value a farmer places on the view of a particular individual/group, the more influence that party will have on the farmer's decision to use forecasts. According to Ajzen (1988), the product of the answers to these two questions measures the influence of the social norms on forecast use in farming decisions.

Questions asking farmers to report their perceptions of the forecasts in terms of usage barriers also were included in the survey. Those barriers were identified by the focus groups, and measured farmer-perceived ability to use forecasts in farming decisions [third term on the right-hand side of Eq. (1)], as well as some potential barriers (discussed in section 3d) that have not been examined in previous studies.

[1] These *independent variables*, which are theorized to affect forecast use/influence, were measured using a 0–6 scale, and 9 = "does not apply" (see appendix). However, the data were recoded such that $9 \rightarrow 0$, $0 \rightarrow 1$, $1 \rightarrow 2$, . . . , $6 \rightarrow 7$ to create a 0–7 scale in which "0" indicates that the person felt that the goals were not relevant to him/her (e.g., "sharing limited water resources" would not be relevant to someone who did not irrigate), "1" indicated that the person found the outcome relevant but felt that a type of forecast was "extremely unlikely" to facilitate the outcome, and "7" indicated that the forecast was "extremely likely" to facilitate the outcome.

TABLE 2. Percentage of farmers reporting different degrees of influence from use of weather information on CRPC, STF, and LTF in the 2002 growing season. The "0" column is set off from the other responses to distinguish reports of "no influence" from reports varying in extent of influence. Boldface entries indicate percentages of farmers with potential confusion on forecasts. The column "*M*" in each category shows the mean influence of that particular type of forecast on the farming decisions made in 2002. The mean influences of the CRPC, STF, and LTF were compared for each decision using paired *t* tests and a $p < 0.01$ level to determine statistically significant differences between their influence on the same decision; italicized values have similar influence (the influences are not statistically different from one another).

	Climate information/forecast														
	CRPC					STF					LTF				
Farming decisions	0	1–2	3–4	5–6	*M*	0	1–2	3–4	5–6	*M*	0	1–2	3–4	5–6	*M*
Agronomic decisions through planting	18	17	36	29	*3.1*	20	25	34	21	2.7	**19**	**19**	31	31	*3.1*
Summer growing-season decisions	17	17	33	33	*3.2*	**15**	**15**	33	37	*3.4*	20	22	31	27	2.9
Harvest and postharvest decisions	26	17	28	29	*2.8*	26	17	31	26	*2.7*	**30**	18	27	25	2.5
Purchasing crop insurance	36	12	18	34	*2.8*	42	18	**20**	**20**	*2.6*	**33**	**9**	20	38	3.3
Crop marketing	25	17	30	28	*2.7*	25	20	34	21	2.1	**21**	10	30	39	*2.9*

Last, various measures of financial capability were queried in terms of total farm sales, farm debt, and farm income. The influence of this variable on motivation and intention is examined in Artikov et al. (2006).

The collective outcome [the *dependent variable* on the left-hand side of Eq. (1)] of these effects was measured in the survey by answers to a question asking farmers to rate "the extent to which the various forecasts have influenced each of those decisions in 2002," on a scale ranging from 0 (no, it did not influence my decision) or 1 (yes, it did influence my decision a little) to 6 (very much). Note that here we specifically asked farmers how or if a forecast *influenced* their decisions rather than more generally asking if they *used* the forecast. We felt that the term "use" was too vague a concept that focused on *access* to the forecast and would not reveal if the forecast had actually influenced a decision. In contrast, the question of "influence" more clearly focuses on the *impact* of the forecasts that the farmers accessed. Although access to forecasts is a prerequisite for allowing forecasts to have an impact on decisions, we were specifically interested in explaining why some farmers allowed forecasts to influence their decisions and some did not.

The rest of the questions in the survey were designed to complement and enhance our understanding of farmers' reasons for allowing forecasts to influence their farming decisions. These questions pertained to social demographics, education, and personality traits. A hard copy of the final survey, which consisted of 31 multilevel questions (i.e., questions containing subquestions), was mailed[2] in February of 2003 to all 2211 farm operators[3] in Otoe, Seward, and Fillmore Counties. Participant feedback indicated that the length of the survey (which farmers reported took approximately 1 h to complete) may have prevented more farmers from responding. However, the return rate (34%) was better than that generally obtained for surveys of farmer populations (likely because of the offer of payment for returning it) and provided a sample size that was more than adequate. After screening the data for validity and level of completion (extent of missing data), 698 usable surveys were digitized. The data were further screened for quality assurance and then were used in analyses.

