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IMPORTANCE OF WEATHER MONITORING INFORMATION FOR DECISION MAKING IN AGRICULTURAL PRODUCTION – A CASE STUDY OF OKLAHOMA

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IMPORTANCE OF WEATHER MONITORING INFORMATION FOR DECISION MAKING IN AGRICULTURAL PRODUCTION – A CASE STUDY FOR OKLAHOMA

A THESIS APPROVED FOR THE
DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL SUSTAINABILITY

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Abstract

Extreme weather events and climate variability are among the most significant factors negatively affecting agricultural production in the United States. Approximately 8 out of every 10 acres in Oklahoma is used for agricultural production (Oklahoma Water Resources Board, 2011). Due to constant weather variability in Oklahoma, accurate, updated and timely weather monitoring information is indispensable for farmers to consider throughout their agricultural production decisions. Previous studies developed conceptual models supporting land management and production decisions in order to better understand the use of information by farmers. One increasingly important informational aid applied by farmers in the state of Oklahoma to protect their production against extreme weather events is weather monitoring information provided by the statewide weather monitoring system, the Oklahoma Mesonet. Farmers in Oklahoma have repeatedly acknowledged the value of Mesonet information, which has also been substantiated by several qualitative studies. However, the perception of value and the level of use of Mesonet information for agricultural production decisions have not yet been measured and evaluated quantitatively with scientific methods. This research aims at determining farmers' perceptions about the value of the Oklahoma Mesonet information for their farming practices and farm profitability. The level of importance that Mesonet weather information has on farm profitability was determined and analyzed based on geographical location and frequency of information use from the Mesonet. The results illustrate farmers’ perceptions about their potential benefits from using Mesonet.

Key Words: *Weather monitoring information, Oklahoma, Agriculture, Mesonet, Farming, Land Management, Agricultural Production Decisions*

1. Introduction

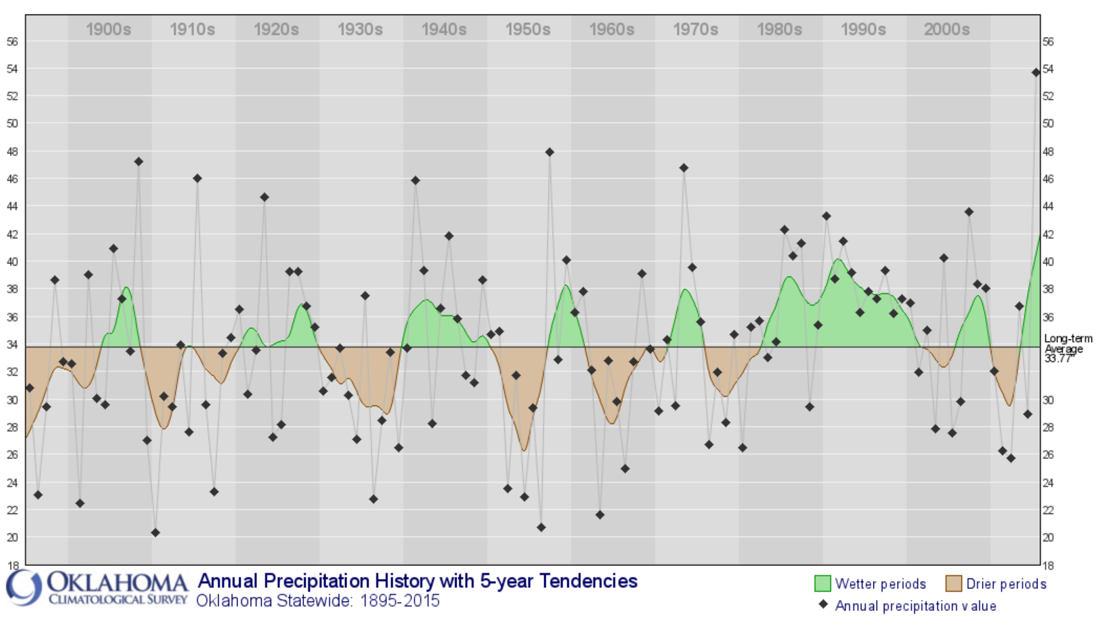
The Oklahoma Mesonet is a statewide environmental monitoring network of 120 automated stations, at least one station for each county in Oklahoma, that continuously collect and transmit soil and atmospheric data every 5 minutes throughout the year. The densely spaced automated weather stations, defined as a mesoscale weather network, provide critical data on weather events such as thunderstorms, wind gusts, heat bursts, and dry lines that would otherwise go undetected. (Oklahoma Mesonet, 2015). The Oklahoma Mesonet's ability to both record weather events that range in size from about 1 mile to about 150 miles and to track multiple atmospheric and environmental measurements, provides information that is of benefit to weather forecasting, education, emergency management, wild land fire management, the energy industry, transportation, scientific research, and the focus of this analysis, agriculture. This study aims at providing a deeper understanding of what factors influence farmers in Oklahoma to use weather information throughout the agricultural production cycle. Different variables that were hypothesized to have an effect on the perception of value from using information provided by the Oklahoma Mesonet were examined and included in the analysis.

Oklahoma's history is very much intertwined with significant weather events and its effects on agriculture and society. By the time of European arrival to the America's in the 16th century, several Indian tribes living in Oklahoma were farming. Agricultural development continued with the arrival of the 'Five Civilized Tribes' in the early 19th century from East of the Mississippi River which led to the establishment of many farms and plantations in the Indian Territory, now Eastern Oklahoma (Gibson, 1984). Throughout the territorial period, pasture and meadowlands in Central and Western

Oklahoma were burned and intensively plowed to make way for the rich topsoil. The lack of understanding for the effects of erosion enhanced the effects of heavy rains and strong winds in the 1930's that led to the infamous 'Dust Bowl' era where an estimated 80 percent of Oklahoma's soil suffered from at least some erosion (Gibson, 1984). The 'Dust Bowl' was, "mainly the result of stripping the landscape of its natural vegetation to such an extent that there was no defense against the dry winds" (Worster, 1979). As cited by the Soil Conservation Service (1935), Worster (1979); Hansen & Libecap (2004), and Egan (2006) in Arthi (2014), "Dirt deposited downwind suffocated livestock, buried property, and smothered yet other crops." References in literature regarding the significant impacts of weather on agricultural production in Oklahoma are thus plentiful and the most referenced weather event relates to the social and economic effects of this historical drought and destructive dust storm era in Oklahoma's history (Peppler, 2011) (Arthi, 2014). The Dust Bowl resulted in the failure of many farms and consequently led to out-migration in the state which reduced the number of farms by 33,638 between 1935 and 1940 (Fite, 2016). The drought would nonetheless end around 1940 and although farmers saw generally favorable crop yields and prices throughout the 1940's, by 1950 Oklahoma had 142,246 farms, down 71,079 from a high of 213,325 in 1935 (Fite, 2016). The Dust Bowl was the impetus for many of the soil conservation and land management practices currently in place in Oklahoma and in the rest of the country. In a 2011 event of the National Association of Conservation Districts, Gary McManus, the assistant state climatologist for the Oklahoma Climatological Survey, said, "If it wasn't for the efforts of the conservation movement, the state and the nation would have suffered recurrences of the Dust Bowl several times in its history" (Oklahoma Conservation Commission, 2016). The Dust Bowl era foreshadows the recent expansion of interest in droughts by atmospheric scientists, “stimulated in part by the need to understand possible causes of and impacts of anthropogenic climate change” (Mcleman et al., 2014), that are largely possible because of “sophisticated global climate models and greater availability of climate datasets” (Mcleman et al., 2014).

The Oklahoma Water Resources Board indicated that “Oklahoma’s rainfall history is dominated by a decadal-scale cycle of relatively consistent alternating wet and dry periods lasting approximately 5 to 10 years,” and that the state experienced an extensive wet period from the early 1980’s through the first decade of the 2000’s with the exception of 2006 (The Oklahoma Water Resources Board, 2012). The alternating wet and dry periods are clearly represented in the Oklahoma Climatological Survey’s “Annual Precipitation History with 5-year Tendencies” chart (Figure 1).

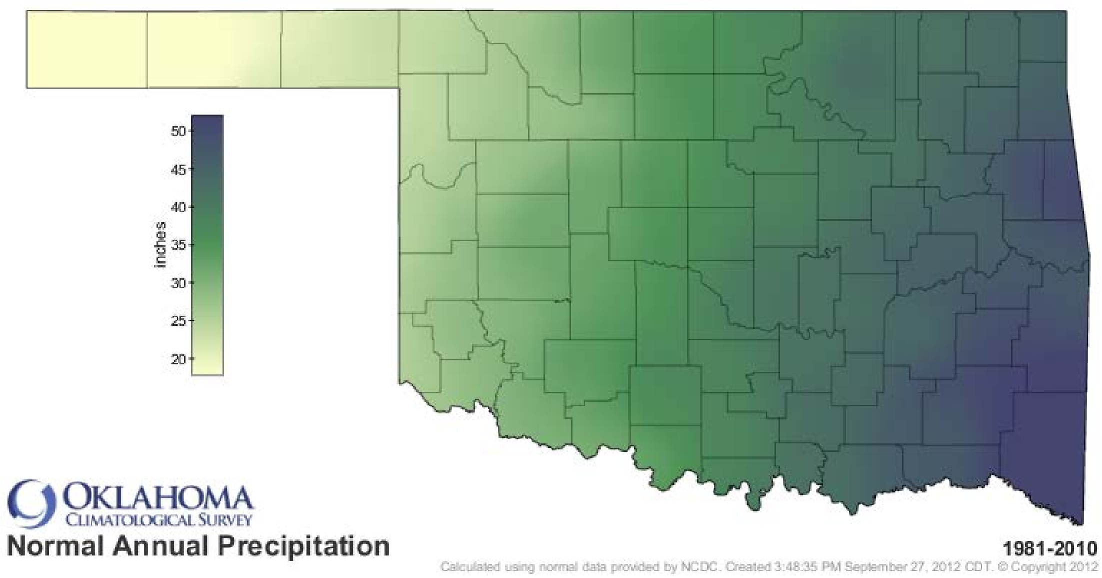
Figure 1: Annual Precipitation History with 5-year Tendencies



Source: Oklahoma Climatological Survey, 2015

In addition to the decadal-scale cycle, Oklahoma reflects a large variability of precipitation within the state itself, “average annual precipitation ranges from about 17 inches in the far western panhandle to about 56 inches in the far southeast” (Oklahoma Climatological Survey, 2016) (Figure 2).

Figure 2: Normal Annual Precipitation (1981-2010)



Source: Oklahoma Climatological Survey, 2015

Farmers in Oklahoma and in the broader Southern Great Plains have had to continually cope with extreme weather events and variability in weather patterns (Steiner et al., 2015). One of the coping strategies employed includes utilizing the most accurate weather information available to make the farm management decisions that both help reduce the potential for losses and either improve crop yields or cattle weight gains. Literature describes input timing and usage, planting schedules, irrigation scheduling, pesticide application, and prescribed burning as some of the critical farm management decisions for Oklahoma farmers directly affected by climatic variables (Kenkel & Norris,

1995) (Klockow & McPherson, 2010). Partially to address this very exact issue and provide agricultural producers with accurate weather information, scientists at Oklahoma State University and the University of Oklahoma developed the statewide Oklahoma Mesonet network for agricultural, hydrological, and meteorological monitoring which was officially commissioned with funding from the State of Oklahoma in 1994 (Brock et al., 1995). Before commissioning, a contingent valuation survey of 146 farmers was conducted by Kenkel and Norris (1995) largely to inform the developers of the Mesonet on the potential willingness to pay of agricultural producers for mesoscale weather data. The study found that the expected monthly willingness to pay for raw weather data was $5.83 and $6.55 for both raw weather data and value-added information or agricultural decision aids (Kenkel & Norris, 1995). More recently, a behavioral qualitative study on the use of Mesonet information by agricultural producers in Oklahoma found that, "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" (Klockow & McPherson, 2010). The Oklahoma Mesonet, commissioned in 1994, has served its users for over 20 years and has since been continually developing new agricultural decision tools and enhanced accessibility options for its users. Quantitative studies that reflect the level of significance of the Oklahoma Mesonet and that of its added capabilities to agricultural producers throughout the state are missing in the literature.

To determine the appropriate method to conduct this study, different literature sources were reviewed, for example: literature on climate variability in Oklahoma, uncertainty in agricultural production and the expected utility theory, theories on the adaptive capacity and decision making behaviors of agricultural production, agricultural technological transitions and social networks, and on the value of information in agriculture. The methodology section provides a discussion of Oklahoma Mesonet valuation methods applied in the literature, on the selection of predictor variables that were hypothesized to have an effect on the perceived level of importance of the Mesonet's information to farm profitability, and on the considerations taken for data collection and data interpretation. The methodology section is followed by an in-depth analysis of the results and the final conclusions for Oklahoma Mesonet operators, Oklahoma policymakers, and university researchers to take into consideration.

2. Problem Statement

The 2012 drought, classified by NOAA (National Oceanic and Atmospheric Administration) as the most extensive drought to affect the United States since the 1930's (National Centers for Environmental Information, 2016) led to an estimated agricultural related loss in the state of Oklahoma of just over $426 million (Shideler D. , et al., 2013). The estimated loss represents approximately 6% of the just over $7 billion of agricultural production receipts for the state of Oklahoma in 2012 (USDA, 2016). Just one year before, the 2011 drought had led to an even larger estimated crop, horticulture, and livestock production loss of close to $1.7 billion, or 24%-25% of the state's total agricultural value of production (Shideler et al., 2012). The increased occurrence of droughts, floods, tornadoes, and extreme rainfall due to climate change *predicted by the National Climate Assessment and the National Wildlife Federation* in the United States could potentially lead to more common and larger loses in agriculture without the appropriate application of preventive measures (U.S. Global Change Research Program, 2015). The Oklahoma Mesonet provides increasingly important value added weather monitoring information that allows farmers to apply preventative measures into their production decision making process that can reduce the effects of extreme weather events and in some cases provide valuable input savings (Klockow & McPherson, 2010). For example, if an agricultural producer is able to eliminate one pesticide application by relying on value added weather information, he could save $8-$12 per acre (Kenkel & Norris, 1995) and according to more recent estimates by the USDA, savings can total $13 to $40 per acre depending on the type of crop and the type of pesticide or herbicide applied (Scuderi, 2015). The potential benefits of incorporating the Oklahoma Mesonet weather monitoring information into agricultural production decisions has been repeatedly acknowledged in the literature however, the perceived value and the level of importance attributed by farmers to the information provided by the Oklahoma Mesonet has not yet been measured. Furthermore, research that leads to the potential identification of the differences in the perceived value attributed by individual farmers has not yet been performed.

