Journal of Agricultural and Resource Economics 20(2):356–372

Agricultural Producers' Willingness to Pay for Real-Time Mesoscale Weather Information

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Mesoscale weather networks can provide improved weather information to agricultural producers. This technology can potentially improve production decisions, reduce irrigation and pesticide inputs, and reduce weather-related losses. Developing a mesoscale network to disseminate real-time mesoscale weather information requires a substantial investment. In addition, there are costs associated with maintenance of the system and distribution of the information available. While public funds may be available to support initial development of the system, there may be less public support for maintaining the system and subsidizing users' access to the information. This study uses the contingent valuation technique to determine the willingness of Oklahoma farmers and ranchers, as one set of potential users, to pay for real-time mesoscale weather information. The results indicate that agricultural producers are willing to pay only a modest fee for improved weather information. Gross sales, irrigation, and past weather losses are among the factors shown to significantly impact willingness to pay.

Key words: contingent valuation, decision aids, mesoscale weather information

Introduction

Flooding in the Midwest during 1992 and 1995 underscores how weather contributes to the overall risk faced by farmers and ranchers. Precipitation and other climatic variables affect a producer's decisions regarding input timing and usage, irrigation scheduling, and marketing decisions. Producers also assess current wind conditions in order to apply chemicals safely or to undertake controlled burning activities. Weather conditions directly affect producers' income and profitability.

Advances in technology have made it feasible to improve the quality of weather information and interpreted weather information products. A good example is the development of mesoscale weather networks. This new technology provides more timely and accurate weather information by using a denser network of observation points and more frequent observations. However, access to these improved weather information networks will be more expensive than current weather information sources.

In 1990, researchers in Oklahoma began work on a $2.7 million mesoscale weather network which is referred to as "Mesonet." The annual costs of maintaining and operating the Mesonet system have been estimated to be between $500,000 and $700,000. Because Mesonet offers important data for a number of public uses, several public sources are expected to assist with financial support for the system. However, user fees are also expected to provide support for the system. The development and support of agricultural decision aids based on the mesoscale data also depend on projected user fee revenues. If a good portion

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of the development cost of these decision aids (estimated at $100,000 each) cannot be recouped through user fees, it is unlikely that they will be developed. State legislators are unlikely to devote public funds to develop information products which benefit a single category of users.

The important question raised by the developers of Mesonet was how much agricultural producers could be expected to pay in user fees to receive mesoscale weather data, interpreted weather data, and weather information–related decision aids. Several researchers have documented the theoretical value of good weather information to agricultural producers (Katz, Murphy, and Winkler; Tice and Clouser; Sonka et al.; Winkler, Murphy, and Katz). Agricultural producers' perceptions of the usefulness of weather information have also been investigated (Seeley, Graham, and Schrader; Sonka, Changnon, and Hofing; Getz; Carlson; McNew et al.). However, there has been little previous research on the willingness of agricultural producers (and other decision makers) to pay for improved weather information.

In a Michigan study, over half of the respondents to a survey of agricultural producers indicated that timely weather information had a monetary value of over $1,000 (Carlson), although these producers may have been indicating their weather-related crop losses since they were not asked about their willingness to pay for weather information. Vining, Pope, and Dugas found that, on average, Texas producers were willing to pay $40/month for current weather information and from $24/month to $118/month for perfect weather information, depending on how far in advance the forecasts were provided. The Texas survey was not designed as a contingent valuation of willingness to pay and the authors described their measurement of willingness to pay as "a pragmatic attempt to evaluate perceptions of the usefulness of weather information provided to Texas farmers" (p. 1319). Thus, while these previous studies have documented the usefulness of weather information to agricultural producers, none have used the contingent valuation method to obtain an accurate estimate of farmers' willingness to pay for weather information as a measure of the value of improved weather data. This study fills that gap. While the Mesonet developers' urgent need for information presented a unique opportunity to apply the contingent valuation technique, the study faced both time and financial constraints. Thus, the study also afforded the opportunity to determine whether the contingent valuation method can provide useful information when time and resources are limited.

Synoptic versus Mesoscale Weather Data

Agricultural producers receive weather information from a variety of sources including television, radio, weather scanners, newspapers, other producers, and on-farm observation (McNew et al.). In most states the weather information available to producers commercially and through the U.S. Weather Service is based on regional or synoptic scale observations. Synoptic scale weather data comes from a large number of weather stations which are scattered over a wide area. It provides a general view of the atmosphere in a particular region. Synoptic weather stations are usually spaced hundreds of miles apart and the weather observations are typically updated no more frequently than once an hour (Fujita).