3. Results

a. *Forecast influence on farming decisions*

We first describe our dependent variable [on the left-hand side of Eq. (1)], that is, the magnitude to which farmers reported that forecasts influenced various farming decisions in 2002. In Table 2, we show both the percentages of the farmer population who allowed forecasts to influence their decisions at various magnitudes and the average magnitude of the influence on the farming decisions. The results indicate that, for both

[2] A letter accompanying the survey explained its purpose and offered a $25 incentive for its completion and return. (A form requesting the $25 was sent back to the study team in a separate return envelope; the questionnaire itself was mailed back anonymously; 87% of those who returned surveys requested the payment.) A follow-up reminder postcard was mailed two weeks after the initial mailing.

[3] Farm operators include owners but exclude those who are only landlord–owners and are not actively farming. This mailing to operators reflects the focus in the study on direct decision making. The influence of landlords, which in some cases does affect farmer decisions, then, is addressed through the influence of others in the social-norm variable.

STF and CRPC, about 62%–65% of the farmers allowed the forecasts and climate information to influence their agronomic decisions through planting at magnitudes from "somewhat" (3–4) to "a great deal" (5–6, on the 0–6 scale). The percentage of farmers who allowed LTF to influence their agronomic decisions "a great deal" is slightly higher than the percentage of farmers allowing CRPC to influence those same decisions (31% vs 29%). Meanwhile, 35%–38% of farmers allowed little or no effect of CRPC or LTF on their agronomic decisions. The average magnitude of forecast influence on the agronomic decisions is 2.7 from STF to 3.1 from both LTF and CRPC, on the 0–6 scale (the "M" columns in each category in Table 2). Thus, on average, the climate forecasts and information only "somewhat" influenced the agronomic decisions in 2002.

Similarly, about 70% of the farmers allowed STF to affect their summer growing-season decisions from "somewhat" to "a great deal" (3–6), and 66% indicated CRPC influence, a result showing farmers combined the recent-past condition and short-term forecasts in decisions during the summer growing season. Also, 58% of the farmers reported LTF as influencing those short-term growing-season decisions, but it remains unclear how such decisions could be made with monthly to seasonal forecasts. The average magnitude of influence of CRPC and forecasts on the summer growing-season decisions is from 2.9 to 3.4, the highest among all the forecast effects on decisions in Table 2. This result could have reflected the most frequent use of climate information in those repeated decisions during the growing season.

In making the longer-term financial decisions such as purchasing crop insurance and marketing crop goods, nearly 40% of farmers reported allowing LTF to influence those decisions "a great deal." About 30% of farmers also used CRPC "a great deal" in those decisions. Farmers also reported that marketing decisions were moderately influenced by STF. It is intriguing, however, that examination of the influence on crop insurance decision revealed that farmers are largely divided on the two extreme ends of either allowing each of the forecasts to affect the decision "a great deal" (5–6) or ignoring the forecasts completely (0). This "0–1"-like distribution in forecast influence may indicate a unique process in making insurance decisions. Nonetheless, the average magnitudes indicate that the LTF had a relatively larger influence on these longer-term decisions than did the CRPC and STF.

To summarize, 60%–70% of farmers allowed weather information and forecasts to influence specific decisions to various magnitudes. Among those farmers, about one-half reported that forecasts influenced some of their decisions "a great deal" (ratings of 5–6). Meanwhile, the variation of the mean magnitudes of influence across the decision spectrum in Table 2 (the "M" columns) also was encouraging, showing that farmers, as a group, had some expertise for appropriate application of specific forecasts in particular decisions. On the other hand, the results also suggest some problems. Perhaps the most obvious one is that there is a sizable group of farmers who report that they allowed seemingly irrelevant forecasts to influence some specific decisions. For example, in addition to the previously discussed issues (e.g., the number of farmers reporting that LTF strongly influenced short-term growing-season decisions), 40% of farmers reported that STF had moderate to great influence (ratings of 3–6) on their crop insurance decisions, which are made before 15 March and for the entire year. These results were unanticipated during survey design; thus, the exact reason why these farmers responded in this way is unknown and indicates the need for further research.

