On the Economic Nature of Crop Production Decisions Using the Oklahoma Mesonet

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ABSTRACT

Because of the sensitivity of agricultural production to both short-term weather and long-range climatic patterns, the availability of reliable and relevant meteorological data and climate products can potentially affect the entire production process. This study focuses on the use of information from a dense meteorological network—the Oklahoma Mesonet—and its AgWeather program in support of agricultural production decisions. Production decisions that are particularly dependent on information from the Mesonet are identified. Producers in Oklahoma are influenced by Mesonet data at several levels, including agricultural policy, production choices, and risk management. Additionally, producers use the Mesonet to attain their financial goals, through such measures as cost saving and maximization of quality and quantity, in addition to others. Potential savings from Mesonet data for the state’s agricultural sector are also estimated.

1. Introduction

The Oklahoma Mesonet, a joint effort between the University of Oklahoma and the Oklahoma State University (OSU), is a network of 120 stations that provides weather and soil measurement information every 5 min (Brock et al. 1995; McPherson et al. 2007). While automated weather measurements are its basic function, the Mesonet enterprise also creates specialized products, and trains and supports decision makers, including emergency managers, nonprofit organizations, teachers, agricultural extension educators, and agricultural producers. These products and services span the range from short-term meteorological information and data support to climate-based services. Participation in Mesonet programs has been increasing since the inception of the network in 1994, totaling thousands of participants through dozens of specialized products and programs.

While substantial anecdotal evidence of the Mesonet’s impact on its user groups exists, neither a robust qualitative description nor a careful quantification of the value of these impacts has been conducted. The goal of this research is to begin investigating the use of Mesonet information in a qualitative context that will result in the development of a cognitive model informing future quantitative research, and to motivate such quantitative research with a very rough quantitative estimate. Twenty-one in-depth, semistructured interviews with producers provided the information that was used to develop the cognitive model. The resulting model depicts the use of Mesonet observations and the Mesonet’s agricultural program, AgWeather, in agricultural production decisions.

After an introduction to relevant literature (section 2), the details of the survey design and implementation (section 3) and the resulting cognitive model (section 4) are discussed, as well as risk decisions and potential economic impacts (section 5).

2. Background

a. Use of weather and climate information in agribusiness

Weather and climate conditions present opportunity, risk, and uncertainty for agribusiness operations, and the use of weather and climate information is increasing because of increasing competition, greater availability and access to meteorological information, improving
quality of predictive climate information, and increasing application of meteorological expertise to the field of agriculture (Sonka et al. 1988; Changnon and Kunkel 1999; Changnon 2004). Risk and weather are closely linked in pest, disease, weed, and crop loss scenarios, and input decisions rely upon probability assessments of risk and deviations from expected conditions (Britt et al. 2002; Chavas 2006). Some studies note that the successful use of information about weather-related risks can mean the difference between profit and loss in a growing season (Weiss and Robb 1986; Diak et al. 1998). Of particular relevance to the Mesonet operation are short-term forecast information and current weather conditions, known to be important to the decision-making processes of producers (Changnon 1992; Weiss and Robb 1986; Apfelbeck et al. 2008).

The bulk of existing work examining value can be characterized as either prescriptive—examining how producers should behave in a broad sense given the available information and forecasts—or descriptive—eliciting the ways in which agricultural producers actually use information to aid their decision making. Prescriptive studies typically apply cost–loss scenarios to value weather and climate information in agriculture subject to weather forecasts and climate predictions of varying skill and quality (Murphy and Ye 1990; Murphy et al. 1985; Livezey 1990). The use of weather and climate information affects many production decisions, and some special problems examined using prescriptive approaches include the “fallowing/planting” problem and the “frost–freeze” problem. In these cases, actions on the part of producers are functions of their probabilistic weather risk, cost–loss ratio, and the extent to which they discount the future (Brown, Katz and Murphy 1986; Wang et al. 2006). This body of work hinges on forecast information, as opposed to real-time information, for its conceptualization.

Descriptive studies exploring the effect of meteorological information on agriculture focus on the ways in which producers actually use information over an array of decision points. Each crop type corresponds with a unique production model and is subject to a specific combination of weather-sensitive processes, including fertilization, planting, and harvest timing (Sonka et al. 1987; Hu et al. 2006). While the prescriptive approach noted above makes use of these processes, descriptive studies do so in a manner that is geared toward revealing farm-level specific practices and decision-making procedures. Stewart et al. (1984) applied such an approach, and by using interviews, observations of actual decision making, and analysis of hypothetical decisions, they identify major variables influencing decisions and differences among decision makers, noting that decisions were not simply a function of expected outcomes to protective measures, but also of psychological comfort. Subsequent analysis identifies a mix of social psychological theory (theory of planned behavior) and behavioral economic theory (theory of planned demand), elucidating factors that describe how producers make their decisions (Hu et al. 2006; Artikov 2006). Actions are described as a function of attitude, social norms, perceived control, financial capability, and environment. These descriptive studies highlight the ways in which the decision making on the part of producers is a highly complex problem extending beyond rational economic models, whereby weather and climate information factor into many parts of the process.