3. Research Objective

This study aimed at identifying the different levels of importance placed by farmers for the Oklahoma Mesonet's weather monitoring information's contribution to farm profitability. The objective was to determine what contributes to the differences in the levels of importance placed by farmers on the use of weather monitoring information in order to provide key decision makers within the state of Oklahoma, specifically members of the Oklahoma Mesonet Steering Committee and other stakeholders, with meaningful information regarding how farmers perceive the range of agricultural production benefits provided by the Oklahoma Mesonet. The Oklahoma Mesonet Steering Committee is responsible for guiding strategic planning, developing fund raising strategies, verifying compliance with state and federal statues, monitoring long-term risks, and assessing requests for substantial changes in operational and service activities (Board of Regents of the University of Oklahoma, 2016). As approved by the Mesonet Steering Committee on August 17th, 2011:

> *"The mission of the Oklahoma Mesonet is to operate a world-class environmental monitoring network, to deliver high-quality observations and timely value-added products to Oklahoma citizens, to support state decision makers, to enhance public safety and education, and to stimulate advances in resource management, agriculture, industry, and research. The Mesonet receives recurring state funding to support a portion of its operating expenses. In addition, the Mesonet must raise several hundred thousand dollars annually in external grants, contracts, and data sales to operate the network"* (Oklahoma Mesonet, 2016).

State funds, external grants, and data sales are required annually by Oklahoma Mesonet operators in order to efficiently provide its users with reliable weather information. By surveying agricultural users and non-users of the Oklahoma Mesonet and determining farmer perceptions towards the Oklahoma Mesonet's impact to profitability and the potential economic benefits obtained as a result of the Oklahoma Mesonet agricultural production decision aids, this study provided valuable and currently non-existent information in literature to both Oklahoma Mesonet operators, potential grant funding organizations, and different stakeholder groups.

4. Literature Review

4.1. Coping with Climate Variability

Climate variability is one of the most significant factors influencing year to year crop production, even in high yield and high technology agricultural areas (Kang & Khan, 2009). Some studies have determined that globally, climate variability accounts for roughly a third of the observed variability in crop yields (Ray, 2015). In June of 2008, the Mississippi River flood generated crop losses of at least $8 billion throughout much of the Midwestern U.S. (Gleason, 2008). As part of the FY2008 Supplemental Appropriation Act, Congress appropriated approximately $480 million in emergency USDA funding mainly directed at conservation activities in the flood-affected regions (Schnepf, 2008). Coping with climate variability has always been a challenge for many farmers throughout the United States, particularly for those in the Midwest and the Great Plains. “Across the Midwestern United States, the number of days with heavy rainfall more than tripled in the past 50 years, particularly in the spring (Hatfield JL C. R., 2013). Increases in summer temperatures are also projected to increase soil water evaporation and crop transpiration, further increasing soil water deficits and economic losses (Hatfield JL B. K., 2011)” (Gaudin & al., 2015). Ray, et al. (2015) identified that temperature variability was more important in the upper Midwest while precipitation variability was more important in the central Midwest. The same study identified that in many counties within Great Plains states both precipitation and climate variability are significant factors. Surprisingly enough, sales of agricultural products in states located in the Midwest (Iowa, Nebraska, Minnesota, Kansas, Illinois, Wisconsin, Indiana, South Dakota, North Dakota, and Ohio) accounted for $165.1 billion or approximately 42% of total agricultural sales in the United States in 2012 (USDA, 2015). If agricultural sales from the Great Plains states of Colorado, Oklahoma, Wyoming, Montana, and most of Central to Western Texas were added, the percentage clearly surpasses the 50% mark. As a result, farmers' ability to cope with climate variability in this part of the country becomes critical to safeguarding livelihoods and the nation's food supply.

Experience, practice, and technology have typically been identified as the primary coping mechanisms that have allowed farmers to generally adapt successfully to climate variability within the limited temporal boundaries of agricultural production. Changes in crop rotations, planting times, genetic selection, fertilizer management, pest management, water management, and shifts in areas of crop production are some of the adaptive tools employed by the agricultural sector (Grotjahn at al., 2015). Employing these tools has proven to be an effective strategy that has provided for the continued growth in production and efficiency throughout the United States (Grotjahn et al., 2015). The planting, growing, and harvesting seasons for crops go through an extremely complex and crop specific process where everyday decisions regarding irrigation, the application of agricultural chemicals, and what measures to take to protect a crop against frost damage or disease can make the difference between profit and loss in a growing season (Diak, Anderson, & Bland, 1998). The risk behind many if not most of these decisions is enhanced due to variability in weather conditions. It is important to remember that agricultural production decisions enhanced by the risks of changing weather patterns affect not just the type, yield, and quality of crops but in most cases a farmer's own livelihood.

4.2. Descriptive and Normative Agricultural Production Decision Making Theory

Descriptive decision theory is based on empirical observation and experimental studies of actual choice behaviors (Wang & Ruhe, 2007) while normative decision theory, “assumes a rational decision-maker who follows well-defined preferences that obey certain axioms of rational behaviors” (Wang & Ruhe, 2007), or in other words, what people should do. Literature has often described and conceptually modeled agricultural production systems (Peart & Curry, 1998) (Stoorvogel & Antle, 2004). With the emergence and formalization of system dynamics, the advent of computer programming in the 1980’s, increased knowledge of ecosystem interactions, and larger concerns for sustainability issues, the modeling and simulation of agricultural systems took off (Peart & Curry, 1998) (Stoorvogel & Antle, 2004). The expected utility model, formally developed by von Neumann and Morgenstern (1944), is a typical normative decision theory that has, “long been the dominant framework for analysis of decision-making under risk” (Machina, 1987). The model has been used to describe how farmers with a low degree of relative risk aversion are more likely to plant new and untried crops, forgo insurance, hold unprotected grain stocks or livestock inventories, and in general have portfolios weighted toward risky undertakings (Just & Pope, 2002). Moschini & Hennessy (2001) defined the main sources of uncertainty and risk as production uncertainty, price uncertainty, technological uncertainty, and policy uncertainty. These sources of uncertainty and risk are critical variables that can affect the individual use and valuation of weather monitoring information. Hansen et al. (2013) encapsulated these sources of uncertainty and risk within the mental models, or the context of existing beliefs that guide the decisions people make to protect themselves and others from weather-related damages to crops. Other studies have looked into the variables that specifically influence production decision making, Stewart et al. (1984) identified the 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 (Klockow & McPherson, 2010). The psychological comfort function relates well to the notion of risk which is typically represented in terms of the probabilities of deviations from an expectation (Just & Pope, 2002). Specifically defining what that expectation is and how it differs from one farmer to the other, as evidenced by examples of empirical work provided by Just & Pope (2002), lead to more accurate understandings of what value is placed on information that can influence production decisions. Describing a general framework for conceptualizing the value of information, Macauley (2005) provides the following four conclusive factors: (1) the level of decision maker uncertainty, (2) the aggregate value of the resources or activities that are managed, monitored, or regulated, (3) how much it would cost to use the information if the user could locate it himself, and (4) what is the price of the next best substitute (Macualey, 2005). According to Macauley's research, the larger the level of decision maker uncertainty and the larger the value of the resources managed which are at stake as an outcome of decisions taken, the larger the value placed on information.

Of particular importance to the value placed on information is that agricultural production decisions do not stem exclusively from climate forecasts but from the interactions between weather, the soil and biotic environment, the physiology and phenology of the crop, and market conditions (Hansen, 2002). An additional factor into the agricultural production cognitive process that incorporates weather monitoring data and needs to be taken into consideration is that many critical agricultural decisions that interact with climatic conditions must be made several months before the actual impacts of climate materialize (Hansen, 2002). Furthermore, (Hu, 2006) in (Frisvold & Murugesan, 2012) acknowledged that "farm-level decisions about weather data use are not necessarily made by a single individual in isolation of considerations of – and input from – household members, business partners, fellow producers, neighbors, media sources, or farm consultants." Because of these multiple factors and the overall unpredictability of climate throughout the growing season, conservative risk management strategies are usually applied to reduce the negative impacts in poor years, but this often comes at the expense of reduced average productivity, inefficient use of resources, and sometimes accelerated natural resource degradation (Hansen, 2002).

Researchers have also looked into the management capacity qualities that have allowed farm managers to optimize the technical and biological processes at their farms through decision making (Rougoor et al., 1999). This particular empirical study that related farm results to management variables, in a similar fashion to most literature sources on agricultural production decisions, acknowledged the distinguishing risk and uncertainty behind the stochastic, or randomly determined, elements from the environment. Moschini & Hennessy (2001) define the agricultural production function as stochastic, "due to the fact that uncontrollable elements, such as weather, play a fundamental role in agricultural production." Furthermore, the authors pointed out that long production lags are dictated by the biological processes inherent with crop production. The same time lag also creates uncertainty for the final market price of the agricultural output, which is one of the non-climatic factors mentioned in the literature that also impacts the adaptive decisions of farmers (Smit & Skinner, 2002). The other non-climatic factors affecting the adaptive decisions of farmers typically mentioned in literature are technology, society, and policy effects. These non-climatic variables, that literature states have strong effects on adoption of technology, are directly related to the sources of uncertainty and risk identified by Moschini & Hennessy (2001) such as, production, price, technology, and policy uncertainty. The availability of quality, accurate, and consistent weather monitoring information coupled with useful value-added agricultural decision aids could in theory provide agricultural producers with some of the reassurances to make informed decisions that better prepare them for adverse conditions or that better allow them to take advantage of favorable conditions.

4.3. The Value of Information in Agricultural Production

Frisvold & Murugesan (2013) defined the assessment of value by farmers and ranchers for weather information as a discrete-continuous choice problem. The discrete choice is defined as whether to use any weather information for a particular discrete decision while the continuous choice is defined as the level or intensity of use given to that information. This method of portraying the value of weather information to farmers is consistent with Hansen's (2002) five prerequisites to beneficial climate forecast use. The first prerequisite is that "forecast information must address a need that is both real and perceived" (Hansen, 2002). The second prerequisite is that a benefit should arise "only through viable decision options that are sensitive to forecast information" (Hansen, 2002). The third prerequisite is the need for sufficiently accurate and timely predictions of the components of climate variability at relevant periods for the relevant decisions being made. The fourth prerequisite is that the right audience receive the right information at the right time and it is appropriately interpreted so that it can be applied to the decision problem. The fifth and final prerequisite is that institutional commitment to providing forecast information and support for its application to decision making and policy that favors the beneficial use of climate forecasts is required to sustain the use of forecasts. The second prerequisite, which relates to the awareness that certain decisions are sensitive to the incremental use of forecasts, and the fourth prerequisite, which refers to the appropriate application of the correct type of weather forecast information, are particularly reflective of the discrete-continuous choice problem defined by Frisvold & Murugesan (2013). The International Research Institute for Climate Prediction (IRI) suggests that, based on the difference of how people process description based information and experience based information, in order to increase the value of externally provided climate information, interventions may help farmers map description based forecast information onto their own knowledge base derived from personal experience (Hansen et al., 2013). Ultimately, "information (e.g. forecasts) is only of value insofar as it leads to an optimal policy that differs from the optimal policy that would be followed without the information" (Katz et al., 1987).

The differences in how people process description based information and/or experience based information is often tied to historical, cultural, demographic, and socioeconomic factors. The influence of these factors over farming production decisions and the value judgments placed on externally provided weather information compared to on-farm situated knowledge and local social network information has been studied in literature (Peppler, 2011) (Smith et al., 2007) (Gillespie & Mishra, 2011). Approximately

(88%) of primary farm operators in the state of Oklahoma are identified as Male (United States Department of Agriculture, 2012) compared to the (86%) average in the United States. The average age of the principal operator is 58.3, equal to the total average of 58.3 in the United States. Approximately (86%) of farms are operated by people identifying themselves as White compared to the national average of (96%). This significant difference in the farmer operator percentages is primarily due to the large percentage of American Indians in Oklahoma. The percentage of American Indian operators in Oklahoma is the third highest overall at (10%) while the national average is closer to (2%) (United States Department of Agriculture, 2014). The research findings of Peppler (2011) about the conceptualization of weather and climate by Native American farmers in Oklahoma, described that "many of the farmers explained that while they consult modern weather and climate forecasts to help guide their farming decisions, they prize their own observations and indicators as providing a local relevance and situational awareness they cannot obtain from other informational sources, and they use the insights gained from them as a key part of an actionable knowledge complex for decision making" (Peppler, 2011). The percentage of farmers who list farming as their primary occupation is the other notable difference between the 2012 USDA Census results for Oklahoma and those for the U.S. (Table 1). In effect, studies have shown that "the average U.S. farm household receives 85% of its income from off-farm sources" and that this can lead to differences in production decisions (Mishra et al., 2002) in (Gillespie & Mishra, 2011). Oklahoma has a higher percentage of farmers, compared to the U.S average, who list off-farm work as their primary occupation (Table 1).