A mesoscale weather network has more observation points and they are spaced between 10–100 km apart (Fujita). Mesoscale weather networks also represent an advancement as measured by the time dimension. Since local weather conditions change rapidly, the advantage of a mesoscale network in providing more localized weather information can only be realized when the time between observations can be measured in minutes rather than hours, that is, real-time or near real-time reporting. Mesoscale networks record weather events which would be missed by synoptic observations (Fujita). A mesoscale network can also supply agricultural users with new variables such as solar radiation, soil temperature, soil moisture, and wind gusts (important for spraying and controlled burning) which, due to differentials in local conditions, are not meaningful when provided on a synoptic scale.

In the longer run, mesoscale information can be used to establish local climatological data bases which can be used to determine variables such as first and last frosts, rainfall patterns, and other information which helps to determine the feasibility of specific agricultural enterprises in a given area (Thomson). Mesoscale weather data also provide potential for improving weather forecasts, although the development of mesoscale-based forecasts has been hampered by inadequate data availability and computer resources (Smith et al.).

Like many improvements in technology, the development of mesoscale weather networks is costly. A mesoscale network requires a large number of stations, high quality automated measuring systems, and the computer capabilities to compile and analyze the data (Thomson). Realizing the full benefits of improved mesoscale weather information and forecasts will also require that new systems be developed to disseminate information to users in a timely fashion (Smith et al.). Despite the potential benefits of a mesoscale weather network, agricultural producers will incur costs, in terms of time and money, in gaining access to this improved weather data.

The Oklahoma Mesoscale Network

Because of Oklahoma's diverse climate, currently available (synoptic) weather data often do not reflect the local conditions faced by agricultural producers. Rainfall varies from 16 inches in the western portion of the panhandle to over 54 inches in the southeastern region. Elevations range from 300 feet above sea level in the southeast to over 4,900 feet in the western panhandle. Crop and forage varieties range from gulf-coastal, warm-season types to cool-season varieties. Irrigated crop production is substantial in several regions while dryland crop production occurs throughout the state. Cattle production systems range from extensive cow/calf operations in eastern and central Oklahoma to small-grain grazing of stocker cattle in the wheat-producing areas and intensive feedlot operations in the western panhandle (McNew et al.). Because of this variability in climate and agricultural enterprises, Oklahoma provides an ideal location to assess the benefits of a mesoscale network.

The Oklahoma mesoscale network, which was officially dedicated in March 1994, consists of 111 automated observing stations with an average separation of 19 miles. The stations record 15 weather parameters at five-minute intervals and relay the information to a base station located in the Oklahoma Climatological Survey in Norman, Oklahoma. The base station employs a mainframe computer to compile, analyze, and check the information from the various stations. Weather data and weather information products are then distributed to paid subscribers via computer networks and computer bulletin boards.

The Oklahoma Mesonet also provides the opportunity to develop "value-added" weather information products which are based on the mesoscale weather data. An irrigation scheduling program, for example, determines potential evapotranspiration values based on 15-minute weather data averages, the stage of crop development, and soil wetness. The grower can determine the amount of irrigation which is needed based on past rainfall and irrigations. Other examples include the Peanut Leafspot Advisory Index which advises growers when sufficient hours of temperature and humidity have accumulated to warrant spraying for peanut leafspot and the Alfalfa Weevil Advisory Index which forecasts the weevil's development based on degree-day accumulation. If, as the Mesonet developers anticipate, the use of this information eliminates one pesticide application, it should save producers $8–$12/acre.

Other value-added products serve to interpret the basic weather data. For example, the Cotton Planting and Growth Stage Advisory interprets soil temperatures in terms of acceptability for planting and uses accumulated degree days to project the growth stage. Similarly, the Chemical Application Advisory provides a spraying condition index which is based on ground level and 10-meter wind speed, temperature, and relative humidity; the Fire Danger Rating System calculates the spread component and the energy release component (Deeming, Burgan, and Cohen) based on the local wind speed and direction, temperature, and relative humidity data.

Due to the high cost of maintaining and operating the network, identifying interested subscribers and determining the level of user fees or subscription which they would be willing to pay are critical to the success of the Oklahoma program. It is also essential that the potential demand for value-added products be accurately determined since much of the development and implementation costs must be recouped from user fees.

Analytical Framework

The contingent valuation (CV) method was used to estimate agricultural producers' willingness to pay for Mesonet weather information. The CV method, which elicits consumers' willingness to pay for a specific good or service, is most often used to assess the value of nonpriced environmental amenities. However, the CV method can be used to ascertain the demand for a good when a market for the good does not exist or when a test market experiment would be time consuming, costly, or otherwise difficult to develop.

A growing body of survey experiments has shown that, generally speaking, CV is as accurate as other available methods for assessing what people are willing to pay for specific goods. These results have held for public goods such as outdoor recreation and environmental quality (Brookshire and Coursey; Brookshire et al.; Sellar, Stoll, and Chavas), for extramarket commodities such as hunting permits (Bishop and Heberlein 1979, 1980), and for specific privately provided products (Dickie, Fisher, and Gerking).