b. The Oklahoma Mesonet and AgWeather

Given the sensitivity of Oklahoma’s agricultural production to moisture and temperature variables in the air and soil, from its inception in 1994, providing data and services to agriculture was a priority of the Oklahoma Mesonet. The Mesonet was developed with the idea to observe these variables at temporal and spatial scales that closely matched the needs of producers. As improvements in the Internet and computer technology occurred, the Mesonet enterprise enhanced their products and freely distributed this information to Web pages. The Mesonet began the AgWeather program in 1996 to address the needs of the agricultural user group via a Web-based platform. AgWeather grew in 2001 with more labor devoted to outreach and product development, and underwent a major phase of growth with the deployment of phase two of the AgWeather Web site in 2003. The most recent version of the Web site serves as a portal for Oklahoma’s agricultural community and includes Mesonet-derived data and models for all of the key agricultural products in the state, links to local National Weather Service hourly forecasts, and updated market information.

The value of the Mesonet was estimated before commissioning. Researchers posited that the Mesonet would benefit agriculture by improving production decisions, reducing irrigation and pesticide inputs, and reducing weather-related losses, as well as other benefits (Kenkel and Norris 1995; Cohen and Zilberman 1997; Kenkel and Norris 1997). Kenkel and Norris (1995) used a contingent valuation survey approach and found an expected willingness to pay (WTP) of $5.83 month$^{-1}$ per producer for raw mesoscale information and $6.55 month$^{-1}$ ($1995) for mesoscale information with value-added products (e.g., data-derived models for specific pests). Producers who irrigated, had higher gross sales, and had prior weather-related losses bid higher than others. While Cohen and Zilberman (1997) asserted that this estimate was likely biased downward, particularly because
of the fact that producers did not have sufficient information about the impact Mesonet products would have on their operations, Kenkel and Norris (1997) contended that estimates could likely have been biased too high as well because of strategic motivations in WTP responses. Though these authors differed in their theoretical approaches to obtaining a narrow estimate of the value of the Mesonet to agricultural producers, and a large body of literature indicates that WTP estimates will differ from estimates given after a good or service has been provided (Horowitz and McConnell 2002), the studies agree that there was demand for Mesonet information and products before these services were available. Producers in the original WTP study had several ideas about how this information could be of value to their operations.

When the Mesonet was first established, technology adoption in Oklahoma rated second lowest in the nation, which did not immediately favor adoption of meteorological technology and information. However, the value Oklahomans placed on information technology ranked the second highest in the nation, with many stating that it helped them to achieve their goals and concerns regarding production factors and to reduce transaction time (Batte 1986). Technologically adept farmers were more likely to network, spend time at intrafarm meetings, work with academia and consultants, and have larger farms (Doye 2005). The producers who were likely to be sampled in this study comprised a technologically savvy group.

The landscape of agricultural production with respect to the use of meteorological information and services will change in the coming years because of a few key demographic factors. In the near future, the age composition of farm management is likely to change significantly, because a large fraction of producers are currently nearing retirement. In Oklahoma and Texas, there are almost 8 times as many farmers over 65 yr of age than there are farmers under 35 (Schmedt 2005). The younger producers taking over for the retiring generation may be more likely to use computer technology, and an increase in the use of computer systems in agriculture increases the use of climate and weather information by producers (Changnon and Kunkel 1999). This situation presents a unique opportunity for outreach to a new group of technologically savvy producers, because a greater number of total producers in the state will be able to utilize Mesonet data and products for their operations.

3. Survey design and implementation

To assess what products and information producers use, and for what purposes, this study used an in-depth, semistructured interview. In-depth interviewing is a qualitative method designed to combine flexibility and structure so that specific, important topics can be addressed while still leaving the interviewer freedom to address pertinent topics and issues important to the producer, as they arise (Ritchie and Lewis 2003). Because the end goal of this research was to create a cognitive model of production, the truest representation of the production process would result from such a method. Although this method promotes flexibility and enables a more ethnographic approach, it does not serve well as a quantitative method unless it is highly structured. These interviews were semistructured; they followed a set of guiding questions but allowed considerable room for follow-up questions and anecdotes from the producers.