Table 1: USDA 2012 Census of Agriculture Demographic Characteristics – Oklahoma & U.S. (Percentage of Total Farm Operators)

Characteristic	Oklahoma	U.S.
Male (Principal Operator)	88.7 %	86.3 %
Female (Principal Operator)	11.3 %	13.7 %
Primary Occupation (Farming, All Operators)	38.5 %	44.4 %
Average Age (All Operators)	56.2	56.3
Spanish, Hispanic, or Latino 1 (Principal Operator)	1.5 %	3.2%
American Indian 1 (Principal Operator)	9.3 %	1.8 %
Black or African American 1 (Principal Operator)	1.7 %	1.6 %
White 1 (Principal Operator)	86.3 %	95.4 %

1 Data were collected for a maximum of three operators per farm (USDA)

Source: 2012 USDA Census of Agriculture (USDA, 2015) (USDA, 2016)

Many studies have provided estimates of the economic benefit of improved weather forecasts to agricultural producers for specific agricultural commodities in relatively small geographical settings (Adams et al., 1995). Katz et al., (1987) particularly focused on estimating the value of precipitation forecasts for spring wheat farmers that are faced with the 'fallowing/planting problem' in the western portion of the Northern Great Plains. Fallowing itself "refers to land that is plowed and tilled but left unseeded during a growing season" (Encyclopedia Britannica, 2016) to help replenish soil moisture and maintain the natural productivity of the land. The 'fallowing/planting problem' therefore refers to whether a farmer should plant a crop or simply leave the land fallow. This decision affects "both the return that he (the farmer) will receive in the current year and the amount of soil moisture that will be available the following year" (Katz et al., 1987). Stochastic dynamic programming was applied by the authors to model the economic value of both currently available precipitation forecasts issued by the U.S. National Weather Service (NWS) and hypothetical improvements in the quality of such forecasts (Katz et al., 1987). The model itself describes the different economic values from different levels of precipitation forecast qualities at two specific locations (Havre, Montana & Williston, North Dakota). The differences in expected dollar per acre returns based on improved weather forecast qualities for spring wheat farmers at the two locations is attributed to one location being wetter than the other. The authors made a series of assumptions that included, three categories for growing season precipitation, four states of available soil moisture, year-over-year soil moisture states, and the expected yields in kg/hectare based on soil moisture and precipitation. This information was combined with the estimated price per harvested unit of Spring Wheat ($4 per bushel), production costs estimates for raising a crop ($51 per acre), and a discount rate of 0.90 (Katz et al., 1987). The authors ignored any price changes due to market shifts in production, costs and returns associated with fallowing, growing season temperature and its effect on yields, and biological factors such as pests. The study concluded that, "the value of perfect information comes not through growing a crop more often, but simply through the advantage of planting in those years known to be relatively wet" (Katz et al., 1987). In general, farmers in areas with less consistent precipitation would see a higher economic return from improved precipitation forecasts than farmers in areas with more consistent precipitation levels.

The development and actual use of improved weather forecasts is very much intertwined with improvements in weather monitoring capabilities and technology. In order to identify the value of information provided by the use of advanced technologies for crop production some studies have applied the contingent valuation (CV) method (Kenkel & Norris, 1995) (Hudson & Hite, 2003) (Marra et al., 2010) to determine farmer Willingness-To-Pay (WTP) while others have statistically demonstrated the relationship between actual and expected agricultural proceeds (Diafas, Panagos, & Montanarella, 2013) (Bontems & Thomas, 2000) (Wang, Prato, & Qiu, 2003).

The Kenkel & Norris (1995) contingent valuation (CV) survey was the first attempt to determine the willingness-to-pay (WTP) of agricultural producers for mesoscale weather data and related agricultural decision aids. The survey applied what is known as price categories to elicit producers' willingness to pay. The price categories approach allows respondents to select the maximum amount they would be willing to pay for the good or service being valued from a series of payment values (Kenkel & Norris, 1995). In a comment to Kenkel & Norris' (1995) CV approach, Cohen & Zilberman (1997) argued that there are problems with willingness-to-pay measures in assessing a technology's market potential (Cohen & Zilberman, 1997). Cohen and Zilberman (1997) argued that the Kenkel and Norris (1995) survey, "resulted in negatively biased benefits estimates due to the lack of producer information about the technology's potential benefits, the strategic behavior of those surveyed, and the exclusion of many potential adopters from the survey" (Cohen & Zilberman, 1997). The authors argue that "potential adopters are inexperienced, and users of a product are often followers who need to see it to believe it" (Cohen & Zilberman, 1997). The argument primarily stemmed from the belief that the respondents' underestimated willingness to pay, for a technology not yet available, would discourage investment in the publicly provided system. At the time of the initial WTP survey, no commitment of public funds to continually operate the Oklahoma Mesonet had been made, therefore the project developers thought it important to project user WTP (Kenkel & Norris, 1997). Strategic bias, affecting not just CV surveys but any type of survey eliciting a type of value response, is another issue discussed. It surfaces because of two important factors, (1) the respondent believes the provision of the good or service is contingent upon his/her response, and (2) the respondent will have to pay the exact amount revealed (Kenkel & Norris, 1997). The strategic bias is one of the potential biases inherent in surveys attempting to elicit a type of value response, others include how the information is given to respondents in surveys, whether alternative choices are provided (information or 'framing' effect), and the tendency to say 'yes' (yea-saying) (Choi & Ritchie, 2010). Ultimately, Kenkel & Norris (1997) agree that solely estimating the uptake of a product on the product developer's perception of the benefit is risky, and this is particularly evident with the adoption of technology.

The specific crops selected in the Kenkel & Norris (1995) study (alfalfa, peanut, and cotton) are increasingly susceptible to variability in weather conditions and it was therefore theorized that farmers of these specialty crops would exhibit a higher willingness to pay. Similar producer WTP studies have looked specifically at specialty crop farmers and their adoption of environmental or field data enhancing technology (Marra, Rejesus, & Roberts, 2010) (Watcharaanantapong & Roberts, 2014). Any study eliciting the value of importance of weather monitoring information to its users should therefore attempt to assess the differences in values between traditional and specialty farmers. Applying predictor variables provides researchers with a framework to better understand the value placed on weather information within the cognitive and normative elements of agricultural production decisions.

In both of the Oklahoma based studies (Kenkel & Norris, 1995) (Klockow & McPherson, 2010), survey populations were obtained with assistance of the Oklahoma State University, a land-grant university originally known as the Agriculture and Mechanical College of Oklahoma Territory (Rulon, 2015). The interviewees thus primarily consisted of larger and higher income producers that are characterized in the studies as more educated and technologically savvy. Approximately (81%) of farms in Oklahoma have less than 500 acres, studies attempting to determine the value or importance of the Oklahoma Mesonet to the entirety of the farmer population should amplify their reach to include smaller producers. In particular, the Klockow & McPherson (2010) study, consisting of 21 in-depth interviews, was "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 the study." Alternatively, the Kenkel & Norris (1995) study had a much wider selection sample of 645 farmers, 508 cotton, peanut, alfalfa, wheat, and diversified crop/livestock producers and 137 irrigated crop producers who provided a higher WTP than the non-irrigators (Kenkel & Norris, 1995). In the most recent USDA Census of Agriculture (2012), irrigated farm acres in Oklahoma totaled 479,750, or approximately 6% out of the total harvested cropland. Any study considering the level of importance of weather monitoring information should thus consider potential differences in the perception of value between irrigators and non-irrigators.

The Kenkel & Norris (1995) survey achieved a response rate of (27%) for respondents who effectively answered the WTP question. Comparable studies that strive to determine the willingness to pay of agricultural producers for either precision agriculture information or technology have included a significantly larger number of respondents into their models. One such study, which aimed to determine the WTP of Mississippi crop producers for site-specific management technology (SSM), applied 423 of 780 questionnaires into its regression model (Hudson & Hite, 2003). Another study, which aimed to determine the demand and WTP of Southeastern cotton farmers for either retrofitting yield monitors on cotton pickers or to purchase a new cotton yield monitor, applied 743 of 6,423 questionnaires sent out into its regression model (Marra et al., 2010). In terms of response rates, the Kenkel & Norris (1995) falls somewhat in between the Hudson & Hite (2003) study, with 71.4%, and the Marra et al. (2010) study, with a 19.4% response rate. The following table (Table 2) provides a detailed description of the three WTP contingent valuation surveys and the Klockow & McPherson (2010) semi-structured interviews as a comparative tool to the additional valuation methods applied in literature. The surveys were used to assist in the development of this study's survey and the results of the two Oklahoma Mesonet based studies were used to comparatively analyze the level of importance and potential current valuation of the Mesonet.

Table 2: Valuation Methods for Weather Monitoring Information and Technology

Study Authors	Kenkel & Norris (1995)	Hudson & Hite (2003)	Marra et al. (2010)	Klockow & McPherson (2010)
Purpose	The WTP of Oklahoma agricultural producers for Oklahoma Mesonet raw and value added weather information.	The WTP of Mississippi farmers with +250 acres of cropland for site specific management (SSM) technology at different levels of government subsidies to analyze adoption level impacts.	WTP of Alabama, Florida, Mississippi, Tennessee, Georgia, and North Carolina cotton farmers for either retrofitting yield monitors on a cotton picker or purchasing new yield monitors with a new cotton picker.	Cognitive Decision Model and the resulting cost savings by using the Oklahoma Mesonet decision aids

Method	Contingent valuation with price categories: 623 mailed surveys 175 completed surveys	Contingent valuation by way of factorial design; Each respondent received one purchase price/variable cost combination. 780 mailed surveys 98 per survey type 557 completed surveys	Single bounded dichotomous choice contingent valuation with 6 pre-set hypothetical prices assigned randomly to each of the participants. 6,423 mailed surveys Complete: 1,131 WTP Question: 743	In-depth Semi Structured Survey & Bounded Range Estimate 21 interviews
Response Rate	28%	71.4%	19% - 12%	100%
Results	Raw Data: $5.83 per month Raw & Value Added Data: $6.55 per month Yearly Range: $359,304 - $2,236,368	SSM Package WTP: $3,316, (represents an 80% government subsidy) SSM Package WTP: $4,547 (when "0" WTP group is dropped)	'Don't Know' Omitted Retrofitted Cotton Picker: $991 New Cotton Picker: $3,364 'Don't Know' is No Retrofit: -$2,541 New Picker: -$1,171	Estimated Total Annual Cost Savings $2.8 – $5.4 million Reduced fertilizer and pesticide applications and reduced irrigation costs

In their study, Kenkel & Norris (1995) addressed a critical component of contingent valuation surveys by attempting to, "remove any incentive for the respondents to underrepresent their true willingness to pay" (Kenkel & Norris, 1995). They achieved this by stressing in a cover letter that funds were limited for the Mesonet system and that, "the survey results would be used to determine what programs or services would be developed for agricultural and nonagricultural users" (Kenkel & Norris, 1995). The study also addressed an additional valuation issue by providing values on alternative informational services currently used by farmers which is an important aspect to consider since previous studies have indicated that internal and external reference prices affect consumer perceptions and willingness to pay (Nunes & Boatwright, 2004). Indeed, there are many factors that can contribute to either overestimation or underestimation in valuations studies. Literature has determined that in CV studies where the WTP of a new technology or service is being studied, respondents are likely to underestimate the benefits due to a lack of knowledge or even intentionally understate the value offered (Cohen & Zilberman, 1997). Furthermore, survey respondents can relate the offered WTP to the institution conducting the survey, "lack of trust in the institution's ability/willingness/capacity to properly manage the funds and provide the good makes people reluctant to contribute, and will likely increase protest responses" (Adaman & Karali, 2011). These issues are equally relevant in studies that attempt to elicit the level of importance for a specific product or technology.

In their development of a cognitive model for agricultural production decisions in Oklahoma, Klockow & McPherson (2010) provided some additional context as to the adoption issues previously reflected by both Kenkel & Norris and Cohen & Zilberman that merits some discussion because of their potential effects on survey design and implementation. Klockow & McPherson (2010) acknowledge in regards to the adoption of technology that "technologically adept farmers were more likely to network, spend time at intrafirm meetings, work with academia and consultants, and have larger farms" (Doye, 2005) (Klockow & McPherson, 2010). It is also stated that the landscape of agricultural production would change in the near future due to the potential trend of younger producers taking over the retiring generation. The technological adoption factors inherent to the population being surveyed should thus be critical components to keep into consideration within the design of any type of survey eliciting valuation or importance levels.

Another increasingly important factor to the perception of value from using the informational decision aids provided by the Oklahoma Mesonet relates to the indemnities paid to farmers by the Federal Crop Insurance program. Federal crop insurance was first made available in 1938 for a limited number of crops in a limited number of counties (Glauber, 2013). Premium subsidies were first implemented by the Federal Crop Insurance Act of 1980 to encourage enrollment and, "make crop insurance the primary form of catastrophic protection available for producers" (Glauber, 2013). By 2011, largely due to the passage of farm bills by Congress throughout the 1990's and early 2000's that provided further insurance premium subsidy provisions and increased the number of farming activities covered, "enrollment in the crop insurance program rose from 182 million acres insured in 1998 to over 265 million acres in 2011, a 45% increase" (Glauber, 2013). After ranging between $2.1 billion and $3.9 billion during FY2000-FY2007, government costs for crop insurance rose to $7 billion in FY2009 (Bonner, 2015). Largely due to unfavorable extreme weather and surging crop prices, government costs rose to $11.3 billion in FY2011 and to $14.1 billion in FY2012 (Bonner, 2015). The 2011 drought was estimated to have resulted in crop losses of more than $1 billion just in the state of Oklahoma (Shideler D. , Doye, Peel, & Sahs, The Economic Impact of the 2011 Drought, 2012). As evidenced by the increased government expenditures during the drought of 2011 and 2012, the potential for enhanced climate variability or warming could lead to significant taxpayer burdens that according to one study could be as high as $923 million with a uniform 1°C increase in temperature (Tack, 2013). Both Oklahoma studies cited in this paper (Kenkel & Norris, 1995) (Klockow & McPherson, 2010) reflect that producers taking part in any type of federal assistance program place a higher value on the Oklahoma Mesonet.