Developers of the Mesonet system hope to market the system's products, establishing a price for the products based on individual buyers' demand for the products. The CV method can determine the extent to which individual buyers could be expected to purchase access to the Mesonet products and the prices they would be willing to pay. For this study, producers' willingness to pay was elicited using a series of price categories (also called the payment card or checklist approach) (Mitchell and Carson; Jordan and Elnagheeb). With this approach, respondents select, from a series of payment values, the maximum amount they would be willing to pay for the good or service being valued. Eliciting willingness to pay in this way is simpler than the sequential bidding approach and avoids the nonresponse problem which has been found with the open-ended format (Cameron and Huppert).

Using data elicited with the category approach to estimate average willingness-to-pay values or a functional relationship between willingness to pay and characteristics of respondents presents a unique estimation problem. When the data are intervals rather than points, ordinary least squares (OLS) regression methods could be applied using the midpoints of the intervals to represent values on the willingness-to-pay continuum. However, Cameron and Huppert have shown that biased estimates may result. They concluded that the application of maximum likelihood (ML) methods for "interval regression" is a more reliable approach than OLS used on interval midpoints. Jordan and Elnagheeb also compared results using OLS on interval midpoints and ML for interval data. Both studies adopted the lognormal distribution as a first approximation for the valuation distribution in recognition of the fact that valuation distributions are frequently skewed.

Given that the true willingness to pay, Y_i, lies within the interval between t_{il} (the lower bound) and t_{iu} (the upper bound):

$$(1)\quad \text{Prob}[t_{il} \le Y_i < t_{iu}) = \text{Prob}(\ln t_{il} \le \ln Y_i < \ln t_{iu}) = \phi[\ln t_{iu} - X_i\beta / \sigma] - \phi[\ln t_{il} - X_i\beta / \sigma],$$

where $\phi[]$ is the standard normal distribution function, X_i is a vector of explanatory variables, β is a parameter vector, and σ is the standard deviation of the error. If z_{il} and z_{iu} are the lower and upper limits of the ith interval, the corresponding log-likelihood function is

$$(2)\qquad \ln L = \sum_{i=1}^{n} \{\ln[\phi(z_{iu}) - \phi(z_{il})]\}.$$

The maximum likelihood approach was used for this study to estimate willingness to pay for mesoscale weather data and to determine characteristics of producers which might be used to identify those producers particularly interested in accessing mesoscale weather data. A lognormal distribution for willingness to pay was used, and parameter estimates were obtained using LIMDEP's grouped data procedure (Greene).

The independent variables included in the maximum likelihood model are defined in table 1. Farm or ranch characteristics hypothesized to increase interest in mesoscale weather information and thereby increase a producer's willingness to pay include cotton, peanut or alfalfa production, and a high level of past weather-related losses. Cotton producers might value weather information more highly than other farmers. Soil temperature is an important factor in the timing of cotton planting. The number of degree days before the first frost in the fall is also an important yield and quality determinant. Peanut production is another high input crop affected by weather conditions. Peanut producers would be expected to have a strong interest in spraying conditions and in plant disease and insect models. Alfalfa hay is another example of a high value crop where good drying conditions are essential at the time of harvest. Alfalfa is also susceptible to insects and plant diseases which are exacerbated by weather conditions.

Gross sales is hypothesized to be positively related to willingness to pay for weather information. The relationships between willingness to pay and total acreage and willingness to pay and number of crops are difficult to predict. Generally, one might expect producers with larger operations to exhibit a higher willingness to pay. However, in Oklahoma, producers with larger acreages tend to focus on production of wheat and cattle, while the producers with smaller acreages may grow crops, such as peanuts or vegetables, which are

Table 1. Variables Hypothesized to Explain Willingness to Pay for Mesoscale Weather Data

Variable	Unit	Hypothesized Sign	Definition
NEWS	\$10	+	Annual payment for journals and magazines
DATA		?	1 if subscribes to electronic data service
ACRES	100 acres	?	Total crop acreage
DEBT	%	+	Ratio of long-term debt payments to gross farm income
FULL		?	1 if a full-time farmer
COMP		+	1 if uses a computer
SALES	\$10,000	+	Average annual gross sales
IRRIG		+	1 if irrigation is used
ALFALFA		+	1 if alfalfa is produced
PEANUT		+	1 if peanuts are produced
COTTON		+	1 if cotton is produced
LOSS	%	+	Average annual weather-related crop losses as percent of sales
CROPS		?	Number of crop enterprises
YEAR1[a]			1 if 10 years or less of farming experience
YEAR2		+	1 if 11–20 years of farming experience
YEAR3		+	1 if 21–30 years of farming experience
YEAR4		+	1 if 31–40 years of farming experience
YEAR5		+	1 if more than 40 years of farming experience
EDUC1[a]			1 if a high school graduate
EDUC2		+	1 if some college education
EDUC3		+	1 if a college graduate

[a] These variables denote the reference category and were excluded from the models.

higher dollar, riskier enterprises. Large producers may also operate several noncontiguous acreages. They might, therefore, be somewhat diversified against local adverse weather events and less likely to perceive that weather information would lower their production risk. Similarly, a manager of a more diversified farming operation—one with a larger number of crop enterprises—is faced with a greater number of production decisions, many of which are affected by weather. On the other hand, more diversified operations are also less risky. As such, farmers with more enterprises may feel that they have a lower exposure to weather-related production risks.