Interviewees were selected using a snowball method of reference. Snowball sampling is a purposive reference-style method of identifying subjects to include in a sample population. When a sample population is either difficult to access or is underrepresented, purposive sampling methods may be used to obtain a sample population of interest to the particular topic being pursued (Wong 2008). In this research, the relative underrepresentation of Mesonet users in the overall agricultural community was a potential concern, and there were time constraints to the interview period because of seasonal crop-planting practices in Oklahoma. Thus, a purposive method was deemed appropriate. Wong stated that while such a sampling method would not lead to generalizability for a random sample of the population, it might generate valid causal hypotheses that could be used to underpin theory. Because the goal of this research was to pave the way toward the development of causal explanations relating Mesonet information and products to production outcomes, a small and purposive sample was adequate.

Interviewees were selected with assistance of the Oklahoma State University agriculture extension educators, who provided references to producers that use Mesonet information (at any level). This procedure sampled what should be the most educated and technologically savvy group of farmers in the state. Twenty-one interviews were performed with crop producers; additionally, six Farm Service Agency (FSA) officials, eight researchers at the Samuel Roberts Noble Foundation, three researchers at Oklahoma State University, and 11 agricultural extension educators were interviewed or consulted to provide additional information about production concerns across the state. Each institution has a unique mission and method to interact with the Oklahoma agriculture community, as follows:

- The Noble Foundation is “an independent, nonprofit institute headquartered in Ardmore, Okla. . . conduct[ing] direct operations, including assisting farmers
and ranchers, and conducting plant science research and agricultural programs, to enhance agricultural productivity regionally, nationally and internationally” (Samuel Roberts Noble Foundation 2010). The foundation focuses on operations in southern Oklahoma and northern Texas. All correspondence for this study was conducted in person at its Ardmore, Oklahoma, research campus.

- The FSA is a branch of the U.S. Department of Agriculture (USDA), whose goal is to achieve economically and environmentally optimal solutions for agriculture, involving an array of specific programs that may vary by state and are implemented at local offices. Correspondence with the FSA was primarily through personal visits to local offices; however, there was some phone and e-mail correspondence with the state office in Stillwater, Oklahoma.

- Oklahoma State University is a land-grant institution and co-owner (with the University of Oklahoma) of the Oklahoma Mesonet. This partnership began in 1987 to design, implement, maintain, and fund the Oklahoma Mesonet. Additionally, the Oklahoma Cooperative Extension Service is a component of OSU’s Division of Agricultural Sciences and Natural Resources. County-based extension educators work with the producers to “help [them] solve problems, promote leadership, and manage resources wisely” (more information on the Oklahoma Cooperative Extension Service available online at http://www.dasnr.okstate.edu/extension, cited 2010). A variety of individuals associated with OSU provided input throughout the duration of this project. The extension educators provided both references for the sampling process and useful information regarding the production process. Several OSU faculty and staff members provided their feedback on the cognitive model and other specific technical issues.

Each of these groups represents experts over a particular domain of producer behavior and the production process in general, and they served as an expert panel to vet the cognitive model of production.

Interviews were conducted statewide in order to encompass, insofar as a small sample can, the range of geologic and climatological concerns for producers across the state. Each interview was between 30 min and 1 h in duration, and was conducted either at the farm of each producer or the county extension office. Interviews were transcribed and coded. The coding scheme was influenced a priori by the temporal nature of the production process for crop growth as described by the county educators.

The questions that were posed encompassed six categories: 1) background information, 2) farming systems, 3) production decisions, 4) weather impacts and adaptations, 5) sources of information on climate and climate variability, and 6) use of AgWeather and/or other Mesonet information. The interview was designed to allow farmers first to describe their operations, then to address their weather challenges, and finally to discuss their use of Mesonet data and products. The open question format allowed the producer to frame his/her process and concerns. These answers were helpful in establishing a true representation of the relative importance for decisions made in production (Morgan et al. 2002). Many farmers shared information about the cost of various production choices, their production goals in terms of quality and quantity, and how their decision making changed when they began using Mesonet information.

4. Agricultural producers in Oklahoma—A production model

A cognitive model of agricultural production was created based on interview responses and refined by agricultural experts (Fig. 1). Cognitive models are used, among other purposes, to illustrate the way that processes interact to affect decision making. The cognitive model described in this paper is a decision model, and the following analysis explains how producers described the decision factors included in the model. Each topic is labeled in a box, referred to as a “node,” and key factors that producers claimed to face at each step are highlighted to demonstrate the use of Mesonet information in that area.