4.4. Weather Monitoring Networks in Agricultural Production

The history of the first systematic weather observations in the United States can be traced back to Reverend John Campanius Holm in 1644 Colonial America (Fiebrich, 2009). W.R. Baron (1992) historically accounts for temperature observations that were recorded in Philadelphia, Pennsylvania between 1731 and 1732 to understand the climate effects on crop yields and if growing populations affected climate (as cited in Fiebrich, 2009). The systematic collection of weather data through a network of observers would gradually intensify after various attempts by the U.S. Army, Board of Regents, Congress, and the Smithsonian Institution (Fiebrich, 2009). The significant relationship between solidifying weather observations throughout the country and agricultural production is evidenced in Abbe (1909) and Kincer (1935). Both studies, as cited in Fiebrich (2009), referenced the endorsement of Isaac Newton, the first U.S. Commissioner of Agriculture for the USDA, in 1865 of the Smithsonian Institution's first secretary's plan to establish an extensive weather service for the benefit of agriculture. State weather services offices were first organized in 1883, while in 1890 the U.S. Weather Bureau, originally established in 1870 by Congress, was transferred to the Department of Agriculture and the Cooperative Observer Network (COOP) was formed to help establish the climatic characteristics of the United States (Fiebrich, 2009). The first remote automated weather station, made practicable because of radio communication technology and the advances in instrument technology, was deployed operationally by the Bureau of Aeronautics in the U.S. Navy in 1941 (Wood, 1946). The weather station was able to measure and transmit pressure, temperature, relative humidity, wind speed, wind direction, and rainfall (Wood, 1946). It has only been approximately 46 years since the first modular automated weather station networks in the U.S. were developed. It started with the Remote Automatic Meteorological Observing System (RAMOS) in 1969 and continued in the 1970's with the PAM (portable automated mesonet) and the SNOTEL (Snowpack Telemetry) network which was established by the Natural Resource Conservation, and followed by many others (Fiebrich, 2009). Throughout the 1980's and early 1990's both federal and non-federal automated weather stations were deployed at increasing rates (Fiebrich, 2009) (Meyer & Hubbard, 1992). The increased deployment was partially due to, "rapid advances in microelectronics, computers, and communication technologies" (Fiebrich, 2009), "the need for more specific meteorological data from a greater number of stations" to provide for new functional uses (Meyer & Hubbard, 1992), and the ability to record meteorological variables at low costs and without AC power if need be (Meyer & Hubbard, 1992). Meyer and Hubbard specifically point to the significance of accurate weather and climate data for agricultural producers and their specific application in production decisions. As cited by Meyer and Hubbard (1992) some of the specific applications include: crop water use estimates (Meyer, et al. 1989), irrigation scheduling

(Heermann, 1981), livestock management (Hahn, 1981), integrated pest management (Jones et al. 1981), crop canopy temperature estimates (Sagar et al. 1988), forestry management (Running, 1981), crop and soil moisture modeling (Meyer et al. 1991; Robinson & Hubbard, 1990), frost and freeze warnings and forecasts (Martsolf, 1981; Ley & Kroeger, 1988), crop growth monitoring (Arkin & Dugas, 1981), crop consulting and determination of crop insurance rates (Snyder, 1991), and drainage design and management (Curry et al. 1988).

Critical information intended to support agricultural producers delivered by networks of weather monitoring stations, such as the Oklahoma Mesonet, is thus significantly largely a result of the developments in monitoring capabilities and information technology of the 20th century. Cox (2002) reminds us using a well-known phrase that, ‘if you cannot measure it you cannot manage it’ and also provides a detailed analysis of some of these technological acquisition, recording, and communicating tools that are either present in, or are used in tandem with, weather monitoring stations (Cox, 2002). Exactly because of this, much has been written about the agricultural adoption of technology and its actual use by farmers (Aubert & Schroeder, 2012) (Watcharaanantapong & Roberts, 2014) (Koundouri & Nauges, 2005). Literature generally states that farm size, land quality, land ownership, farmer age, farmer education, and farmer income have significant correlations with the adoption of technology. Some of the literature includes interesting insights into additional statistically significant variables such as levels of livestock production, levels of profit variances experienced, levels of debt, and subsidies received that should be further studied within specific geographic areas and specific crops. Furthermore, literature has shown that some technologies require, “skills in acquiring, interpreting, and handling layers of data, which impedes the pace of adoption relative to embodied technologies” (Watcharaanantapong & Roberts, 2014). Such is the link between environmental monitoring and technology that in a 2014 Wall Street Journal special report on agriculture, the Association for Unmanned Vehicle Systems International predicted that 80% of commercial drones would be used for agricultural purposes within the next decade (Hasler-Lewis, 2014). The potential scenario is further exemplified in the same special report with the following statement, “we'll have networks of sensors that detect moisture in the ground or on plants themselves and transmit their data to drones, which are poised to become farming's new intelligence-gathering tool of choice” (Hasler-Lewis, 2014). This scenario is not as farfetched when one considers that cropland has been shifting to significantly larger farms according to the USDA (MacDonald, Hoppe, & Korb, 2013) and that the challenge of getting the land sowed or crops harvested in time increases as farms expand their size because temperature and soil moisture for planting are just right for a short period (Berry, 2011).

Most of the technologies attached to weather monitoring networks, although not necessarily directly related to the Wall Street Journal’s special report, would fall under the same category, where there is information generated and collected that can have positive effects on farmer management decisions. A common theme in literature is that the application of weather monitoring data in agricultural decision making is usually included in the ‘precision agriculture’ debate. ‘Precision Agriculture’ includes all practices, “that use information technology either to tailor input use to achieved desired outcomes, or to monitor those outcomes (e.g. variable rate application (VRA), yield monitors, remote sensing)" (Bongiovanni & Lowenberg-Deboer, 2004). The fundamental concept of precision agriculture largely stems from the development of, statistical tools that were able, "to include problems associated with slopes and systematic differences in soil" (Franzen & Mulla, 2015), soil sampling strategies to address field heterogeneity, the statistical subfield of geostatistics in the 1960's, and of the Global Positioning System (GPS) (Franzen & Mulla, 2015). GPS became available for civilian use in 1983 and soon after, "companies began developing what is known as "variable rate technology," which allows farmers to apply fertilizers at different rates throughout a field. After measuring and mapping such characteristics as acidity level and phosphorous and potassium content, farmers match the quantity of fertilizer to the need" (Lowenberg-DeBoer, 2015). GPS also provided farmers with yield monitoring technology that uses sophisticated sensors and algorithms to measure variations within fields (Lowenberg-DeBoer, 2015). This capability allows farmers to more tightly correlate the effects of weather conditions and cultivation practices to actual yields and has therefore brought forth the emergence of "big data" in agriculture (Lowenberg-DeBoer, 2015) (Sabarina & Priya, 2015) (Tien, 2013) (Gustafson, 2014). The Climate Corporation, a start-up that uses "weather and soil data to create insurance plans for farmers and generate recommendations for which crop varietals are best suited to a particular plot of land" (Lowenberg-DeBoer, 2015), was acquired in 2013 by Monsanto, who provides seeds and chemicals to farmers, for approximately $930 million (Upbin, 2013). The Climate Corporation, "aims to build a digitized world where every farmer is able to optimize and flawlessly execute every decision on the farm. The company's proprietary Climate FieldView™ platform combines hyper-local weather monitoring, agronomic modeling, and high-resolution weather simulations to deliver Climate FieldView products, mobile SaaS solutions that help farmers improve profitability by making better informed operating and financing decisions" (The Climate Corporation, 2015). Ultimately, the ability to have up to the minute, accurate, and site specific weather observations made possible by data collection and aggregation technologies, as defined by the USDA's Agricultural Research Service, can increase the resilience of production systems with a better understanding of the interactions between crops, animals, soil, water, weather, and climate (USDA Agricultural Research Service, 2013). The question that remains is, how should the value added information generated by these data collection and aggregation technologies be measured and what are the production system levels of improvement and the potential ecosystem benefits that accrue because of site specific environmental monitoring information use.

5. The Oklahoma Mesonet

5.1. Overview of the Oklahoma Mesonet

The Oklahoma Mesonet was officially commissioned in March 1994 (Shafer, Fiebrich, & Arndt, 1999), following the successful establishment of nonfederal automated weather stations throughout the 1980's and early 1990's (Fiebrich, 2009). In much the same way as the Oklahoma Mesonet, the Nebraska Automated Weather Data Network (AWDN) was initiated in 1981 by the University of Nebraska-Lincoln for the continuous collection and reporting of near real time weather data (Wilhite & Hubbard, 1988). The successful statewide automated weather networks developed by pioneering states demonstrated the technical capabilities for weather data collection, quality control, and for archiving data (Wilhite & Hubbard, 1988). By 1988 more than 15 states had established automated weather data networks (Wilhite & Hubbard, 1988) and by 1992, "at least half of the U.S. states had or were developing networks of automated stations" (Fiebrich, 2009). Literature states that the primary motivating forces for the development of these nonfederal AWS networks were to provide spatially dense coverage, to decrease data latency, and to obtain data not routinely collected by existing datasets (Fiebrich, 2009) (Meyer & Hubbard, 1992). These same motivations along with the successful deployments of the AWDN and the CIMIS in 1982 led agricultural researchers at Oklahoma State University and meteorological scientists at the University of Oklahoma to join forces in 1987 and successfully seek state funding for The Oklahoma Mesonet Project in December of 1990 (Oklahoma Mesonet, 2015). The Mesonet currently operates 120 automated solar-powered stations, at least one station in each of the 77 Oklahoma counties, that measure air temperature, relative humidity, wind speed, wind direction, barometric pressure, rainfall, incoming solar radiation, and soil temperatures (Oklahoma Mesonet, 2015). The Oklahoma Mesonet has led to a significant number of published peer reviewed journal articles that have analyzed the spatial distribution of rainfall patterns across coherent regions in Oklahoma (Boone et al., 2011), soil moisture-based forecasts of extreme temperature events (Ford & Quiring, 2014), and the impact of the assimilation of 5-min observations from the Oklahoma Mesonet with radar data to predict mesovortices in a tornadic mesoscale convective system (MCS) (Schenkman et al., 11/2011). As cited by (Fiebrich et al., 2006), Oklahoma Mesonet data has further led to, "research on land-air interactions (e.g., Illston et al. 2004; McPherson et al. 2004), unique or severe weather events (e.g., Fiebrich and Crawford 2001; Schultz et al. 2004), and public health or agricultural products (e.g., Rogers and Levetin 1998; Grantham et al. 2002).” From the data collected by the Oklahoma Mesonet instruments at regular intervals, researchers at the Oklahoma Mesonet are able to generate value added advisors that are specifically aimed at helping and guiding farmers and cattle ranchers in Oklahoma throughout their agricultural production cycles. Table 3 demonstrates the extent of agricultural decision support products offered by the Oklahoma Mesonet.

Table 3: Oklahoma Mesonet Agricultural Advisors and Tools

AGRICULTURAL ADVISOR	ADVISOR DESCRIPTION
Alfalfa Weevil Advisor	The alfalfa weevil (pest) requires a minimum temperature for growth and development to occur (48°F). Once 150 degree-day units have accumulated, fields should be scouted for weevil larvae.
Cattle Comfort Advisor	Provides estimated heat and cold stress levels for cattle based on the Comprehensive Climate Index by Mader, Johnson, Gaughan (2010)
Degree-day Heat Unit Calculator	Each crop or insect has a lower and upper air temperature threshold. The advisor provides agricultural producers a way to estimate the variation in crop growth and pest development.
Drift Risk Advisor	Spray drift is the output from an agricultural crop sprayer that is deflected out of the target area,

	typically caused by wind. The advisor is a weather based planning tool that provides drift risk guidance for spray applications.
Evapotranspiration and Irrigation Planner	Estimates daily water loss of evaporation (from soil and plant surfaces) and plant transpiration. Individual crop coefficients are applied to estimate daily crop water loss.
Farm Monitor	Displays the National Weather Service forecasts and 10 Mesonet agricultural decision support products for each Mesonet site.
Fractional Water Index	Indicates soil moisture at three depths (2-inch, 10-inch, and 24-inch). Provides an indication of plant available water at each depth.
Weather Fronts	The boundary between two air masses (cold/warm fronts)
Grape Black Rot Advisor	Provides grape plant growers fungicide application advice to prevent black rot based on leaf wetness that varies with air temperatures
Inversion	Provides the differences in temperature between 5 feet and 30 feet at each Mesonet site. Inversions can hold fog, smoke, spay particles, or odors close to the ground

Long-Term Averages	Allows users to chart the differences in weather patterns and the extremes between years from 1999 to 2015
Fire Prescription Planner and Fire Danger Index	Tool that provides fire managers with a fire prescription table generated by lower and upper limit inputs.
Peanut Leaf Spot Advisor	Identifies times when the risk of peanut leaf spot infection is high based on an accumulation of 'leaf spot hours' (when air temperature and humidity are favorable)
Pecan Scab Advisor	Aids growers in timing the application of fungicide applications for pecan scab based on scab hour accumulation thresholds specific to each county.
Plant Available Water	The inches of water in a soil column from the soil surface down to 4 inches, 16 inches, and 32 inches based on soil properties of soil samples collected at each site.
Rainfall	Monitors rainfall amounts at each Mesonet site down to a 0.01 of an inch and provides rainfall accumulation maps.
Seed Germination	When soil temperatures are within an optimum range, seeds germinate quickly. The advisor

	provides soil temperature graphs to help growers determine when to plant.
Wet Bulb Globe Temperature	A map product that estimates the effect of temperature, humidity, wind speed, and solar radiation on humans.
Wheat First Hollow Stem Advisor	Estimates probabilities for the date when First Hollow Stem (the optimal growth stage of wheat to remove cattle and optimize returns) is expected to occur.
Wheat Growth Day Counter	Table that shows the number of days when heat degree day units were positive under a specified planting date. The data is used to make nitrogen fertilizer recommendations.
Wind Barbs	A map product that represents both wind direction and speed. Useful to determine pesticide applications.