Characteristics of the producer such as ownership of a computer and subscription to a data service or other news sources might also be expected to affect willingness to pay. Computer ownership would be expected to increase willingness to pay, since the use of a computer suggests an interest in technology and a ready ability to access computer-based information. However, the expected impact of data service subscription is ambiguous. Producers who subscribe to an electronic data service or other news services have a demonstrated willingness to pay for management, marketing, and weather information. For this reason, these individuals might be expected to be more willing to pay for Mesonet. On the other hand, these subscribers already have access to a wide variety of weather satellite information and forecasts.

Farming experience and higher education levels are hypothesized to increase willingness to pay for weather information since farmers who have been farming longer would be more aware of weather risk and more highly educated farmers would be more capable of applying additional information. The expected difference between full-time and part-time farmers with respect to willingness to pay is ambiguous. Part-time farmers are obviously less reliant on farming income and are therefore less susceptible to weather risk. On the other hand, they may have less time available for management and, consequently, might have a higher willingness to pay for decision aids. Farmers with heavier debt loads are expected to have a higher willingness to pay for weather information since they have less capacity to absorb weather-related losses.

Survey Design

Data to estimate the empirical model of willingness to pay for Mesonet access was obtained from a mail survey of Oklahoma producers. The Division of Agricultural Sciences and Natural Resources at Oklahoma State University maintains a list of 1371 producers who have agreed to respond to surveys on particular topics.[1] Although weather data collection was not one of the topics agreed to by the participating producers, a sample of 508 was selected from the list to obtain representation from cotton, peanut, alfalfa, wheat, and diversified-crop and livestock producers. In addition, a sample of 137 irrigated-crop producers was selected from the 5,959 producers holding current irrigation permits. Since the survey population consisted of producers who had previous links with Oklahoma State University or producers with irrigation permits, it is likely biased toward larger, higher income operations. However, this sample is representative of types of producers who would be targeted to subscribe to Mesonet.

Survey design followed guidelines set out by Dillman. The survey questions were designed to be understandable to agricultural producers. Researchers and extension specialists who routinely survey producers on other topics reviewed the survey format and wording. The survey was pretested by county agents and a small group of producers. The survey instruments were constructed in booklet form and mailed to recipients with a cover letter describing the purpose of the survey and a return postage-paid envelope. Because of time and money constraints, follow-up mailings of the survey form were not made to nonrespondents. Surveys were received by 623 producers and surveys were returned by 175 producers. Thus, not counting undeliverable surveys, the response rate was 28%.[2]

[1]The list was compiled in 1989 using names of farmers and ranchers submitted by county extension staff. A preliminary survey of the producers revealed the areas about which they would be willing to respond. Subjects of surveys regularly conducted in the state using this list include cropland- and pasture-leasing rates and custom hire rates. The most recent other survey effort using this list (cropland- and pasture-leasing rates) obtained a 32% response rate.

[2]Mitchell and Carson have observed that response rates for mail surveys used in contingent value studies are generally quite low, with some response rates below 20% reported in the literature. The low response rates raise questions about how the results of analyses using the survey data can be interpreted and expanded to aggregate values. The response rate for this study could have been increased with the follow-up mailings recommended by Dillman. However, time and financial constraints precluded that follow-up. Although the response rate for this study equals or exceeds that reported in a number of studies, the implications of the low response rate for interpretation and expansion of results are addressed in a later section.

The survey included questions for demographic and socioeconomic information, which also elicited perceptions regarding the usefulness of different types of weather information for farm and ranch decision making. In addition, the survey included two questions asking for the maximum amount the respondent would be willing to pay to receive information from Mesonet. The survey was carefully designed to remove any incentive for the respondents to underrepresent their true willingness to pay. The cover letter stressed that Mesonet funds were limited and that the survey results would be used to determine what programs or services would be developed for agricultural and nonagricultural users. The survey also stressed that Mesonet would be offered to agricultural subscribers only if a sufficient number indicated a willingness to pay a fee to access the Mesonet data.