In Fig. 1, shaded nodes depict where weather information was important to Oklahoman crop farmers. The model illustrates a flow of concerns from initial inputs, including initial conditions and constraints, through management evaluation criteria and decision factors to risk management, and this process iterates over the course of the growing season. For this single-season study, crop choice and physical capital were designated as initial conditions (i.e., static quantities) for the producer, as well as influential policy, land, climate, and others. Each part of the model will now be discussed in turn, with general comments at the end.

a. Initial conditions and constraints

The interviewees in this study each had unique mixes of crops farmed and local geographical and climatological concerns, in addition to the demographic characteristics that varied across the sample. Nineteen of the 21 interviewees were male and all were college educated, with most holding a bachelor’s degree from a state college or university. Seventeen producers surveyed grew grains such as wheat, alfalfa, hay, and sorghum, consistent with the majority of crops grown in the state. Farms
managed by producers in this sample were relatively large, because the average farm size was approximately 2000 acres compared to an average size of 405 acres per farm in the state overall. Because Oklahoma has varied topography and regions with distinct climatic characteristics, geographical and climatological issues were somewhat unique for each producer. In the western portion of the state, particularly the panhandle, conditions are often drier, and the water table is relatively deep where the surface landscape is very flat, while eastern portions of the state receive greater amounts of rainfall annually and have a shallower water table; however, farmers there must contend with a hillier landscape. Interviews were conducted in each climate division in an attempt to represent this variability to some degree.

Results of the interviews demonstrated that all producers in the study were concerned with the interplay of the price of commodities, retail items, and costs of production. Every producer in the study had a cellular phone, and several noted that they used these devices to garner updated market information from the USDA or Mesonet up to 3 times a day. The financial goals of crop producers focused primarily on profit maximization. Some farmers were focused on specific parts of the general business formula. Three were focused on minimizing costs, and each of these three farmers grew a variety of crops. One of these farmers, a pecan producer, was concerned primarily with the quality of his product, because he maximized revenue in the pecan retail market through quality. Another producer was yield maximizing, two were working to break even, and one was mostly focused on keeping other farmers in business so that he could maintain his secondary grain elevator and spray businesses. In the course of the interviews, farmers framed production decisions as functions of stated financial goals.

The final node in the initial conditions and constraints column is “influential policy.” Federal and state governmental agencies, like the USDA’s FSA operate many programs to aid producers in situations of difficulty and to monitor farm activities for safety and other regulatory purposes. Many of these programs rely on weather information to verify ground truth. For example, if farmers in a region in drought apply for funds from the Crop Disaster Program (CDP), the FSA will use detailed, high-quality rainfall climatology in the area to determine if crop loss was unavoidable. Oklahoma’s state FSA office uses Mesonet data for daily decisions; Table 1 lists programs that frequently utilize Mesonet information. The FSA maintains that the significantly more reliable Mesonet information allows for more effective implementation of certain programs (denoted with asterisks in Table 1) than previously, allowing for tailoring of these programs to the needs of farmers.

b. Evaluation and initial decisions

The evaluation factors that most affected the decision making of Oklahoma crop producers were complex and varied (Fig. 2). These factors were listed by producers when asked the following question: When you approach a given growing season, what management factors are most important to you? Most farmers conducted this initial evaluation based primarily upon market factors (i.e., price and demand), subject to land and climatological constraints. At this step, producers selected crop varieties, planned land allotments, considered hiring workers, and chose a farming strategy (such as no-till and annual crop rotation, among others), all subject to personal preferences regarding conservation and tradition. After this stage, producers were subject to risks of the present (such as planting conditions and factor input costs), and engaged in risk assessment in order to move
forward into the growing process. Risk assessment, after initial planting, was iterative over the growing season as producers found themselves adjusting to current conditions, as described in the following section.

c. Risk management

Agriculture can be a low-margins business venture, meaning that farmers may face earning little over their costs of production, particularly for small farms or the production of input-intensive or sensitive crops. In this framework, the risks perceived by the producers in this study were factors that threatened immediate, single-year financial aims. Farmers in Oklahoma considered a variety of risks. Producers were primarily concerned with adverse weather that harmed their crops, which included floods, droughts, freezes, damaging heat, wind, and severe weather. The primary weather risks noted by these farmers were in accordance with key weather risks crops are exposed to in the state. Four of the most frequent causes of crop yield loss are hail, excessive dampness, excessive cold, or insufficient moisture during critical points in the growth of plants (Wang et al. 2006).

The next important risks reported by producers were high input costs, crop loss, and market volatility. Pesticides, fertilizer, and irrigation were significant costs for farmers; spray cost $10–$15 acre\(^{-1}\) on average for most crops in this study, fertilizer was $25–$50 acre\(^{-1}\), and irrigation cost ranged from $3 to $25 (acre in.)\(^{-1}\). Failure to control these variable costs easily dissipates the margin for profitable operation, subject to revenue considerations.