Source: The Oklahoma Mesonet (2016)

Even though some of the agricultural decision aids had been available since the commissioning of the Mesonet in 1994, "as of August of 1997, only three agricultural producers had subscribed to the Mesonet system. Although originally 40 Cooperative Extension officers had subscribed to the service, few were actively accessing the system (Kenkel and Norris, 1997)" (Lucius, 1998). The Mesonet AgWeather program would start in 1996 with a specifically designed web-based platform for users to access free of charge and several sites were added from 1996 to 2000. By 2001 the agricultural user base had grown significantly with increased outreach and product development, and with the deployment of the AgWeather website's phase two in 2003, the network experienced an additional growth period (Klockow & McPherson, 2010). The success of the Oklahoma Mesonet allowed its six-person steering committee, composed of the University of Oklahoma and Oklahoma State University, to successfully apply and secure $1.6 million per year in permanent state funding by 2001. The funding proposal included the recommendation from the Association for the Advancement of Science and the funding itself is administered by the Oklahoma State Regents for Higher Education (OSRHE) (McPherson et al., March 2007). In a 2009 National Research Council report, the Oklahoma Mesonet was referred to as the gold standard for statewide weather and climate networks (Oklahoma Mesonet, 2015). Because of the network's reputation and unparalleled amassment of data, that "can only come from taking 120 readings 288 times a day for 22 years" (Dudley, 2016), hundreds of peer reviewed journal articles have cited the Oklahoma Mesonet. Part of the success of the Oklahoma Mesonet is based not just on the amount of data collected but on how the data is packaged and distributed for use in smartphone apps, newsletters, emails, television, social media, and the Mesonet's website free of charge (Brus, 2014). The success of the Oklahoma Mesonet and the intensity of recent extreme weather events has incentivized other states, such as New York, to develop their own statewide systems of automated weather stations (Hill, 2016). The New York State Mesonet, which plans to operate 125 stations, was critiqued for its current data access policy and fees and compared to those of the Oklahoma Mesonet which allows for more open access and distribution of real time and archived data (Coin, 2016). The New

York State Mesonet has since retracted from charging for archived data requests and updated their data access policies to drop some of the restrictions (Coin, 2016).

Ultimately, the value applied to the information generated by the Oklahoma Mesonet by its users and its ‘gold standard’ reputation is tied to the network’s dependability and accuracy in its data measurements. In order to provide the highest quality data measurement capabilities financially possible, periodic and standardized maintenance procedures have been implemented for all of the Mesonet stations. Specialized technicians visit each Mesonet station periodically to rotate sensors, perform sensor tests, document the site with digital photography and perform preventative maintenance tasks that include cleaning, inspecting hardware, and handling vegetation issues. Technicians are also able to respond to emergency situations that require onsite repairs (Fiebrich et al., 2006).

5.2. Environmental Benefits of Weather Monitoring Information in Agricultural Production

Literature has demonstrated that the use of weather monitoring information in agricultural production can lead to improved irrigation efficiencies (Sutherland et al., 2005), more resourceful application of pesticides (Klockow & McPherson, 2010), and a decreased use of fertilizer (Klockow & McPherson, 2010). Widely applied, these benefits can lead to increased water and soil conservation levels, however, not many studies provide quantitatively assessed economic values to these benefits. Bongiovanni & Lowenberg-Deboer (2004) provided three specific research examples by Wang, et al. (2003), Roberts et al. (2001), and Delgado et al. (2001) where the results showed profit maximization when variable rate technologies were implemented to apply nitrogen fertilizer but no specific economic value was placed on the improved water quality or soil fertility benefits. The attributable ecosystem benefits from the wider and improved application of weather monitoring information is an important factor that should be taken into consideration in any study measuring the impact of weather monitoring networks.

In 2005, irrigation accounted for 32% of the 495 million gallons of total surface-water and groundwater withdrawn per day (Mgal/d) in Oklahoma (Tortorelli, 2009). Out of the 495 Mgal/d, 361 Mgal (73%) comes from groundwater, which accounts for 63% of total state groundwater withdrawals. The 2011 Oklahoma Water Resources Comprehensive Water Plan (OCWP) states that the percentage of agricultural irrigation coming from groundwater in 2008 increased to about 80%. More recently, an Oklahoma Cooperative Extension Service published fact sheet with 2013 USDA Farm and Ranch Irrigation Survey results stated that groundwater accounted for (92%) of total agricultural irrigation use (Saleh, 2013), indicating that farmers with irrigation systems are increasingly relying on groundwater versus surface water. That same year, it cost agricultural producers more than $22 million to power 5,351 pumps that are used to either bring water to the surface or pressurize and distribute it across fields (Saleh, 2013). Furthermore, the OCWP suggested that crop irrigation technology and efficiencies varied significantly from one part of Oklahoma to another (Strong, 2015). The Oklahoma Water for 2060 report highlights the need to increase crop irrigation efficiency by sharing best practices and information which includes the development of stronger links between the Mesonet's irrigation planner and on-farm irrigation technology (Strong, 2015). The Oklahoma Mesonet's irrigation planner and evapotranspiration model helps agricultural producers estimate how much water is used by crops from rainfall, irrigation, and water stored in soil which allows them to decide when to irrigate and how much water to apply (Sutherland et al., 2005). To apply the irrigation planner, "farmers have to provide pertinent information about their crops, including the particular crop, planting date, estimated days to maturity and other factors" (Smith R. , 2014). By applying the irrigation planner farmers can achieve improved irrigation efficiencies that can help reduce costs yet the use of the daily evapotranspiration product to determine when to irrigate "was reported by only (8%) of Oklahoma farmers" (Saleh, 2013). In the Oklahoma Mesonet WTP study (Kenkel & Norris, 1995), the authors "purposely overrepresented irrigators since they were perceived as having the highest potential benefit from the Mesonet information." According to the USDA's 1997 Census of Agriculture, just two years after the Kenkel and Norris (1995) study, out of total 33,218,677 farmland acres in Oklahoma, the state had 506,459 irrigated acres (United States Department of Agriculture, 1997). This represents just (1.5%) of total farmland acres but when the total harvested cropland acres are taken into consideration, the corresponding percentage of irrigated acres increases significantly. There were 494,073 irrigated acres in harvested cropland in 1997 that accounted for approximately (5.8%) of the total harvested cropland of 8,462,079, possibly demonstrating a higher potential for successfully harvesting crops in irrigated acres. The 2011 Oklahoma Comprehensive Water Plan Supplemental Report on Agricultural Issues and Recommendations published by the Oklahoma Water Resources Board, cites a federal survey in 2007 that accounted for 3,026 farms with a total of 534,768 irrigated acres, predominantly located in Western Oklahoma (Oklahoma Water Resources Board, 2011). The 534,768 irrigated acres in 2007 corresponded to just about (1.6%) of total farmland acres, but again the 481,000 irrigated acres in harvested cropland corresponded to a much higher percentage (7.4%) of the 6,545,600 total harvested cropland acres in 2007 (Oklahoma Department of Agriculture; National Agriculture Statistics Service, 2012). The groundwater withdrawals are primarily coming from the Oklahoma panhandle counties by way of the Ogallala High Plains Aquifer which accounts for approximately 87% of all groundwater withdrawals and 42% of the irrigated acres from groundwater in Oklahoma (United States Department of Agriculture, 2013). Research has indicated that, "the underground water resources in the Great Plains are being used at a rate higher than the natural rate of recharge because the revenue stemming from their current use is higher than the associated cost of extraction" (Almas et al., 2008). The 2013 USDA report does show that certain USDA and NRCS led conservation initiatives have led the farmers in Oklahoma to reduce withdrawals from the Ogallala High Plains Aquifer by 30% from 2009 levels to 2012, however, the reduction was attributed to the conversion of "about 23 percent of the groundwater-supplied irrigated land to non-irrigated pasture, a permanent conversion" (United States Department of Agriculture, 2013). Primarily due to the depletion of groundwater resources, the recent prolonged and intense drought, and the increase value in production, the average dollar value and cash rent per acre from 2011 to 2015 of irrigated cropland over non-irrigated cropland increased significantly (Oklahoma Department of Agriculture, Food and Forestry, 2015). In 2008, irrigated cropland was about (27%) more valuable than non-irrigated cropland, "primarily because of increased productivity and reduced risk compared to rain-fed dryland agriculture" (Oklahoma Water Resources Board, 2011), the average increased value of production represented about $221 per acre. The addition of recent drought conditions also contributed to decreases in irrigated acres of over 10 percent in Texas, Colorado, Oregon, New Mexico, and Oklahoma (United States Department of Agriculture, 2015). The U.S. Global Change Research Program predicts higher temperatures and decreased precipitation for the Central and Southern Plains which could lead farmers to transition towards dryland agriculture that could in turn reduce crop yields by a factor of two (Ojima, et al., 2014). Therefore, the extension of groundwater use as a direct effect of improved efficiencies possible because of the Oklahoma Mesonet, has an attributable value that stems from crop sales to reduced irrigation pumping costs.

Conservation tillage is a farming practice that is “primarily used as a means to protect soils from erosion and compaction, to conserve moisture and reduce production costs” (Holland, 2004). Due to the potential water savings and the preservation of water quality from crop residues, the practice has been described as a credible tool in Oklahoma’s Comprehensive Water Plan (Oklahoma Water Resources Board, 2011). In order to apply conservation tillage, a large percentage of annual wheat producers engaging in mixed crop-livestock systems and interested in conservation tillage, would require an economically viable rotation crop (Vitale J. et al., 2011). The Oklahoma Mesonet provides information that can assist wheat farmers in timing when to pull cattle from the fields based on a particular growth stage in winter wheat and additional weather data can help farmers decide what rotational crop to farm. Water has become increasingly valuable, as witnessed by the decreasing groundwater supplies and the increasing value of irrigated land vs. non-irrigated land. The Mesonet’s ability to help save and store water as farmers apply conservation tillage aided by Mesonet data therefore leads to a currently unidentified positive economic service that can be attributed to the Oklahoma Mesonet.

Further interpreting the economic and environmental benefits of conservation tillage and the value of groundwater resources could significantly enhance to perceived value of the Oklahoma Mesonet.

These trends reflected in water use, irrigated acres and in government assistance programs are but two of the causal effects that should be important considerations in placing values for the complete economic and environmental benefits of weather monitoring information and its use by agricultural producers.

5.3. Weather Monitoring Information and Organic Agriculture

Total U.S. certified organic farmland acreage has increased from just over 935,000 acres in 1992 to 5,383,119 acres in 2011 (USDA Economic Research Service, 2011), an approximately 475 percent increase. Organic agriculture has been defined as, “a set of management practices aimed at environmentally friendly production by avoiding the use of synthetic fertilizers and pesticides and by strong reliance on closed on-farm nutrient cycling, including biological nitrogen fixation and crop rotations, to support soil fertility by enhancing soil organic matter content” (Leifeld, 2012). The application of different farming practices such as, planting a pest-deterrent species, applying crop residues to fields, or releasing predators of pests (Encyclopedia Britannica. Britannica Academic, 2016), can lead to a variety of different informational needs than those required with the production processes of conventional farming. The Sustainable Agriculture Research and Education (SARE) program, based upon work supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award No. 2014-38640-22173 (Sustainable Agriculture Research and Education, 2012), provide a sampling of some of the best practices applied by farmers and ranchers that strive towards sustainable agriculture. The ‘Best Practice Sampler’ reflects the variety of practices applicable to sustainable agriculture that largely differ from those applied at conventional farming operations.

The differences in practice can lead to dissimilar climate and weather information needs from those required by conventional farming operators. The value placed on weather monitoring information by farmers and ranchers applying practices that improve sustainability may thus significantly differ. Furman et al (2011) claim that, “organic farmers’ commitment to environmental sustainability leads them to integrate longer-term climate change considerations into their planning, such as practices to limit their carbon footprint” (Furman et al., 2011). One of the practices in the SARE ‘Best Practice Sampler’, ecological insect and weed management, describes the use of biological controls such as trap crops, the physical removal of weeds and insects, and selecting crops that can smother or shade out weeds and create habitat for beneficial insects (Sustainable Agriculture Research and Education, 2012). Other practices include rotational grazing systems for livestock, conservation tillage to help prevent soil loss from wind and water erosion, growing cover crops after harvesting cash crops, growing a greater variety of crops and livestock, and a well-managed application of on-farm nutrient sources (Sustainable Agriculture Research and Education, 2012). In their study on the potential of crop diversity to mitigate weather variations and improve yield stability, Gaudin et al. (2015) used yield and weather data from a 31-year long term rotation and tillage trial in Ontario, Canada and determined that crop rotation diversity and reduced tillage significantly contributed to the system’s resilience to multiple environmental stresses mainly attributed to variability in temperatures and precipitation (Gaudin & al., 2015).

Additional studies have also confirmed that conservation tillage reduces runoff ((Wilson et al. 2004, Rhoton et al. 2002, Meyer et al. 1999, Sojka et al. 1984) in (Giangola, 2012) and significantly reduces erosion (Dabney et al. 2004, Rhoton et al. 2002, Meyer et al. 1999, Lal et al. 1994, Lakshminarayan et al. 1994, Edwards et al. 1992, Moldenauer et al. 1983) in (Giangola, 2012).

6. Methodology

The literature on weather monitoring networks, and specifically on the Oklahoma Mesonet, has demonstrated that there are multiple benefits attributed to the use of weather monitoring information by agricultural producers yet it is still not being used by all of its potential users. The potential savings attributed to individual farmers who decide to incorporate weather monitoring information from the Oklahoma Mesonet into their decision making processes have been qualitatively analyzed. However, the quantitative analysis of these benefits and the overall impact they have on farm profitability have not yet been researched. This study applied quantitative data analysis to the results of a structured survey in order to determine the level of importance of the Oklahoma Mesonet to farm profitability. The study also determined what factors contribute to different levels of importance and, for those that did consider its contribution to be important, what that contribution represented over the course of one year.