The willingness-to-pay questions were preceded by a detailed description of the Mesonet system and the kind of information it would make available (appendix). Then, the first willingness-to-pay question asked respondents the maximum amount they would be willing to pay for access to the raw weather data. For the second question, value-added weather information products were described, including: (*a*) Optimal Irrigation Scheduling Model, (*b*) Peanut Leafspot Advisory Index, (*c*) Alfalfa Weevil Advisory Index, (*d*) Cotton Planting and Growth Stage Advisory, (*e*) Chemical Application Advisory, and (*f*) Fire Danger Rating System. Then, respondents were asked the maximum amount they would pay for *both* the basic data and the value-added weather information products.

Respondents were asked to select from one of seven payment categories. The first category indicated that the respondent would not pay for access to Mesonet and would not use the information if it were provided free. The second category indicated that the respondent would not pay for access to Mesonet and would use the information only if it were provided free.[3] The remainder of the categories covered specific values; respondents were asked to select that category which included the maximum dollar amount they would pay. In addition to the categories for zero, the farmers and ranchers had the opportunity to select categories ranging from \$1–\$5/month to \$50 or more per month.

Results

Characteristics of the Sample Farmers and Ranchers

The majority of the respondents were full-time farmers/ranchers and were over 45 years old. Sixty-five percent had gross sales of \$50,000 a year or more and 41% had annual sales equalling or exceeding \$100,000. The average annual gross income was approximately \$154,000. The average proportion of gross income needed to service long-term debt (a measure of producer's ability to bear risk) was approximately 20%. The majority of the respondents either owned or had access to a computer. However, less than 7% had ever used a computer bulletin board service. Thirty-four percent of the respondents subscribed to an agricultural information service. Based on the published fees for the information services selected, most of these producers are paying around \$30/month for agricultural information. On average, the respondents also paid \$73/year for agricultural magazines.

[3] Responses to this category were considered protest bids. That is, they did not reflect zero demand but, rather, an apparent belief that the information should be available free.

Table 2. Comparison of Survey Respondent Characteristics to Characteristics of Oklahoma Farms with Annual Sales Exceeding $10,000

	Survey Respondents	Farms with Sales Exceeding $10,000[a]
Average age	54	55
Gross income	$154,421	$115,720
Full-time farmers	71.6%	68.9%
Average farm size	964 acres	889 acres
Farms with irrigation	26.3%	6.9%
Percentage involved in selected crop and livestock activities:		
Wheat	74.0	45.8
Hay	40.9	59.7
Cotton	20.4	5.4
Peanut	10.5	2.9
Cow-calf	71.3	85.6
Swine	2.6	4.0
Sheep	1.8	2.0
Broilers	1.8	1.6
Dairy cattle	1.2	3.5

[a] U.S. Department of Commerce

In table 2, characteristics of the survey respondents are compared to characteristics of Oklahoma producers with agricultural sales exceeding $10,000/year. As the table indicates, the respondents appear to be representative of Oklahoma's commercial producers. The sampling technique purposely overrepresented irrigators since they were perceived as having the highest potential benefit from the Mesonet information. Cotton and peanut farmers were also disproportionately represented in the returned surveys. Producers with these higher value crops may have been more likely to have established a relationship with the university and were therefore more likely to be included in the original mailing list.

The respondents were also asked to estimate their annual loss in crop and livestock sales due to adverse weather conditions for the past five years. Only 6% indicated no losses due to adverse weather. Thirty-seven percent indicated annual losses of $10,000 or more. On average, the farmers and ranchers experienced weather-related losses each year totaling $11,700. This represented 14.6% of their gross farm income. Data from the 1992 census of agriculture classified 1.73% of Oklahoma's planted cropland as "land on which all crops failed." Based on census data for average crop revenues from all crops, failed crops represent an average loss in gross sales per farm of $13,473, which is similar to the loss reported by the survey respondents.

The survey respondents' choices among the willingness-to-pay categories are shown in table 3 for the raw weather data and for the raw data plus value-added information. Completed, useable surveys were received from 146 respondents. However, based on their decisions not to respond to one of the willingness-to-pay questions, all 146 respondents were not included for each model. In addition, for each willingness-to-pay question, there were respondents who indicated that they would use the weather data only if it were provided

Table 3. Distribution of Respondents' Willingness to Pay for Raw Weather Data and Raw Data Plus Value-Added Weather Information

Payment Interval (dollars)	Distribution of Respondents: Raw Weather Data		Value-Added Information	
	Number	Percent	Number	Percent
Zero	14	9.72	20	14.2
1 – 5	45	31.3	43	30.5
6 – 10	35	24.3	29	20.6
11 – 25	13	9.03	19	13.5
26 – 50	0	0.00	3	2.13
More than 50	0	0.00	0	0.00
Protests	37	25.7	27	19.1
Total usable surveys	144	100	141	100

free. These were considered protest bids and were excluded from the estimation sample. The final sample sizes for model estimation were 107 for the raw data model and 114 for the value-added model. The higher number of protest bids given for the raw weather data as compared with the raw data/value-added combination suggests that respondents are more likely to expect provision of the raw data as a public service.