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<th>Farm Service Agency programs</th>
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<td><strong>Noninsured Assistance Program (NAP)</strong></td>
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<td>Direct and Countercyclical Program (DCP)</td>
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<td>Emergency Conservation Program (ECP)</td>
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<td>Conservation Reserve Program (CRP)</td>
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<td><strong>Crop Disaster Program (CDP)</strong></td>
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<td>Supplemental Revenue Assistance Payments (SURE) Program</td>
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<td>Livestock Forage Disaster Program (LFP)</td>
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<td>Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (EALHF)</td>
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<td><strong>Environmental Quality Incentives Program (EQIP)</strong></td>
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<td>Livestock Compensation Program (LCP)*</td>
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<td>Livestock Indemnity Program (LIP)*</td>
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<td>Emergency Loans*</td>
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TABLE 1. Listing of Farm Service Agency programs that use Mesonet data to increase accuracy of program payouts and resource allocation. List provided by Oklahoma state Farm Service Agency office. Bold text denotes those programs that the Oklahoma FSA office notes rely extensively on Oklahoma Mesonet data for operability. Asterisks denote those programs affected by Secretarial Disaster Designations, which use Oklahoma Mesonet data to determine eligibility.

![Figure 2](http://journals.ametsoc.org/wcas/article-pdf/2/3/224/4620514/2010wcas1034_1.pdf)  
**Fig. 2.** Main management evaluation and decision factors listed by the interviewees. Responses are cumulative. Producers most frequently reported that they were influenced by market factors, such as price and commodity demand, as well as costs of factor inputs and land and climatological constraints.
Fertilization could be ineffective if the proper soil moisture and temperature conditions were not met, pesticides could be lost if winds were too high, and irrigation could be unnecessary if soil was already sufficiently moist. To minimize wasteful spending, producers must make optimal decisions over the life cycle of their crops, based on real-time weather conditions.

When producers considered the evaluation criteria and present risks as described, they developed strategies to work around those risks. A few strategies were common (Fig. 3). Having a rotation and knowing how to manipulate that rotation was a tool for mixed-crop farmers, and these farmers used Mesonet information to make adjustment decisions in critical time periods. To adjust to conditions presented to their land from the start of the growing season onward, producers would strategically plant, irrigate, apply chemicals, and even manipulate the near-surface environment in order to best provide for their crops. These strategies are discussed in further detail to demonstrate the role of Mesonet information in each case.

When asked the question, “What are the main factors you consider for planting?” producers listed a combination of factors (Fig. 4a). Producers use Mesonet information extensively for planting decisions. Those farmers not using Mesonet information followed a prescribed calendar for rotation, and reported less flexibility in planting times. The choice of planting time affects the final quality of the product, the ability to rotate crops (to maximize total yield), and the plants’ exposure to climatological extremes (e.g., planting before the last freeze, which may result in replanting costs). Planting decisions have a nontrivial impact on profitability. The farmers who are able to time activities optimally based on soil and meteorological conditions noted that they could release themselves from a structured rotation, allowing them more freedom to pursue their financial goals. One producer using Mesonet information stated, “For a long time we thought we’d married that rotation, but ever since we divorced ourselves from it, it hasn’t been hard to stay away from it. The weather kept us from it.” This sentiment was not uncommon; producers who previously relied on rules of thumb required substantial trust in another source to change their decision process (Artikov et al. 2006). Producers demonstrated considerable trust in the Mesonet’s data and products when breaking their rotations.

A majority of Oklahoma’s cropland is unirrigated; roughly 500,000 acres out of 14 million crop acres and 1 out of every 28 farms irrigate their land. Nine of the 21
producers in this study irrigated their crops, presenting a bias in the sample toward irrigation concerns. However, given the large average farm size for those who irrigate (roughly 1000 acres), this sample is more representative of larger producers, which dominated the study sample. One-third of the farmers who use irrigation reported directly applying Mesonet information in these decisions (Fig. 4b). One producer used Mesonet information to help conserve land for future generations. Two others used it indirectly to guide irrigation decisions with the Environmental Quality Incentives Program (EQIP), a federal program that subsidizes producers who follow a prescribed schedule that is designed to reduce overall irrigation and the environmental impacts of overirrigating. One other EQIP user utilized Mesonet information to fill out the required EQIP balance sheets, but did not use the recommendations from the EQIP formulas as a practical guide for irrigation. One EQIP user noted that he was “actually learning more about the crops,” and particularly how to visually identify water-stressed crops, as he followed the EQIP recommendations. Given the success this farmer was having with yields while reducing water consumption, he also was learning to trust the recommendations. These producers desire more information to further improve irrigation decisions.