The American Statistical Association (ASA) describes the term ‘survey’ as, “a method of gathering information from a sample of individuals” (Scheuren, 1980). The sample of individuals typically represents a fraction of the population being studied, which in this study’s case equals to the total farmers and cattle ranchers in the state of

Oklahoma that may or may not use weather related information from the Oklahoma Mesonet for their specific production decisions. There is strong agreement that cognitive researchers benefit by thinking of surveys as experiments for testing their theories (Jabine et al., 1984). In its attempt to describe users and non-users of the Oklahoma Mesonet, this study employs its surveys to test theories on variables that lead to the use or non-use of the Oklahoma Mesonet and to different levels of importance for the information's value to farm profitability. The self-administered survey was delivered to a randomly selected group of 128 farmers and cattle ranchers from Oklahoma via e-mail while one survey was conducted via telephone. Out of the 128 farmers and cattle ranchers who received an invitation to participate in the online survey, 40 ultimately provided responses (response rate of 31%). The response rate is quite similar to other farmer based surveys (Kenkel & Norris, 1995) (Marra et al., 2010) (Giangola, 2012) that posted response rates of (28%), (19%), (34%) respectively. Contrary to previously conducted research, this study analyzed numerical data using mathematically based methods, particularly statistics (Lach, 2014). By applying statistical analysis to the level of importance given to the Oklahoma Mesonet's contribution to farm profitability and what this level of importance represents economically, previously unknown issues related to the use of the Oklahoma Mesonet may be brought to light.

E-surveys were used because they generally provide faster response times and decreased costs (Sproull & Kiesler, 1986) (Mehta, 1995) (Alan, 1995). E-mail surveys incorporating multimode approaches (e.g. telephone/postal mail) have been found to yield higher response rates in the literature (Finchman, 2008) however, due to time constraints and costs this study only distributed pre-notification and an e-survey.

Research also shows that other factors, beyond the administration method alone, are what actually lead to different response rates (Reynolds, Woods, & Baker, 2007). For example, in both mail and e-mail surveys, pre-notifying survey respondents and following up on contacts can lead to an increase in response speed and response rates (Sheenan, 2001). Furthermore, other studies have found that incentive schedules or method of contact has no effect on the answers provided in phone and mail surveys (Groves, 2006) (Keeter et al., 2000) (Ryu et al., 2005) in istead demographic differences between survey respondents are more indicative of variability in response rates (Ryu et al., 2005) in (La Rose & Tsai, 2014). The web-based survey, designed using the Qualtrics Insight Platform software, was of the sampled category in which respondents, as also performed by (Reynolds et al., 2007), are randomly selected from a larger population, notified of the chance to participate in the survey, and directed to survey's website.

"Simple random sampling, or random sampling without replacement, is a sampling design in which (n) distinct units are selected from the N units in the population in such a way that every possible combination of (n) units is equally likely to be the sample selected" (Thompson, 2012). The simple random sampling technique was utilized in this study to include all potential farmer groups and have a variety of demographic, crop production, and geographic locational differences. The research sample included 22 private landowners that have Mesonet monitoring stations physically located on their lands, 22 participants of a USDA led agricultural workshop in Seminole county, and 84 farmers and cattle ranchers that included both user and non-users of the Oklahoma Mesonet from different counties across Oklahoma. The 84 farmer and cattle rancher list was provided by the 77 individual county representatives of the OSU Agricultural

Extension Service and experts at the Oklahoma Mesonet. Each potential survey participant received an e-mail detailing the nature of the study along with IRB information privacy guidelines. Primarily due to time constraints and the difficulty with obtaining uniform contact information to farmers, our sample did not contain an exact equal number of farmers from each county. Nonetheless our overall sample was able to include a representative sample from the Northwest, Northeast, Southeast, and Southwestern portions of Oklahoma.

Sample-based surveys are widely accepted as a research technique that are nonetheless subject to sampling errors, coverage errors, non-response errors and measurement errors (Bethlehem, 2008). Potential errors notwithstanding, surveys were utilized to better determine the naturally occurring variations between variables and provide more realism in results than those of experimental research (Roberts, 1999). The actual survey design was based on the USDA's National Agricultural Statistics Service's (NASS) survey samples (USDA NASS, 2014), on the (Kenkel & Norris, 1995) Oklahoma Mesonet based survey and on the (Klockow & McPherson, 2010) semi-structured interviews of agricultural producers in Oklahoma. The survey in this analysis consisted of 28 questions (APPENDIX C) that included a mixture of rating questions, open ended questions, and closed ended questions on topics related to agricultural management issues, Mesonet observation products, farming practices, crop land uses, weather related losses, and demographics among others. Question number 11 (i.e. Q11) and question number 12 (i.e. Q12) were directed at attempting to determine how had Mesonet observations, based on farmer perception, contributed to improve farm profitability and what value, if any, did the Mesonet information and data provide to farming operations over the course of one year. The results were comparatively analyzed with the predictor variables gathered from the survey's additional questions.

Correlations are able to measure the extent to which the value of two (or more) variables are related or linked (Abbott & Mckinney, 2012). The most common method of measuring intra-level variables is by determining the Pearson correlation coefficient which calculates a number between -1.0 and +1.0 (Abbott & Mckinney, 2012). The strength of the correlation is ultimately determined by the closer the coefficient value is to -1.0, negative correlation, or to +1.0, positive correlation. In this study, correlations were used to determine the strength of relationships from a series of predictor variables with two outcome variables, the perceived level of importance of Mesonet observations to farm profitability (Q11) and the perceived value that the observations provide over the course of one year to the farm (Q12). The outcome variables are, in theory, linked to changes in some of the predictor variables which can therefore help explain some of the differences in the levels of importance and one year values for the Mesonet observations by individual farmers. In order to employ correlation analysis and determine what some of the potential causal effects to the value perception of weather monitoring information are, predictor variables were included in the form of survey questions. The hypothesized predictor variables were used to determine correlations with the survey respondents' 1-10 rating scale selections for the perceived farm profitability benefit of Mesonet observations and with the Mesonet yearly values. The predictor variables were conceptualized by the study's researchers after having analyzed previous Oklahoma Mesonet literature (Kenkel & Norris, 1995) (Lucius, 1998) (Klockow & McPherson, 2010) and agricultural economic literature on the farmer decision making process

(Ohlmer, Olson, & Brehmer, 1998) (Verstegen, Huine, & Dijkhuizen, 1995). The variables asked for in the Kenkel & Norris (1995) contingent valuation (CV) survey, and determined as relevant for use in this study, included weather related losses, years of farming experience, and educational level.

After reviewing literature and determining survey questions, predictor variables were selected to compare against and possibly explain the different levels of importance placed on the contribution of Mesonet data and information to farm profitability. The predictor variables for this study are described in the following (Table 4).

Table 4: Predictor Variables Hypothesized to Explain Farmer Value Perceptions of the Mesonet's Effect on Profitability

Predictor Variable	Survey Question	Hypothesized Effect	Definition
AG_MGMT_1	1	+	Importance of soil quality
AG_MGMT_2	1	+	Importance of access to water
AG_MGMT_3	1	-	Importance of labor costs
AG_MGMT_4	1	+	Importance of fertilizer and pesticide costs
AG_MGMT_5	1	+	Importance of weather events
AG_MGMT_6	1	+	Importance of USDA assistance
AG_MGMT_7	1	-	Importance of crop insurance

WEATHER_OPS_1	2	+	Importance of weather information to field preparation and planting
WEATHER_OPS_2	2	+	Importance of weather information to pest/disease control
WEATHER_OPS_3	2	+	Importance of weather information to irrigation scheduling
WEATHER_OPS_4	2	+	Importance of crop harvesting
YEAR_MESO_USE	6	+	1: (1994-1997) – 1st Use of Mesonet 2: (1998-2001) – 1st Use of Mesonet 3: (2002-2006) – 1st Use of Mesonet 4: (2007-2011) – 1st Use of Mesonet 5: (2012-2016) – 1st Use of Mesonet
MES_PRODUCT_1	7	+	Use of degree-day heat unit calculator
MES_PRODUCT_2	7	+	Use of drift risk advisor

MES_PRODUCT_3	7	+	Use of irrigation planner and evapotranspiration tool
MES_PRODUCT_4	7	+	Use of plant available water tool
MES_PRODUCT_5	7	+	Use of fire danger or burning index
MES_PRODUCT_6	7	+	Use of first hollow stem advisor
MES_PRODUCT_7	7	+	Use of cattle comfort advisor
MES_PRODUCT_8	7	+	Use of dispersion conditions and forecast tool
MESO_USE	9	+	1: Use Mesonet every day 2: Use Mesonet 1 to 3 times a week 3: Use Mesonet 1 to 3 times a month 4: Use Mesonet Less than once a month 5: Never use Mesonet
YEARS_FARMING	16	-	1-10 years of farming experience 11-20 years of farming experience

			21-30 years of farming experience +31 years of farming experience
PRES_BURNING	17	+	Take part in prescribed burning
ACRES_2015	18	+	Acres owned and rented in 2015
CATTLE	18	+	Cattle operations in 2015
WEATHER_LOSS	19	+	Experience with weather related losses (very significant to very insignificant)
USDA_ENROLL	20	-	USDA Programs: NAP, LIP, TAP, ELAP, Emergency Loans, ECP, CRP
COUNTY	21	?	NW, SW, SE, NE, Central
AGE	23	-	Farmer age
EDU	25	+	Education Level: Less than High School to Graduate Degree or higher
%_FARMING	27	+	Farming % of total annual income

The primary intention of the first survey question (Q1) was to understand the population sample's perceived level of importance of agricultural management issues to their farm operations (AG_MGMT predictor variables 1 thru 7). The agricultural management issues included the following: soil quality, access to water, labor costs, fertilizer and pesticide costs, weather events, USDA federal assistance programs and or price/supports, crop insurance, and other. Respondents were asked to rank the agricultural management issues by selecting from the following scale: low importance, slightly important, neutral, moderately important, and very important. The primary intention of the second survey question (Q2) was to determine the importance of timely and accurate weather information for a set of typical agricultural management decisions with the same scaled rating. The decisions were grouped into the following 5 categories: field preparation and planting, pest/disease control, irrigation scheduling, crop harvesting, and other. Both questions were used to provide predictotr variables that were hypothesized to positively correlate with the Oklahoma Mesonet's use contribution value to farm profitability, for example, the consideration of timely and accurate weather information as 'very important' to field preparation and planting leading to a high value of the Oklahoma Mesonet's level of importance to farm profitability.

There are potential differences in regards to what specific Mesonet observational products are used at the farm, for what purpose, and how often. There are also differences among respondents related to informational services used by farmers and to how long some have been aware of the Mesonet's existence. The survey included a series of questions that specifically addressed these potential differences. Question (Q3) specifically asks if services or information from the Oklahoma Cooperative Extension

Services at Oklahoma State University are used to aid in farming decisions. The Oklahoma Cooperative Extension Service (OCES) officially started in late 1914 with the Smith-Lever Act signed by into law by President Woodrow Wilson to provide agricultural education to the state's farmers and farm families (Causely, 2009). The OCES is based out of the Oklahoma State University and its specialists, located in each of the 77 Oklahoma counties, take part in communicating the benefits of new farming techniques, programs, and seed varieties along with the services offered by the Oklahoma Mesonet. This would imply a potential direct relationship between the use of services from the OCES and knowledge of the Oklahoma Mesonet. Question's (Q4) and (Q5) directly ask if anyone in the production process has knowledge of the Oklahoma Mesonet Network and if Mesonet information is being used for farming decisions. Question (Q6) was intended to elicit a typed response for the year in which the respondent first started using Mesonet while question (Q9) determined how often Mesonet information was used at the farm for decision making in the 2015 planting, growing, and harvesting cycle. In order to categorize the use factor responses and perform statistical analysis on the results, (Q6) responses were grouped into the following five categories: (1) 1994-1997, (2) 1997-2001, (3) 2002-2006, (4) 2007-2011, and (5) 2012-2016. Also, question (Q9) responses were grouped into the following five categories: (1) Every day, (2) 1 to 3 times a week, (3) 1 to 3 times a month, (4) Less than once a month, and (5) never. Finally, in order to measure the specific effect that certain Mesonet agricultural advisors may have on the overall perceptions of value and importance, the following eight observational products were selected and included in the survey from the Oklahoma Mesonet Agricultural Advisors list (Table 2): (1) degree-day heat unit calculator, (2) drift risk advisor, (3) irrigation planner and evapotranspiration tool, (4) plant available water (PAW), (5) fire danger or burning index, (6) first hollow stem advisor, (7) cattle comfort advisor, and (8) the dispersion conditions and forecasts.

A second series of survey questions included a few external issues that were hypothesized to have an effect on the overall use of the Oklahoma Mesonet. The first question in this group (Q17) was directly attributed towards determining the effect of a specific practice, prescribed burning, that the Oklahoma Mesonet specifically targets with the burning index and dispersion conditions tool to prevent uncontrollable fires (Bidwell, Weir, Carlson, & Masters, 2006). Clay Pope, a lobbyist for the Oklahoma Association of Conservation Districts, states that, "fire is an economical way to cut down on the Eastern Red Cedar tree 'infestation.' The trees can consume 100 gallons of water per day, contributing to the financial and health problems posed by drought conditions as well as ruining the natural wildlife habitat" (Francis-Smith, 2006). Experience with weather related losses in the past 10 years (Q19), the second question in this series, was used to measure the effects, if any, that recent weather related losses may have on the perceptions of value and importance. The third and final survey question of this series included a list of seven USDA federal farm programs that respondents had to select if they had previously enrolled in the programs (Table 5).