Willingness to Pay for Mesoscale Weather Information

The two objectives of the study were to estimate average willingness to pay and to determine the characteristics of producers who would pay to access and use mesoscale weather information. To this end, two maximum likelihood models were estimated: one for the raw Mesonet data and one for the raw data/value-added information combination. When protest bids were removed from the regression data, as is standard in CV analyses, the final number of observations for the raw weather data model was 107 and the final number for the value-added model was 114. Results of the model estimation are shown in table 4. Chi-squared statistics testing the joint significance of the models' parameters indicated that both models were significant at the 0.001 percent level.[4]

Variables representing payments for agricultural publications, full- versus part-time farming, gross sales, use of irrigation, and weather-related crop income losses were found to significantly impact the willingness to pay for raw mesoscale weather data. Specifically, farmers paying more for agricultural magazines are likely to pay more for the mesoscale weather data. Full-time farmers could be expected to pay about $0.55 per month less than part-time farmers (all else constant) for the weather data; this may reflect that they have more time available to obtain and study existing weather information sources and, as such, perceive a limited benefit to the mesoscale information. Results suggest that those producers

[4]The fragility of the model results was tested using an abbreviated specification for each model. The new model coefficients and their significance were virtually identical to the longer models' results.

Table 4. Factors Affecting Willingness to Pay for Mesoscale Weather Information

	Raw Weather Data		Value-Added Data	
Variable	Mean	Parameter Estimate	Mean	Parameter Estimate
NEWS	7.58	0.0237* (0.0135)	7.69	0.0188 (0.0155)
DATA	0.364	0.1833 (0.2296)	0.351	0.1901 (0.2683)
ACRES	9.30	−0.0049 (0.0110)	9.65	−0.0173 (0.0122)
DEBT	21.0	0.0029 (0.0059)	21.3	−0.0051 (0.0064)
FULL	0.271	−0.5494** (0.2461)	0.254	−0.3711 (0.2869)
COMP	0.364	0.1466 (0.2445)	0.351	−0.0137 (0.2778)
SALES	17.2	0.0131** (0.0065)	17.9	0.0185** (0.0072)
IRRIG	0.252	0.7632** (0.2764)	0.263	0.7594** (0.3074)
ALFALFA	0.402	−0.0051 (0.2323)	0.404	0.0280 (0.2626)
PEANUT	0.112	−0.3683 (0.3868)	0.114	−0.2074 (0.4196)
COTTON	0.224	−0.0501 (0.2526)	0.237	−0.0745 (0.2822)
LOSS	0.144	1.1589** (0.5234)	0.144	1.4004** (0.5798)
CROPS	2.64	0.0297 (0.0868)	2.670	0.1377 (0.0996)
YEAR1	0.028	−0.3233 (0.6176)	0.026	−0.1775 (0.7295)
YEAR2	0.280	0.1208 (0.3000)	0.298	0.0077 (0.3243)
YEAR3	0.234	0.0602 (0.3131)	0.237	−0.2113 (0.3487)
YEAR4	0.215	−0.0780 (0.2942)	0.211	0.0796 (0.3377)
EDUC2	0.271	0.1368 (0.3092)	0.281	0.0090 (0.3318)
EDUC3	0.495	0.4014 (0.2910)	0.491	0.0779 (0.3368)
Constant		0.3645		0.2183

Note: One asterisk denotes significance at the 10% level and two asterisks denote significance at the 5% level.

with higher sales are likely to pay slightly more for the mesoscale weather data. In addition, those producers with irrigated acres could be expected to pay more for the weather data (about \$0.76 per month more, all else constant) than producers who do not irrigate. Irrigated crops are generally more intensively managed, and irrigators could be expected to value information which aids them in monitoring soil moisture and scheduling irrigation. Finally, as expected, those producers who have suffered larger weather-related crop losses expressed a higher willingness to pay for the weather data; an increase of one point in the percentage of crop sales lost due to weather would result in a \$1.16 per month higher bid. It is not surprising that producers with higher weather-related losses would be interested in ways to reduce weather-related risks.

For the raw data/value-added combination model, sales, irrigation, and weather-related losses were found to significantly impact willingness to pay. The relationships of sales, irrigation, and weather-related losses to willingness to pay were again positive, as expected. The impact of sales is again slight. Irrigators bid about \$0.76 per month higher than nonirrigators, and an increase of one point in the percentage of crop sales lost due to weather would mean a bid of \$1.40 more per month for the value-added information. The coefficients for crop acres and number of crops were significant at the 0.15 and 0.16 levels. While the negative crop acres coefficient suggests that the diversification effect of larger acreages reduces the perceived value of weather data as a risk management tool, a positive coefficient on number of crops suggests the opposite.

For the raw data/value-added model, the production of peanuts, cotton, or alfalfa did not significantly impact willingness to pay. This was somewhat surprising since much of the proposed value-added weather information addresses problems and needs specific to those producers.