Five of the nine farmers who irrigated did not use a particularly scientific method to make irrigation decisions, which is consistent with expert reports of the behavior of average producers in Oklahoma. Dr. Michael Kaiser at Oklahoma State University stated that farmers would eagerly come to seminars geared at saving money in chemicals, but he would not draw a crowd if he was speaking about irrigation scheduling (H. M. Kaiser 2008, personal communication). Dr. Kaiser doubts that more than a small percentage of producers used any careful measurement in irrigation decisions. One potential explanation Dr. Kaiser posited for this behavior of a majority of producers was risk aversion to revenue loss. Producers seemed more concerned with losing the quality and quantity of production than they were worried about increasing their costs, particularly a cost that may have seemed less negotiable than a chemical application. While this account does not comprehensively treat the issue (e.g., the producers could choose to purchase federal crop insurance to offset a portion of their revenue risk), producers exhibited the behavior. Were a producer risk averse, their production choices would not simply be a function of maximizing expected profit (Chavas 2006).

Chemical application, including pest control, disease treatment, and fertilization, was another important production control that farmers utilized (Fig. 4c).
six producers hired custom applicators or primarily used visual inspection methods, 15 farmers of the 21 surveyed reported that weather information was extensively used in pesticide application decisions. This was especially true of Mesonet users. The pecan scab model was popular for pecan farmers. Up to 40% of the yield of pecans was informed directly by Mesonet information and models such as the pecan scab model, according to agricultural specialists at the Oklahoma Mesonet. The model was cited in interviews to be useful as long as producers had property that had similar characteristics to the location of the nearest Mesonet tower(s).

Strategies to mitigate and adapt to risk carried costs. Farmers incurred the largest costs with respect to spraying, irrigating, fertilizing, and planting. Mitigating risk often resulted in physical stress on both capital resources and the farmers, as in the case of producers with rotations who made the decision to turn down a crop partway into the growing season, and use their land completely for the other crop in the rotation. However, managing weather risk was essential to production, and knowing when to implement mitigation strategies was worth the cost as long as the strategies were successful. An example to demonstrate the point was the crop protection strategy of one producer of a variety of crops, specifically including peaches. He reported that on a freezing night, a 2°F difference in temperature could mean the difference between losing 10% and 90% of his orchard. The significance of this difference becomes clear when the dollar value of those crops is estimated. Using the price of peaches during June 2008 ($585 ton⁻¹; U.S. Department of Agriculture, National Agricultural Statistical Service 2008a), this producer could save himself from a loss of roughly $145,000 by increasing the near-surface temperature of the orchard by 2°F over the course of the night. Based on information he obtained from the Mesonet inversion model, he would implement expensive measures such as helicopters (to physically mix out the inversion), diesel heaters, and large fans to increase the temperature. The usefulness of accurate meteorological information to inform the producer in this high cost–high loss scenario was clear.

d. General comments

A glance at the model reveals that weather had an impact on several areas of production. Before production began, weather was a significant concern to producers, thus becoming part of the framework for how the entire production process was approached. While this study captured the views of farmers over only a single year, a majority of the producers in the study noted that their production practices had in some way altered after the inclusion of Mesonet data into their regular practice. The degree to which these behavioral changes were profitable depended on many factors, including, but not limited to, the ability of producers to reduce costs while maintaining both quality and quantity of production, and the risk-averse preferences of the producers. Many producers used Mesonet data to support their participation in government programs, such as those run through the FSA, and these programs often carried financial incentives for participation. While this study was qualitative in nature and does not provide the information required for a rigorous quantitative analysis of the economic impact of the Mesonet on agriculture in Oklahoma, it does provide the initial behavioral information to inform a subsequent quantitative study.

5. Risk and Mesonet impact

As noted in section 4, Mesonet information was factored into the production model (Fig. 1) at several points for the interviewees. The information became a tool that producers used, subject to initial conditions and productive potential, to reach financial goals and make costly production decisions. This section contextualizes the financial risks of the typical Oklahoma farmer at the time of the study, how those risks changed over the 10 yr prior to the time of the interviews, and how the producers in this study were able to manage costly inputs using the Oklahoma Mesonet. In addition, a rough estimate is provided for how much money might be saved in the state in aggregate due to the use of Mesonet information by crop producers in Oklahoma.

The goods produced by crop farmers often were sold in commodities markets. The marginal profits that the average farmer faced in these markets were normally small, after accounting for prices for which their goods sold and the costs of production to which they were subject. During the time of the study (April–June 2008), the market created a more pressing environment than normal, because commodities prices had increased at abnormal rates of change over the previous months (Fig. 5a). This jump in the price for which their goods sold was favorable for producers’ revenue, but they also faced quickly rising costs of production (Fig. 5b). Between 2004 and 2008, production costs for crop farmers had risen about 70% nationwide, and revenue had increased at about the same rate. Hence, the stakes for each risk management decision (planting, irrigating, and chemical application) were increasing. With input costs being high, mistakes were costly. Therefore, scientific decisions were desirable to producers to minimize their chances of loss and maximize the effectiveness of their production measures. One producer stated specifically that the Mesonet was a powerful scientific tool that helped him know
important factors that influenced his choices, and using data and forecasts was crucial to making the best choices. Given the risks of loss that producers faced, many sought to optimally manage cost inputs while achieving revenue goals. The producers in this study focused on two main areas where they were able to reduce costs directly because of their use of Mesonet information: reduction in chemical spray application and reduction in irrigation. Additionally, producers made use of the Greenseeker program, a web-based decision-support system in which farmers submitted farm-specific information and were provided recommendations for fertilization to decrease their fertilizer usage. Greenseeker used Mesonet information for locations in Oklahoma as input data for the model. One producer reduced spraying by 75% after they began to use Mesonet pest models for their pecan trees, and noted no adverse effect on revenue. Though an extreme example, it highlighted an ability to change practices with better, trusted information. The amount saved was different for each farmer and depended on the particular meteorological circumstances and other pertinent management considerations. While each producer had a unique situation, many behavioral changes were noted across individuals in the study, and a rough estimate of a large-scale impact from Mesonet information can be posited.