Table 5: USDA Federal Farm Programs

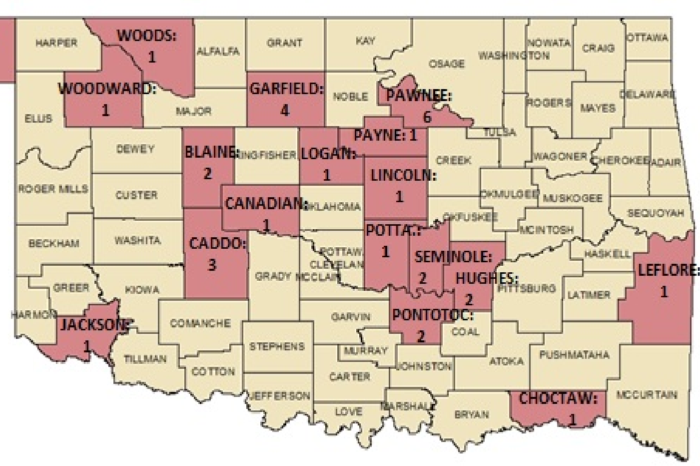
Federal Farm Program	Abbreviation	Description
Non-Insured Crop Disaster Assistance Program	NAP	Provides financial assistance to producers of non-insurable crops when low yields, loss of inventory, or prevented planting occur due to natural disasters.
Livestock Indemnity Program	LIP	Provides benefits to livestock producers for livestock deaths in excess of normal mortality caused by adverse weather. In addition, LIP covers attacks by animals reintroduced into the wild by the federal government or protected by federal law.
Tree Assistance Program	TAP	Provides financial assistance to qualifying orchardists and nursery tree growers to replant or rehabilitate eligible trees, bushes and vines damaged by natural disasters
Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish Program	ELAP	Provides Emergency relief to producers of livestock, honey bees, and farm-raised fish. Covers losses from disaster such as adverse weather or other conditions, such as blizzards and wildfires not adequately covered by any other disaster program.
Emergency Loan Program	-	USDA's Farm Service Agency (FSA) provides emergency loans to help producers recover from production and physical losses due to drought, flooding, other natural disasters or quarantine.
Emergency Conservation Program	ECP	Provides farmers and ranchers with funding and assistance to repair damage to farmlands caused by natural disasters and to help put in place methods for water conservation during severe drought.
Conservation Reserve Program	CRP	In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality.

Source: USDA Farm Service Agency: Programs and Services (2016)

In (Teclaw, Price, & Osatuke, 2012), “ (Stoutenbourgh, 2008) lists four advantages to placing demographic questions at the end: (1) to engage and build rapport with respondents, (2) to prevent breakoffs caused by personal questions, (3) to prevent primacy effects, and (4) to allow survey questions to be answered before “boring” demographic questions”. The last category of survey questions were therefore primarily demographic and included, geographic location by county, number of people living in the household, age, sex, education, and the percentage of farming to the total annual household income. Out of the 40 survey respondents, 34 provided a response to the geographic location by county question (Q21) which is represented in Figure 3. To simplify the categorization of the geographic location, counties were placed in one of five regions using the intersections of I-35 and I-40. The five defined regions are, northwest, southwest, southeast, northeast, and central. The central region was defined as all counties directly bordering Oklahoma County. The figure displays the counties represented in the survey with a dark garnet color and a bold county name along with the number of respondents by region.

Figure 3: Oklahoma Counties Represented in Survey

N.W.	11
S.W.	4
Central	4
N.E.	7
S.E.	8



Source: Own presentation based on U.S. Census Bureau (2015)

One additional question (Q18) required respondents to fill out a table (Table 6) asking for farming production information which included, acres owned or rented, total production, total production costs, losses due to weather events, fertilizers used in tons, pesticides used in gallons, and field production information. Respondents were asked to provide their closest estimates from 2001 to 2015 (broken down into (4) timespans). Out of the 42 completed surveys, 23 partially filled out the table information with most of the data coming from the 2015 timespan.

Table 6: Farming Production Data

Farm Data: Please provide the closest estimates of average crop land use and agricultural production in the following time spans: (2001-2005), (2006-2010), (2011-2014), and for 2015

	2001-2005	2006-2010	2011-2014	2015
Total Farm Acres Owned and Rented				
Total Annual Production (bushels)				
Total Annual Revenue ($)				
Total Production Costs ($)				
Losses due to Weather Events (Acres)				
Fertilizers Used (tons)				
Pesticides Used (gal)				
Water Used (acre feet)				
Type of Tillage:				
Other (please describe)				
Irrigated Acres				
Planted Acres of Wheat				
Planted Acres of Corn				
Planted Acres of Hay				
Planted Acres of Soybeans				
Planted Acres of Sorghum				
Planted Acres of Cotton				
Planted Acres of Pecans				
Planted Acres of Peanuts				
Planted Acres of Oats				
Planted Acres of Rye				
Planted Acres of Specialty Crops				
Planted Acres of Other Crops				
All Cattle Livestock (Head)				
All Hogs and Pigs (Head)				

The survey's results were obtained directly through the Qualtrics Survey Software's data and analysis function and then coded into Microsoft Excel to perform quantitative analysis. Numerical value keys were created for each survey question followed and populated with survey inputs. The classification and coding of results was employed to perform descriptive statistics, graphical interpretations, and correlation analysis to determine what factors may or may not correlate to the importance level placed on weather monitoring information from the Oklahoma Mesonet. The coded responses of participants 26 to 40, for survey questions 1A to 1E, are provided in (Table 7) as a sample reference to the coding that was performed from the survey results.

Table 7: Coded Survey Results

PARTICIPANT ID						
40	DATE	*Q1A*	*Q1B*	*Q1C*	*Q1D*	*Q1E*
39	12-May	*5*	*5*	*3*	*5*	*5*
38	26-Apr	*5*	*5*	*3*	*4*	*5*
37	14-Apr	*5*	*5*	*5*	*5*	*5*
36	12-Apr	*5*	*5*	*5*	*5*	*5*
35	12-Apr	*5*	*5*	*3*	*5*	*4*
34	11-Apr	*5*	*3*	*3*	*4*	*5*
33	11-Apr	*5*	*4*	*3*	*3*	*5*
32	5-Apr	*4*	*4*	*3*	*4*	*4*
31	1-Apr	*5*	*5*	*2*	*5*	*5*
30	1-Apr	*5*	*5*	*3*	*5*	*5*
29	31-Mar	*5*	*5*	*5*	*3*	*3*
28	29-Mar	*5*	*5*	*5*		*5*
27	29-Mar	*5*	*5*	*5*	*5*	*5*
26	29-Mar	*4*	*3*	*5*	*4*	*4*

7. Results

7.1. The Importance of Weather Monitoring Information

Weather monitoring information from the Oklahoma Mesonet is generally viewed as slightly positive to positive in its contribution to the overall profitability of farming operations in the state of Oklahoma with an arithmetic mean of (6) out of 10, and a standard error of (0.57) (Table 8). The sampling distribution further generated a median of (7) and a mode, the value that occurs most often, of (0). When descriptive statistics are performed on the results of only those respondents who are actively using Mesonet information for their farming decisions (Q5), the arithmetic mean jumps from (6) to (7.82) with a much lower standard error of (0.40) and a lower standard deviation of (2.09). The median increases to (8), and with the reduction in 0 values, the mode increases to (8) (Table 8).

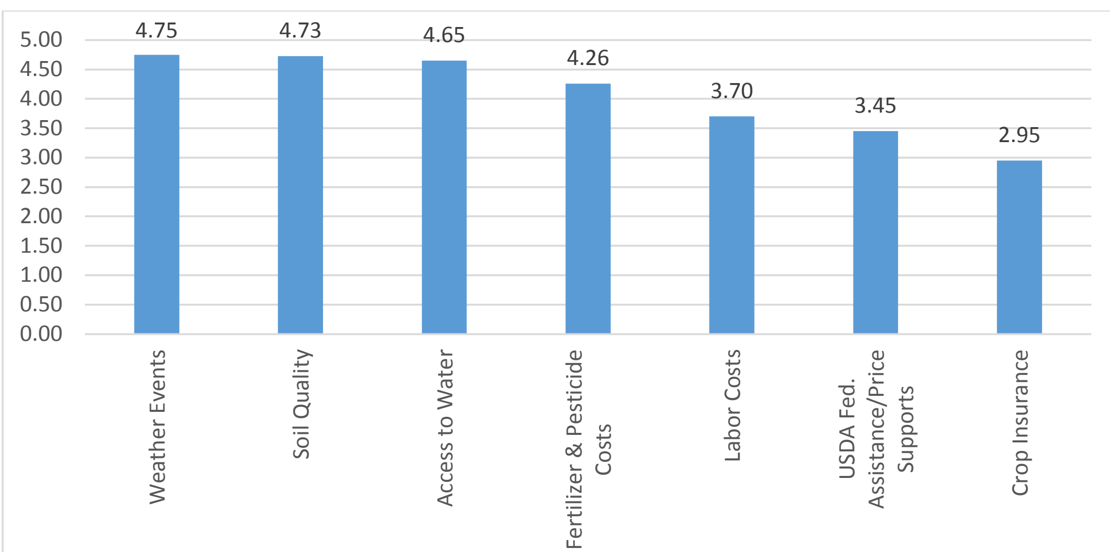
Table 8: Contribution of the Mesonet to Farm Profitability

All Survey Respondents			
Mean	6	Skewness	-0.806551696
Standard Error	0.567269664	Range	10
Median	7	Minimum	0
Mode	0	Maximum	10
Std. Deviation	3.587728372	Sum	240
Sample Variance	12.87179487	Count	40
Kurtosis	-0.776279116	Confidence: 95%	1.147411199

Active Mesonet Users			
Mean	7.821428571	Maximum	10
Standard Error	0.395254828	Sum	219
Median	8	Count	28
Mode	8	Confidence: 95%	0.810995919
Std. Deviation	2.091491961	Skewness	-2.021001293
Sample Variance	4.374338624	Kurtosis	6.368399467
Minimum	0	Range	10

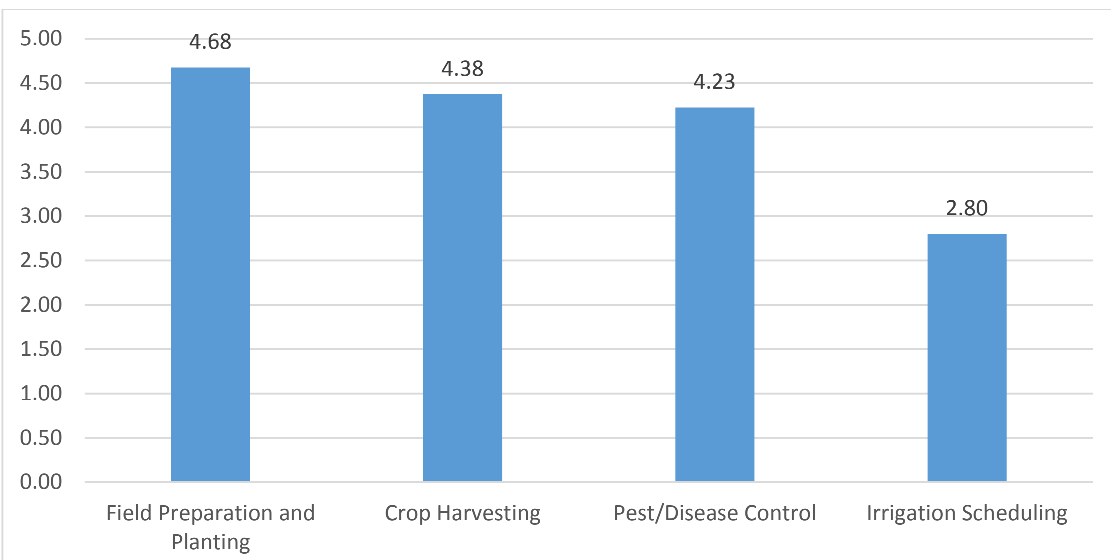
Survey respondents indicated that the most important agricultural management issues, in order of importance to their farming operations from 1 to 5 (1 being of low importance and 5 being very important) are weather events (4.75), soil quality (4.73), access to water (4.65), fertilizer and pesticide costs (4.26), labor costs (3.70), USDA federal assistance/price supports (3.45), and crop insurance (2.95) (Figure 4). The single respondent who indicated that the importance of weather events to their farm operations was neutral (3) or lower, indicated actively using the Oklahoma Mesonet one time per week, experienced very significant weather related losses in the past ten years, and provided a score of 9 out of 10 for the Mesonet's help in improving their farm profitability. Survey respondents who indicated that the importance of weather events to their farm operations was moderately important (4) provided an average score of 5 out of 10 for the Mesonet's help in improving their farm profitability while those who indicated that the importance of weather events to their farm operations was very important (5) provided an average score of 6.2 out of 10.

Figure 4: The Importance of Agricultural Management Issues to Farm Operations



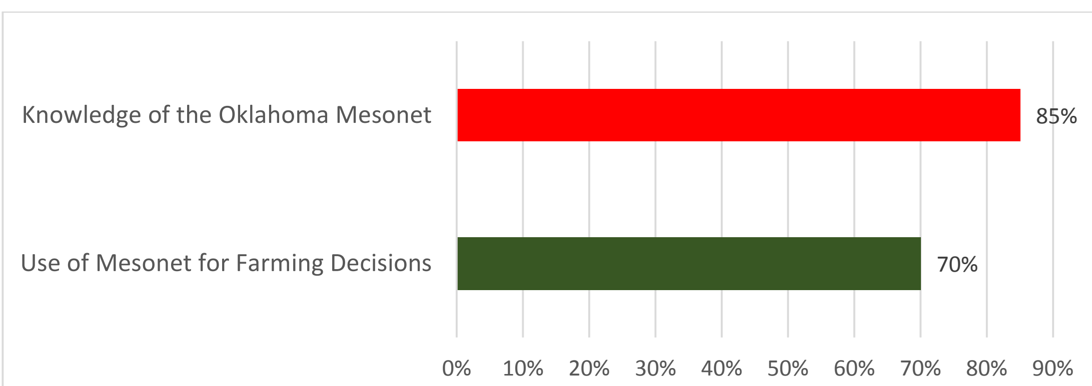
Additional agricultural management issues considered important to farming operations by some survey respondents included commodity prices, markets, organic pest and weed management, and having equal access to resources. The study's results also determined, on the same 1 to 5 low importance to very important scale, that timely and accurate weather information was of most importance to field preparation and planting (4.68) followed by crop harvesting (4.38), pest/disease control (4.23), and finally irrigation scheduling (2.80) with a significantly lower average value (Figure 5). In the "other" option provided in the same question, one respondent listed herbicide application, two listed the use of fire/burning, and one included organic methods as additional agricultural management decisions where timely and accurate weather information is of importance to their farming operations.