According to the TPB, farmer choices to allow the forecasts to influence their specific decisions, as described in Table 2, are primarily affected by farmer motivational variables, that is, farmer attitudes, social norms, and perceived control for using forecasts in the decisions. Thus, it is important to examine these psychological and social factors to understand more fully why some farmers used some forecasts in farming decisions and to determine effective ways, perhaps eventually, to transform forecasts into more valued outcomes.

b. Farmer attitudes (perceived expectancies and values) toward climate forecasts

Farmer-perceived expectancies of the forecasts—that is, their beliefs about the extent to which the forecasts can help to achieve a variety of outcomes—are shown in the CRPC, STF, and LTF columns in Table 3. These results show that farmer-perceived expectancies of forecasts fall at the low end of the scale, below 4.2 on the scale of 0–7. The perceived values of those outcomes to achieving farming goals in 2002 are estimated and listed in the second column in Table 3 (these also have a possible range of 0–7; see the appendix for the "expectancies" and "outcomes" questions used to elicit the data in Table 3).

As noted earlier, these estimated expectancies about forecasts are multiplied by the perceived values of the outcomes to provide a numerical estimate of farmer attitudes toward the forecast use, that is, an estimate of the subjective utility received from allowing forecasts to influence particular decisions. For example, if farmers

TABLE 3. Farmer-perceived expectancies (beliefs) about CRPC, STF, and LTF and values of outcomes from various decisions in the 2002 growing season. The scale for the perceived value and the means is 0–7, after rescaling (see text for details).

Outcomes	Perceived value of outcomes to farmers (from question B in the appendix, rescaled)	Perceived expectancies about the information and forecasts (from question A in the appendix, rescaled)		
		CRPC (mean/std dev)	STF (mean/std dev)	LTF (mean/std dev)
Planting the best crop and variety	5.65	4.14/1.99	4.04/1.96	3.89/2.07
Right amount of crop insurance	4.60	3.22/2.44	2.76/2.27	3.47/2.53
Optimal amount of spraying and irrigation	5.48	3.97/2.07	4.16/2.02	3.63/2.05
Maximize crop revenue in marketing	5.33	3.43/2.11	3.34/2.08	3.79/2.23
Lowest possible costs	5.46	3.50/2.21	3.43/2.13	3.50/2.21
Reducing financial risks	5.38	3.52/2.25	3.41/2.20	3.59/2.31
Sharing limited sources of water	2.79	2.04/2.38	2.04/2.38	2.05/2.39
Reducing fertilizer and pesticides in runoff	4.79	3.41/2.38	3.56/2.41	3.07/2.33
Sustaining rural community	4.75	3.11/2.51	2.94/2.45	3.19/2.58

feel that the LTF are useful in helping them choose the right amount of crop insurance, and if the farmers highly value choosing the right amount of crop insurance, their attitude toward the forecast use will be highly positive and will be likely to motivate and allow the LTF to influence their crop insurance decisions. If either the value of an outcome or expectancy of forecasts for that outcome is low, however, the estimated attitude will be low. Consistent with the TPB, expectancies, values, and the resultant attitudes were correlated with the forecast influence dependent variables (correlation coefficients typically ranged between 0.3 and 0.7 and above the 95% significance level), and even stronger correlations were observed when correspondent attitude-forecast influences were examined [e.g., the attitudes about LTF related more strongly to farmers' reports about the influence of LTF than to farmers' reports of STF and CRPC influences; see also Artikov et al. (2006) for additional discussion beyond correlation, and including causal modeling of the factors]. The low perceived expectancies of forecasts for the anticipated outcomes reported in Table 3 also are consistent with the low use and influence of forecasts in farming decisions in 2002 (Table 2).