Results from the maximum likelihood models were used to calculate mean and median willingness to pay for the raw weather data and the value-added information. Mean willingness to pay for the raw weather data was \$5.83 per month (with a standard error of 0.58); the median was \$4.05. Respondents indicated that they would pay only slightly more for the value-added weather information; the mean willingness to pay for both raw data *and* value-added information was \$6.55 per month (with a standard error of 0.84). The median willingness to pay estimate for the raw data/value-added model (\$3.85) was slightly lower than for the raw data model; this occurred because of the number of observations included in the raw data/value-added regression with a zero bid which were excluded, as protest bids, from the raw weather data model.

The CV method can also be used to estimate the aggregate value of the system. Mesonet's developers are interested in the aggregate willingness-to-pay estimate because it represents the value of the system to agricultural producers. If public funds were to be used instead of user fees, officials would require information on the value of the system to justify the expenditure of public funds. The aggregate willingness-to-pay estimate also provides an upper limit on the proportion of annual operating and development costs which can be recovered from agricultural user fees. The actual revenue which could be collected would be less than the calculated aggregate value, unless the Mesonet developers could implement a system of perfect price discrimination which captured all consumer surplus.

Based on alternatives for aggregating mean willingness to pay which have been applied in the literature (Loomis; Mitchell and Carlson), a range within which the aggregate value of the system would lie can be calculated. To calculate an upper bound on the aggregate value of agricultural users' willingness to pay, the mean willingness to pay estimated in this study could be aggregated over the population of commercial agricultural producers (29,638 in Oklahoma) (U.S. Dept. of Commerce). The implicit assumption is that the nonrespondents have the same willingness to pay as the survey respondents. On the conservative end, a lower bound could be obtained by assuming that the proportion of commercial producers willing to pay for Mesonet access is equal to the proportion of the survey sample that answered the willingness-to-pay questions.[5] This would imply a zero willingness to pay for nonrespondents. When the survey respondents are not representative of the population surveyed, it is also necessary to adjust for this bias in the calculation of aggregate values. Because the demographic characteristics of the Mesonet survey respondents were virtually identical to the population of commercial producers (table 2), no adjustment was made. Using the conservative and optimistic assumptions about the willingness to pay of the nonrespondents, the value of the raw Mesonet weather data was calculated between \$29,374 and \$162,422 per month. For the raw data/value-added information combination, aggregate value was calculated to lie between \$34,943 and \$186,364 per month.

Conclusions

Despite the perceived usefulness of weather information and the impact of weather on farm income and profitability, agricultural producers do not appear to be willing to pay significant fees to access improved weather information. Results indicate that, on average, producers are willing to pay \$5.83 per month for raw mesoscale weather data and \$6.55 per month for the raw data plus value-added weather-related products. Given that the cost to operate and maintain the basic Mesonet system is expected to be \$500,000 to \$700,000 per year, the anticipated income from user fees could cover as much as half of those costs, using the conservative estimate of aggregate willingness to pay for the raw weather data. The range of aggregate willingness to pay calculated for the raw data was \$29,374 to \$162,422 per month (\$352,488 to \$1,949,064 per year).

The value of the basic system to other users such as radio and TV stations, weather forecasters, and emergency information network operators may justify public investment in the program. However, it is unlikely that public investment could be justified (or obtained) to develop agriculture-specific products which benefit a single category of users. Given agricultural producers' low willingness to pay for mesoscale weather information and decision aids, it also does not appear that the costs of developing and supporting these value-added decision aids can be recovered from agricultural user fees. Results show that the value-added products would earn only an additional \$5,569 to \$23,942 per month from the user fees. The survey respondents clearly are not as optimistic as the Mesonet developers in assessing the potential savings from using the Mesonet system to eliminate unnecessary pesticide applications, reduce irrigation expenditures or identify more profitable crop

[5]To avoid overstating the upper bound, the population of 29,638 commercial producers was adjusted downward by the proportion of respondents who gave a protest bid. Thus, for example, 6% of the population was not included for calculation of aggregate willingness to pay for the raw data, because the true demand for the data by the protest bidders is unknown. To calculate the conservative lower bound, only 17% of the population was used to calculate the aggregate willingness to pay for the raw data—that proportion of the sample responding to the willingness-to-pay question but not giving a protest bid.

planting dates. It is possible that their willingness to pay would increase if the value-added products were developed and the savings demonstrated.

The willingness to pay estimates obtained in this study are considerably lower than those reported by Vining, Pope, and Dugas. However, their study was not designed as a CV study. In addition, they asked producers about their willingness to pay for weather information assuming current weather information was not available. Respondents in this study made their willingness-to-pay decisions in the context of existing sources of weather information.