Because this study was qualitative in nature and offered a small sample, the results are not generalizable. An estimate of the potential total cost savings is intended only to demonstrate an amount that could be saved if a range of producers in the state exhibited similar behaviors consistent with producers in this study. During the interviews, producers focused heavily on cost-saving behaviors, so the estimate that follows is based on the cost-saving decisions of the average producer in the sample. While this sample population was highly educated and technologically advanced, and therefore potentially not representative of a large portion of producers in the state, a bounded range is introduced for which behaviors noted in this study may be valid statewide. This estimate makes use of data provided by the small sample of Mesonet-using producers for only 1 yr. To make a robust estimate of the economic implications of behavioral changes, behaviors and outcomes for Mesonet-using producers would need to be compared with those that do not use the Mesonet, or the behaviors and outcomes for Mesonet-using producers would need to be tracked over several years to causally link Mesonet use to profitability. However, a rough estimate can still be useful for offering a potential impact assessment and inviting further research.

Farmers in this study sprayed for different pests depending on crop type. It was difficult to precisely ascertain how much spray the farmers deemed to be excessive after they were provided with more accurate decision tools, but, based on the interviews, spray reduction was conservatively estimated at 15% yr$^{-1}$ for the average producer. Estimates of acreage participation applied a lower bound of 1% using the data in 2007 with an upper bound of 10%, and for cumulative estimates both calculations linearly increased from an initial 0.5% acreage to the respective upper and lower bounds. Total reductions in spraying costs for 2007 were calculated by accounting for the cost of chemical application in the state of Oklahoma, the estimated fraction of producers using Mesonet data and the acreage held by those producers, and the reduction in costs by those using Mesonet (Table 2). If 1% (10%) of chemically sprayed crop acres in Oklahoma were influenced by Mesonet
information as a guide for spraying decisions, $160,000 ($1.6 million) of spray cost could be saved per year.

Cumulative cost savings resulting from spray reduction was estimated using cost information for chemical application in the state of Oklahoma, an estimate of the fraction of producers using Mesonet information each year, the acreage held by those producers, the reduction in costs by those using Mesonet, and an adjustment factor for the relative cost of factor inputs each year (Table 3). This cost-saving behavior could amount to a savings in spray alone of $1.1 million from 1996 to 2007. This estimate does not account for environmental benefits that could also be realized, which were a primary concern for some producers and were a goal for several FSA programs. Because those using Mesonet information were most likely to be among the larger farm operations in the state, up to 10% of crop acreage in the state may have been influenced. Using a linear increase from 0.5% in 1996 to about 10% in 2008, the total savings in spray was estimated at $8.0 million. Further study of the actual percentage of farmers who used Mesonet information since 1996 and their annual patterns of spraying would yield a narrower estimate.

The impact of the Mesonet on irrigation can be estimated by using the same assumptions as before. For a single year, savings were estimated using the average irrigation recommendation for the main crops in the state, the average cost per acre inch of irrigation, the fraction of acreage that is irrigated, the fraction of producers using Mesonet, and the reduction in costs reported by the average producer in the study (Table 4). Cumulative estimates were made using this information, adjusting for the cost of inputs each year and by increasing the numbers of producers assumed to be using Mesonet information each year (Table 5). Between $130,000 and $1.3 million is saved in irrigation cost annually, and between $850,000 and $6.4 million has been saved since 1996.

A final area of savings for producers resulted from fertilization decision support through Greenseeker, but not directly from the Mesonet. In the interviews, two producers explicitly mentioned relying solely on Greenseeker for their fertilization decisions. The information that the service provided farmers in Oklahoma was more accurate than for out-of-state producers because of the use of Mesonet information by the model. Oklahoma Mesonet data from the site closest to the producer was used as a model input. Dr. Bill Raun (2008, personal communication), who developed the Greenseeker program, stated that estimates of fertilizer application are significantly more accurate with Mesonet information as an input, and that they were able to offer an economically efficient outcome for producers when their model incorporated it. In 2007, Greenseeker-based decisions were made for 200,000 acres of wheat, and reductions in fertilizer application saved the average farmer $15 acre$^{-1}$, amounting to a $2.5 million savings in fertilizer. In 2008, Greenseeker was used with 400,000 acres of wheat, resulting in an estimated savings to farmers of $5 million (Dr. B. Arnall 2009, personal communication).