Examination of the specific expectancies and values reported in Table 3 helps to elaborate our understanding of the farmer attitudes that are affecting their forecast use. For example, consider the growing-season chemical (herbicide and pesticide) and water applications ("optimal amount of spraying and irrigation") outcome in column 1. For that outcome, STF had the highest rated perceived expectancy (i.e., likelihood of being useful), with an average rating of 4.16. Other forecasts were seen as less useful for that outcome on average, and STF were seen as not quite useful for other outcomes. However, STF were still only perceived as moderately useful, not highly useful. Thus, even though farmers' perceived value of those outcomes is relatively high, 5.48, farmer attitudes toward using STF to influence those decisions are relatively low: only 22.8 on scale 0–49. Although future research is needed to clarify and to test the accuracy of farmer perceptions of STF for chemical and water applications, it seems to us that their reportedly low perceived expectancies about the utility of STF for summer growing-season decisions are quite out of proportion to the substantial improvements in the accuracy of 1–3-day forecasts [e.g., of precipitation of 0.5, 1.0, and 2.0 in. (1 in. $\simeq$ 2.54 cm) and temperatures, though the improvement varies by seasons; see the National Weather Service Hydrometeorological Prediction Center's threat scores and bias scores that were available online at http://www.hpc.ncep.noaa.gov/html/hpcverif.shtml]. Although correct use of those quality STF forecasts in application plans and schedules could improve farming outcomes, it appears that the attitudes of farmers toward the STF have hindered the use of those forecasts, very likely preventing those forecasts from being as useful as they could be. If we are correct that there is a large difference between the farmers' perceived expectancies of forecasts and the forecasts' actual utilities, it indicates a potentially remediable deficiency in farmer knowledge of forecasts, and a need to improve farmer-perceived forecast utility and value.

Table 4. Farmer-perceived social influences on their forecast-use decisions from various groups in the 2002 growing season. The scale for the means is 0–7 (see text for details).

Social groups	Expectancy of the social group's opinion on forecast use (mean/std dev)	Value of the social groups' opinion on forecast use (mean/std dev)	Social norms (on 0–49 scale)
Emotional relationships			
Spouse/significant other	4.27/1.92	4.79/1.84	20.5
Children/grandchildren	2.92/1.86	3.28/1.93	9.58
Other relatives	2.89/2.10	3.07/2.08	8.87
Friends and neighbors	3.49/1.94	3.53/1.82	12.32
Shared investment relationships			
Landlord	4.01/1.94	4.09/1.82	16.40
Banker; lending agency	3.19/2.37	3.08/2.24	9.83
Expert information			
Chemical and fertilizer dealers	3.47/2.10	3.50/2.01	12.15
Government agencies	2.92/2.08	2.80/1.89	8.18
Crop consultants	4.23/1.87	4.13/1.75	17.47
University cooperative extension service	3.46/2.17	3.37/2.03	11.66
Media sources			
Data transmission network	3.78/2.01	3.58/1.92	13.53
Internet sites	3.56/1.92	3.41/1.79	12.14
Television and radio	4.30/1.95	4.15/1.89	17.85
Magazines, newspapers, and newsletters	4.01/1.92	3.74/1.87	15.0

c. *Social norms*

Another factor that greatly affects farmer use of forecasts is the farmers' perceived social norms. Farmers are likely to be reluctant to allow a forecast to influence their decisions if social influence runs counter to that use. Because farmers are shown to have a strong tendency to yield to their social norms (e.g., Willock et al. 1999) and the social influences that we assessed in this study correlated at correlation coefficient r = 0.2–0.4 with the forecast influence variables (statistically significant at over 95% confidence level), knowing those norms will help us to understand further the reasons why farmers do or do not allow the forecasts to influence their farming decisions (i.e., results in Table 2).

In a similar way that attitudes consist of two attributes, social norms also have expectancy and value components. In the TPB, social norms reflect 1) farmer expectancies that others believe in using forecasts in farming decisions and 2) the extent to which farmers value those others' views. The products of these expectancies and values provide numeric estimates of social pressures. The higher those values are, the greater influence that a group of people has on encouraging or discouraging farmer use of forecasts in farming decisions. To be consistent with the other measures in this study, we measured the social pressure encouraging forecast use. The survey estimates of the expectancy and value for social norms are shown in Table 4 (on the 0–7 scale). As categorized, we surveyed farmers about the specific social influences of 1) persons with whom farmers were likely to have more emotional relationships (spouses, other family members and relatives, friends, and neighbors), 2) those who farmers might see as sharing an investment in their farm, 3) those who farmers might perceive as experts, and 4) media sources of information.

The two groups who are perceived as most supportive of using forecasts in farming decisions (according to the expectancies in column 2 of Table 4) are spouses and crop consultants. Farmers also reported relatively high valuing of their views (according to the value in column 3). Farmers value their spouses' views, indicating both the emotional relationship and common ownership of the farm. Of interest is that children, grandchildren, and other relatives might also share ownership of the farms and have emotional relationships with the farmers; yet these groups are generally perceived as considerably less supportive of forecast use, and their views are less valued than the views of spouses, friends, neighbors, and landlords. Farmers' moderately valuing their landlords' views may also indicate the ownership effects. On the other hand, the higher value for neighbors' view of forecast use may indicate farmers' respect for their neighbors and concern for how they are viewed by their peers when using forecasts. Future research is needed, however, to examine the specific roles that common ownership and emotions such as trust or respect play in determining social influences.