The study results do provide some encouragement in identifying subgroups of producers to whom initial subscription efforts could be targeted. Irrigators and producers with higher gross farm income appear to be the best initial target audiences for Mesonet. The high level of significance of past weather losses also suggests that promotional efforts focusing on weather-related losses are likely to be effective in encouraging producers to invest in the improved weather information. Any attempt to develop a network for education on Mesonet and its benefits could likely benefit from capitalizing on the apparent willingness of these producers to integrate mesoscale weather data into their farm and ranch management plans.

The results also demonstrate that product developers can obtain useful information from the application of the CV method despite limited time and resources for the research. Developers of the Mesonet system can conclude from the results of this study that agricultural user fees cannot be relied upon to recover costs of developing and operating the system. Even with the optimistic assumption that nonrespondents would be willing to pay for Mesonet access at the level of the responding sample, results indicate that user fees would provide less than one-third of the funds needed for development and support of agricultural decision aids based on Mesonet weather data.

In summary, agricultural producers give a high usefulness rating to basic weather information (particularly precipitation and temperature), weather forecasts, and weather-related decision aids which relate to their farming situation. Advances in technology make it possible to provide these agricultural decision makers with much more current and locally specific weather information on a near real-time basis. An on-going project in Oklahoma demonstrates that making this improved information available through the development of a real-time mesoscale weather network will require a substantial investment. This research suggests that supporting a substantial portion of the operating funds through collection of agricultural user fees may be difficult.

[*Received May 1994; final version received October 1995.*]

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Appendix: Material Included in Survey of Willingness to Pay

As you may know, a new multi-million dollar weather monitoring network called "Mesonet" is under development. The location of weather stations in each county along with new computer technology will make it possible for you to accurately monitor current and past weather conditions for your local area. It will also be possible to provide you with production recommendations based on your local weather.

We would like to determine if farmers and ranchers like yourself would be interested in these services. Mesonet is a multi-user system (agricultural civil defense, education, media, utilities, etc.), and we must develop priorities for information products. Because there are not sufficient funds to develop and distribute all of the potential Mesonet products, we also need to know what level of fee you would be willing to pay for access to a particular program(s) or advisory service(s).

Your anonymous response will not commit you to any subscription or enrollment. This information will help us use our limited development funds to most efficiently meet the need in Oklahoma (both agricultural and non-agricultural).

MESONET

DESCRIPTION

Mesonet consists of 108 automated weather stations which are located throughout Oklahoma (an average of 19 miles apart). The Mesonet sensors at each local station monitor weather and soil parameters at 5 minute intervals and relay the information every 15 minutes to a central base station and to individual Mesonet users.

BENEFITS

The Mesonet system is one of the most densely-spaced networks in the U.S. Farmers and ranchers subscribing to the Mesonet system will receive information about their current local weather conditions. This service has never been previously available. Mesonet will provide 15 environmental measurements from 108 weather stations with the measurements updated every 15 minutes, including wind speed and direction, air temperature, relative humidity, solar radiation, barometric pressure, rainfall, soil temperature and leaf wetness.

11. Please indicate the maximum amount which you would be willing to pay each month to have convenient 24 hour/day access to the kind of weather data described above. This weather data would be available at a site within 20 miles of your location as well as other parts of the state.
_____ I would not be willing to pay for access, and would not use this information
_____ I would use this information only if it was provided free
_____ $1–$5 per month
_____ $6–$10 per month
_____ $11–$25 per month
_____ $26–$50 per month
_____ $50 or more per month

OTHER BENEFITS

Mesonet will also include decision models created by extension specialists which analyze and interpret weather data for application by farmers and ranchers. Examples of these decision aids available to farmers and ranchers include:

* **Irrigation** - Optimal scheduling based on local temperature, humidity, solar radiation, and crop needs.

* **Peanut Leafspot Advisory Index** - Indicator of when spraying for leafspot is justified based on local temperature and humidity conditions. Research indicates that two to three applications per year can be eliminated using the advisory schedule.

* **Alfalfa Weevil Advisory Index** - Insecticide application timing recommendations which are based on the accumulated heat units in the local area.

* **Cotton Planting and Growth Stage Advisory** - Soil temperature readings from Mesonet which indicate when to plant. Information on accumulated degree days and historical averages will assist producers in selecting an appropriate variety.

* **Chemical Application Advisory** - Indicator of when local wind and weather conditions are favorable for spraying and the effectiveness of a particular pesticide based on air temperature and humidity.

* **Red Flag Alert** - Fire danger rating system indicates when conditions are favorable for prescribed burns and highlights when there is a high potential for wildfires.

12. Please indicate the maximum amount which you would be willing to pay each month to have convenient 24 hour/day access to both weather data <u>and</u> the weather-based decision aids described above.

______ I would not be willing to pay for access, and would not use this information
______ I would use this information only if it was provided free
______ $1–$5 per month
______ $6–$10 per month
______ $11–$25 per month
______ $26–$50 per month
______ $50 or more per month