Summing all of the estimates of cost savings, an annual total savings was estimated at $2.8–$5.4 million and an accumulative total of $4.4–$16.9 million was estimated from 1996 to 2007. While these estimates were subject to variability from individual choices and changing market conditions, the estimates represent a marginal cost reduction that is useful for farmers that are producing in an

<table>
<thead>
<tr>
<th>Element in estimation of single-year chemical spray cost savings</th>
<th>Data source used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount spent on chemical application in OK</td>
<td>U.S. Department of Agriculture, National Agricultural Statistical Service (2007b)</td>
</tr>
<tr>
<td>Fraction using Mesonet</td>
<td>Average size of farm where a producer used Mesonet data; average number of producers in each county who used Mesonet data (upper and lower bounds of 1% and 10%)</td>
</tr>
<tr>
<td>Percent reduction by those using Mesonet data</td>
<td>Average of estimates provided by interviewees</td>
</tr>
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<td>Cost adjustment factor</td>
<td>USDA NASS Prices Paid by Producers Index</td>
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environment with low (or highly variable) profit margins. In comparison with this figure, the Oklahoma Mesonet is funded by the State of Oklahoma at $1.8 million annually.

6. Conclusions

Agricultural production is sensitive to weather, and the Oklahoma Mesonet provides data and services that are used at many decision points in the crop production process. The nature of crop production is increasingly high risk and high reward. In this framework, producers are facing increasing pressure to become as efficient as possible. This study demonstrated how producers use data and products from the Oklahoma Mesonet to become more cost efficient, to engage in more scientific practices with respect to revenue generation, and to help them achieve their production goals. In today’s environment of market volatility, faster technology adoption, and significant turnover in workforce resulting from shifts in population demographics, scientific decision making in agriculture is more imperative now than in years past. This study highlighted some areas where producers were affected by Mesonet information through influential policy, were using Mesonet information to weight risk-management options, and, in particular, were managing their costly inputs by trusting scientific information, resulting in potentially significant cost savings statewide if behaviors noted among this small sample were in fact generalizable to a larger population of producers.

Acknowledgments. We thank Drs. Ken Crawford and Pete Lamb for their support and numerous helpful comments and critiques over the course of the project. Additionally, Dr. Todd Crane provided essential guidance on the initial iterations of the interview protocol. We also thank Drs. Damona Doye, Michael Kaiser, and Bill Raun of OSU for their guidance, provision of background literature, and support of data in several subdisciplines of agriculture. The many agricultural extension educators that worked closely with the producers and our team to identify subjects for this study, including Courtney Coats, Ted Evicks, Roger Gribble, Rick Kochenower, Wes Lee, Doug Maxey, Michael Pettijohn, Vernon Scogin, Mike Steele, Ron Vick, and Bob Woods. We thank the many producers, researchers, and farm service agents who took the time to be interviewed and share their experiences. Finally, we thank the reviewers for their many helpful suggestions for improvement of this manuscript. The Oklahoma Mesonet and AgWeather are funded by the taxpayers of Oklahoma through the Oklahoma State Regents for Higher Education and Oklahoma Department of Public Safety.

**Table 4. Description of data sources and use in calculation of annual cost savings from irrigation reduction in Oklahoma in 2007.**

<table>
<thead>
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<tr>
<td>Average irrigation recommendation</td>
<td>For each of the nine climate divisions, the difference between the average water requirement for the top seven crops in the state and the average annual precipitation in that climate division</td>
</tr>
<tr>
<td>Average cost for irrigating 1 acre in.</td>
<td>Average of estimates provided by interviewees</td>
</tr>
<tr>
<td>Percent of acreage that irrigates</td>
<td>U.S. Department of Agriculture, National Agricultural Statistical Service (2007a)</td>
</tr>
<tr>
<td>Fraction using Mesonet</td>
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**Table 5. Description of data sources and use in calculation of cumulative cost savings from irrigation reduction in Oklahoma from 1996 to 2007.**

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<td>Average cost for irrigating 1 acre inch</td>
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The research conducted by K. E. Klockow was funded by the Oklahoma Mesonet, and while investigator R. A. McPherson was not funded by the Oklahoma Mesonet, she served as Associate Director of the Oklahoma Climatological Survey, which operates and maintains the Oklahoma Mesonet.

REFERENCES