The higher perceived value of crop consultant view suggests that farmers recognize consultants as "better experts" than others (e.g., the extension service agents and governmental agencies) in applying information in farming decisions. Though the crop consultants are perceived as the most supportive of forecast use when compared with other groups (column 2 in Table 4), they still received a moderate score (slightly above 4 on the scale of 0–7).

In Table 4, television and radio information sources are ranked the second highest. The high value for those media sources suggests that farmers are aware of and perhaps even actively seeking weather and climate information when making farming decisions. This interpretation is consistent with the fact that farmers generally report highly valuing the sources that are perceived as most positive toward effective use of forecasts (column 2 in Table 4). Because the radio and television sources provide interpretations of forecasts for specific areas of coverage as compared with the general NOAA or Internet-site forecasts (which were valued least among the media sources), these results indicate again that farmers prefer to rely on interpretations of the forecasts that give area-specific forecasts and to rely on familiar sources that have established credibility with the farmers over time. These "processed" forecasts from television and radio also could have distracted the farmers' efforts to interpret the "raw" forecasts (e.g., from the NOAA Internet sites) in their decision making, however.

In summary, these social norm results tell us which social entities have the most positive influence on farmer use of forecasts in decisions. By capitalizing on the fact that farmers seem to value some views more than others, it might be possible for us to increase forecast effects in farming decisions if farmers are urged by those valued sources. In other words, farmers' confidence in and motivation for using a forecast could be elevated by enlisting the help of those whom farmers feel trust for, share farm ownership with, or view as expert.

d. *Perceived obstacles to forecast use*

The third factor influencing the motivation for application of forecasts in farming decisions is perceived control. In our survey, we examined the perceived control somewhat uniquely in terms of farmers' perceptions of their ability to understand and to use forecasts correctly in farming decisions and in terms of their perceptions of barriers to forecast use. One reason we focus on farmers' perception of their own ability to use forecasts is that we theorize that improving farmer attitudes toward forecasts might be achieved by developing farmers' abilities to use forecasts appropriately in relevant decisions. Increased abilities would likely result in effective use of forecasts, resulting in more positive farmer perceptions of the forecasts and leading to even more effective use of forecasts in farming decisions. Major obstacles that currently undermine farmers from using the forecasts and thus undermine the development of their ability to use the forecasts effectively also are identified (Table 5).

TABLE 5. Limiting factors on allowing CRPC, STF, and LTF to influence farmer decisions in the 2002 growing season. The scale is 0–6: 0 = "has not limited the influence," 3 = "moderately limited the influence," and 6 = "greatly limited the influence."

Limiting factors	CRPC	STF	LTF
Accuracy	3.9	4.2	4.1
Reliability	3.8	4.0	4.0
Timeliness	3.4	3.6	3.5
Availability for farming area	3.2	3.4	3.3
Personal understanding of information	3.2	3.3	3.2

It is not surprising that the accuracy of the forecasts tops the list in Table 5. It is, however, striking that farmers perceive the reliability of the sources as the second limiting factor on their use of the forecasts. This finding is consistent with focus-group discussions in which farmers indicated confusion over many forecasts available from unspecified sources that could include federal agencies, university research groups, private firms, and some individuals. As also noted by focus-group members, forecasts from unidentified sources often contradict each other—and this is particularly the case for long-term forecasts. When the sources making those forecasts are not specified and are not perceived as trustworthy and reliable by farmers, those forecasts may confuse the farmers. In addition, and perhaps more serious, the existence of many contradictory forecasts creates a situation in which farmers could look for those forecasts that would support their desired (initial) plans, thus resulting in a situation in which farmer decisions drive forecast use rather than vice versa. Such behavior has been described by Slovic (1987), who wrote, "Strong initial views are resistant to changes because they influence the way that subsequent information is interpreted. New evidence appears reliable and informative if it is consistent with one's initial beliefs; contrary evidence tends to be dismissed as unreliable, erroneous, or unrepresentative." Because of such psychological tendencies, the current forecast provision situation (failing to identify the sources for forecasts) could be generally damaging to the credibility of forecasts and to the efforts to improve effective forecast use among farmers.[4]

[4] Although a somewhat similar issue, in terms of forecast "accountability," was mentioned in some prior studies, for example, Easterling (1986), the reliability of the forecast sources and its impact on forecast use have not been quantitatively examined.

It is also interesting to find in Table 5 that farmers perceived their own understanding of forecasts as only a moderately limiting factor in their ability to use forecasts correctly. This perception could indicate that farmers believe they have adequate knowledge for using forecasts in farming decisions if they so desire. Although this indication is somewhat consistent with the overall pattern of results in Table 2, it conflicts somewhat with the Table 5 ratings for "timeliness" and availability of site-specific forecasts. The rating for timeliness suggests that farmers felt STF and LTF were not offered in an adequately timely manner. However, because the short-term forecasts are made every day and are available through various media and long-term predictions are made up to months ahead and are available on the Internet, the timeliness factor may actually reflect the perceived availability of forecasts for a given locale (indeed, in the survey data timeliness is well correlated with perceived forecasts availability, $r = 0.70$–0.74). This confusion of timeliness and availability of site-specific forecasts could be indicating inadequate knowledge about some forecasts among farmers, thus undermining the use of those forecasts and contributing to the overall low influence of the forecasts on farming decisions.

4. Implications and limitations of results

a. *Implications*

Within the TPB framework, reasons for using forecasts extend beyond the characteristics of the forecast, such as accuracy and appearance. In this study, we obtained surveys from 698 farmers and examined a number of psychological variables that are predicted by the TPB to affect farmers' decisions to consider forecasts in farming decisions. These variables include farmer attitudes toward forecasts, the social norms they perceive surrounding forecast use, and the barriers perceived as limiting forecast use (including their forecast-use abilities as one potential barrier). According to the TPB, these factors shape farmers' motivation and affect both their intentions to use and their actual use of forecasts in farming decisions. This theoretical supposition was corroborated by moderate and consistently positive correlations between those factors and the forecast influences on decisions. Although the correlation results are not proof of causation, they do support the potential importance of this descriptive investigation and point to areas for developing models to explore causation as in a companion paper (see Artikov et al. 2006). Thus, in this study, we estimated the levels of specific forms of attitudes, perceived social norms, and perceived barriers, and their subcomponents (beliefs/expectancies and values) in order to describe more fully those factors likely to underlie farmers' decisions to use forecasts and also to establish a reference that can be used for comparison with future studies.

When averaging over various decision categories, we found that farmer attitudes toward allowing forecasts to influence their decisions fell to the low end of the given scale. These low levels of attitudes resulted [see Artikov et al. (2006) for elaboration on this point] primarily from the low perceived expectancies of forecasts (which had means typically ranging over 3–4 on the 0–7 scale) rather than low outcome values (which were rated more highly), suggesting that farmers see such information and forecasts as only moderately likely to be good in arriving at better decisions. Further research is needed to investigate whether these results indicate that there is room for improved knowledge about what forecasts can do to achieve better outcomes. This is especially likely with respect to shared community goals such as using information and forecasts to achieve better outcomes related to sharing limited sources of water, reducing fertilizer and pesticides in runoff water, and sustaining rural community, with expectancies only in the range of 2.05 to 3.56. With respect to more individualized agronomic and financial decisions, the greatest possibility for improving forecast expectancies is for use of STF, which tends to have lower ratings than CRPC and LTF in several cases, for example, in achieving the lowest possible production cost (see Table 3).

Findings from examining social norms indicate that farmers appear to value highly the views of the crop consultants and television/radio (see Table 4). The value of these "expert" views might be related to farmer-perceived low reliability of the sources that make the forecasts (Table 5).[5] Our focus groups reported that viewing conflicting forecasts without understanding why they conflict or which forecast they should believe (which is hindered by the lack of clear identification of forecast makers) severely hampered their interest in developing the understanding and skills needed to use the forecasts effectively. Farmers apparently tend to perceive any new or improved forecast as simply another piece of potentially conflicting information. This situation should be corrected. Another negative effect of this identity issue on forecast use (again, as discussed by the focus groups) is that the multiple forecast choices have allowed farmers to "use" or "find support from" the forecast that fits with the plans they

[5] In support of this idea, we also conducted additional correlation analyses and found small, significant, and positive correlations (correlation coefficients are 0.12–0.20) between perceived reliability barriers and the value of different experts.

have *already* made. In such cases, premature decisions are likely affecting which forecasts farmers use, rather than vice versa. To reverse this sequence, it is necessary to specify and build trust in the forecast sources. This process may be facilitated by examining how farmers learn to trust a radio or a television station. In the focus groups, farmers noted that they gradually established their trust in a radio station (as reflected in the rating results in Table 5) because the station's information was more accurate or more specific to their areas or conditions. In a similar way, farmers could establish trust in a forecaster (source agency) through a similar comparison and selection process for its forecasts over time. Establishing the identity and reliability of forecast sources would help farmers to trust the sources and devote efforts to develop understanding of forecasts and forecast-use skills in farming decisions.

The survey results also show that the farmers value highly the views of their spouses as well as landlords. With high expectancies for these groups also, farmers were shown to be sensitive to the social norms surrounding the use of forecasts in their farming decisions. These results indicate that educating groups on forecast value and usage would likely be more effective than only educating farmers individually, if the goal were to change farmer forecast-use behavior. In addition, it might be useful to have crop consultants deliver the education, to encourage farmers to bring their spouses to any training offered, and to use the television and radio when applicable to deliver educational programs.

b. Limitations of this study

Several limitations of this study suggest directions for future research and should be noted. First, there is some inherent and unavoidable ambiguity related to the survey questions and their answers. Survey responses are generally susceptible to potential response biases. In the case of our survey, one might question 1) how farmers interpreted the "extent of influence" (e.g., use of many forecasts in decisions vs use of one forecast often) and 2) farmers' ability to introspect, estimate, and report accurately the actual influence or weighting of forecasts upon their decisions. In both cases, different farmers may be interpreting the questions differently, resulting in variability that is attributable to question interpretation rather than to actual influence. However, when our focus group members read the questions before the survey, they interpreted the influence questions as clear and reasonable. Meanwhile, the pattern of the mean influence variables, which generally seemed to favor the use of appropriate forecasts for various decisions, supports that farmers were interpreting and answering the questions with accuracy.

Another limitation is that, to ensure the questionnaire was an acceptable length, we grouped forecasts and decisions into related categories. This grouping could have resulted in less than precise results. In cases in which subgroups of farmers seemed to report inappropriate use or neglect of forecasts in certain decisions, we cannot be sure which of the specific forecasts or decisions within the categories those farmers may misunderstand or need additional information about. We tried to minimize the effects of these limitations on the study results by conducting focus groups to ensure correct understanding of the questions, by enlarging the survey population size, and by establishing the consistency of the survey data. However, caution is warranted in interpreting the results.

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APPENDIX

Survey Questions Measuring the Belief (Expectancy) and Value Components of Attitude

This appendix describes two of the questions included in the farmer survey. Question A was asked in reference to three sources of information, 1) current/recent-past conditions, 2) short-term forecasts, and 3) long-term forecasts, and in reference to 10 different groupings of interests and goals, as given in Table A1. For each of the 30 combinations of information source and interest/goal groupings, the farmers were asked to answer question A by choosing a number from 0 through 6, where 0 denotes "extremely unlikely," 1 denotes "somewhat unlikely," and so on through 6, which denotes "extremely likely." If any one of the 10 groupings represented a decision that the farmer did not make, then for that grouping the farmer was instructed to choose number 9, which denotes "does not apply," rather than choosing a 0–6 scale value for each of the three individual sources of information within that grouping. The actual wording of question A was, "In

Table A1. The 10 groupings of interests and goals or outcomes that were used in the survey questions A and B described in the appendix.

Interest and goals/outcomes
Planting the best crop and variety; optimum spring tillage; best planting density and planting date
Right amount of crop insurance
Optimal amount of spraying, fertilizing, and water applied (used); best harvest date
Maximizing crop revenue from marketing
Lowest possible costs of production
Reducing financial risk
Sharing limited sources of irrigation water with others
Reducing fertilizer and pesticides in runoff/ground water
Sustaining rural communities
Others (please specify)

your experience, how likely is it that these weather forecasts and information are any good at producing the following outcomes?" Here, "outcomes" refers to the 10 groupings listed in Table A1.

Question B applied only to the 10 outcome groupings listed in Table A1, not the individual forecasts and sources of information, and so required 10 responses rather than up to 30 as in question A. For each grouping, the farmer was instructed to choose "does not apply" or to choose a number from 0 ("outcome has a low value to me") through 6 ("outcome has a high value to me"). The actual wording of question B was, "How much do you value each of these outcomes?"

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