Figure 5: The Importance of Timely and Accurate Weather Information for Agricultural Management Decisions



Out of the 40 total survey participants, 34 (85%) had knowledge of the Oklahoma Mesonet Network while only 28 (70%) indicated that they were currently using Mesonet information for farming decisions (Figure 6). The data demonstrates that 6 survey respondents with knowledge of the Oklahoma Mesonet either consciously decided to disregard Mesonet information for their farming decisions or alternatively, they may be indirectly and unconsciously using Mesonet information with a third party weather information that sources its data from the Oklahoma Mesonet. In effect, (34.1%) of respondents indicated using a non-Mesonet weather service. The additional weather services provided by survey respondents included, The Weather Channel, Weather Underground, Climate Corp, My Radar, the National Weather Service, DTN Weather, and Planter Co-operative provided weather information that may or may not include data from the Oklahoma Mesonet. It is important to point out that 4 respondents indicated that they are not currently using Mesonet information for their farming decisions however they also provided a response for how often the observations are used at the farm. This would possibly indicate an error in the response or that the respondents are retired and had previously used Mesonet information.

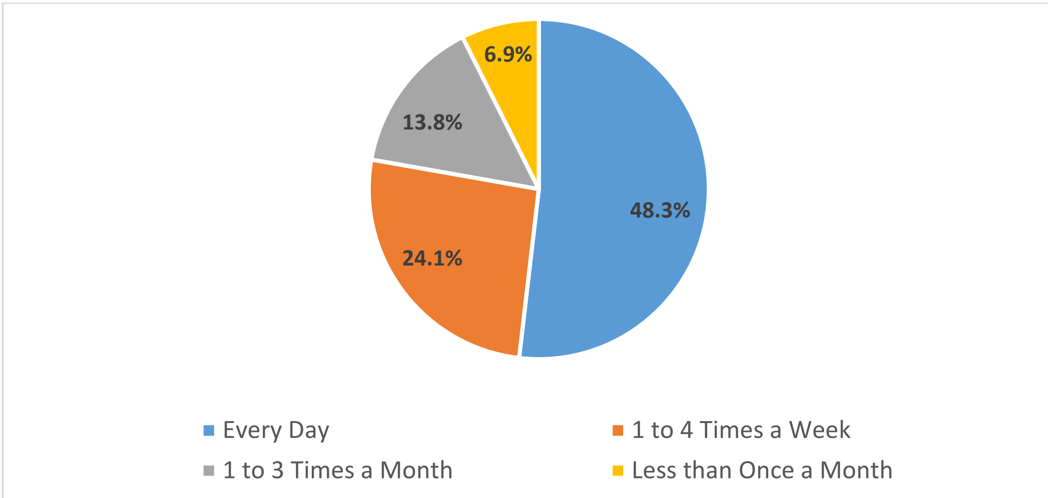
Figure 6: Knowledge of the Oklahoma Mesonet Network vs. Use of Mesonet Information for Farming Decisions



Additionally, 34 respondents (85%) also reported using services or information from the OSU Oklahoma Cooperative Extension for their farming decisions but surprisingly the results for this question did not show a high level of positive correlation with the respondent's knowledge of the Oklahoma Mesonet (correlation coefficient: 0.41). In other words, using services or information from the Oklahoma Cooperative Extension does not necessarily indicate knowledge of the Oklahoma Mesonet network. In effect, three out of the six respondents (50%) that indicated they did not use services from the Oklahoma Cooperative Extension Service also indicated that they use Mesonet information for their farming decisions. Understanding how these agricultural users, who are not using the Oklahoma Cooperative Extension Service, discovered and decided to incorporate Mesonet information into their decision making processes could potentially be important to Oklahoma Mesonet administrators and researchers.

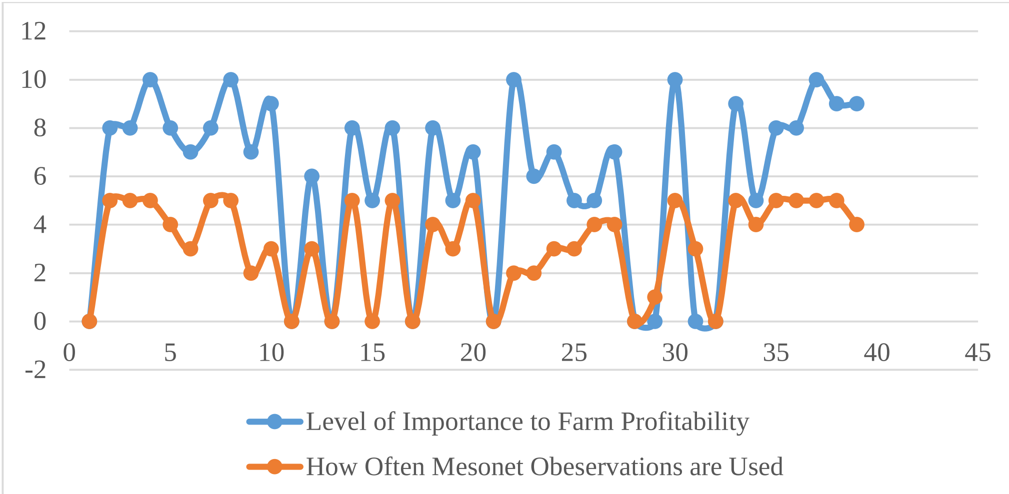
Nonetheless, the respondents actively using Mesonet information also indicated that they were consistently using the available observational products (Figure 7). Out of the 28 active users, 14 reported using Mesonet on a daily basis (48.3%), 7 used the information 1 to 4 times a week (27.6%), and 4 used the information at least 1 to 3 times a month (13.8%) for an accumulated total from this subset of respondents of (89.7%). The 2 users who were classified in the ('Less than Once a Month') category, reported using the Mesonet 10 times per year and 5 times per year. Both respondents provided a lower use level than those categorized in the ('1 to 3 Times a Month') category which reported Mesonet use levels of at least once a month or 12 times per year.

Figure 7: Consistency of Mesonet Information Use for Decision Making (Active Users)



Individuals that consistently used Mesonet observational products on a daily basis reported a higher average level of importance to farm profitability (8.75) compared to the average of all survey respondents (6.00) and of all active users (7.82). The data showed that the high levels of consistent use positively correlated with high values of importance for the weather monitoring information being provided by the Oklahoma Mesonet. The correlation function was used to validate this result (Figure 8) by scoring the consistency of use factor as follow, every day answers were given a score of 5, 1 to 4 times a week answers a score of 4, 1 to 3 times a month answers a score of 3, once a month answers a score of 2, less than once a month answers a score of 1, and never answers a score of 0. The actual correlation function returned a correlation coefficient of 0.83 that validates how high levels of consistent use produce higher levels of importance for the contribution of Mesonet observations to farm profitability. A possible error was reflected in a respondent who indicated that Mesonet information is never used yet also valued the help received from Mesonet observations towards improving farm profitability at a level of 5.

Figure 8: The Level of Importance of Mesonet Observations and How Often Mesonet Observations are used at the Farm



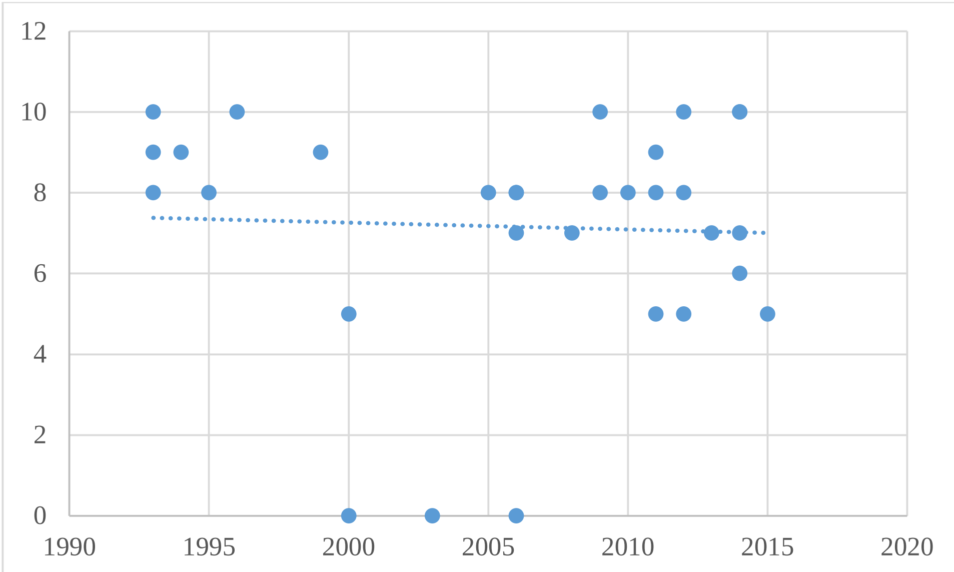
When selectively analyzing the results of survey participants (N=6) who rated the Mesonet's contribution towards improving farm profitability at its highest rating (10), who as a group equate to (15%) of all survey participants (40) and (21.43%) of all active Mesonet users (28), positive relationships were determined with the level of importance placed on weather events, with the level of importance placed on having timely and accurate weather events for field preparation and planting decisions, and with the consistency of use (Table 9). 3 out of the 6 respondents consistently use Mesonet information every day and 1 additional respondent applies a use rate of 20 times per week, which could be considered as equal to or higher than everyday use. Due to the low number of respondents providing the highest score, the correlation function is not able to determine a concrete correlation, therefore, more observations would be required.

Table 9: Factors that Influence a High Value Perception for the Oklahoma Mesonet

	Q11: Are Mesonet observations helping improve your farm profitability?	**Q1E:** Importance of weather events to your farm operations	**Q2A**: Importance of timely and accurate weather information to field preparation and planting	**Q6**: In what year did you start using Mesonet?	**Q9:** How often do you use Mesonet information for decision making at your farm?
Respondent ID	**Scale: 1-10**	**Scale: 1-5**	**Scale: 1-5**	-	-
37	**10**	**5**	**5**	**2014**	**Every Day**
34	**10**	**5**	**5**	**1996**	**-**
32	**10**	**5**	**5**	**2009**	**Every Day**
18	**10**	**5**	**5**	**2014**	**5x per Year**
10	**10**	**5**	**5**	**2012**	**Every Day**
3	**10**	**5**	**5**	**1994**	**20x per Week**

The correlation function measures how closely related or unrelated two measurements are on a scale of -1 to 1, 1 indicating a close correlation and -1 indicating an opposite correlation. Running the correlation function between the level of importance towards farm profitability (Q11) and the importance of weather events to farm operations (Q1E) from all survey respondents returns a correlation coefficient of (0.02) indicating close to no correlation at all. Running the correlation of the importance of timely and accurate weather events to field preparation and planting decisions (Q2A) with (Q11) returns only a slightly higher correlation coefficient of (0.10). There was also no linear positive or negative correlation found between the date of first use of the Mesonet and the level of importance placed towards farm profitability with a correlation coefficient of -0.04 (Figure 9).

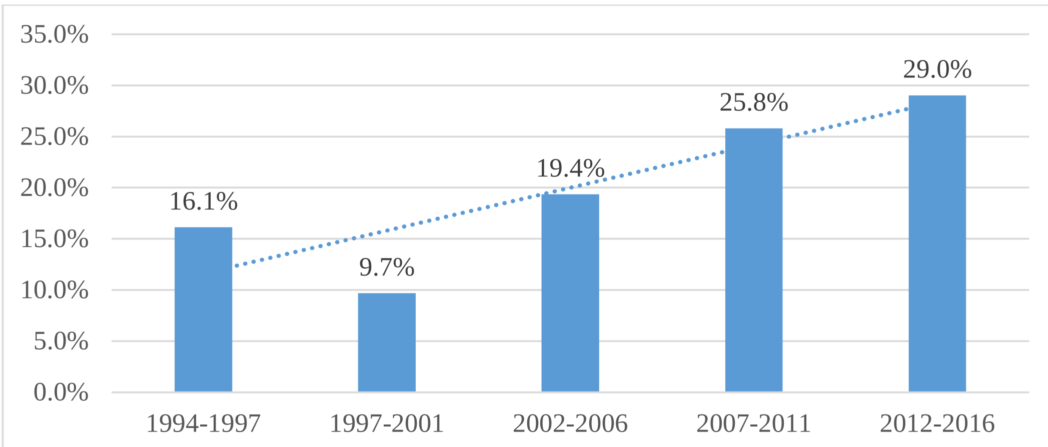
Figure 9: Scatterplot of the Level of Importance of the Oklahoma Mesonet and the Year of First Use



31 out of the 40 respondents, 77.5%, provided a response for Q6 (In what year did you start using Mesonet?). 7 of the 31 respondents, 22.6%, indicated that their first use of the Oklahoma Mesonet was before the year 2000. The remaining 24 respondents, 77.4%, all indicated that the first use of the Mesonet was after the year 2000 (Figure 10). Out of the 31 respondents, those using the Mesonet for the very first time from the year 2010 to the year 2015 made up 42% of the total respondents while those using the Mesonet for the very first time between the year 2000 and 2010 made up 35.5% of the total respondents. Respondents who identified first using the Mesonet from 1994 to 1999, provided an average rating of 9 out of 10 for the perceived level of importance of the Mesonet's contribution to farm profitability (Q11). By comparison, those who identified first using the Mesonet after the year 2000 provided an average rating of 6.6 out of 10. Further breaking up the 'after 2000' group, those who identified first using the Mesonet between the year 2000 and the year 2010 provided an average (Q11) rating of 5.54 while

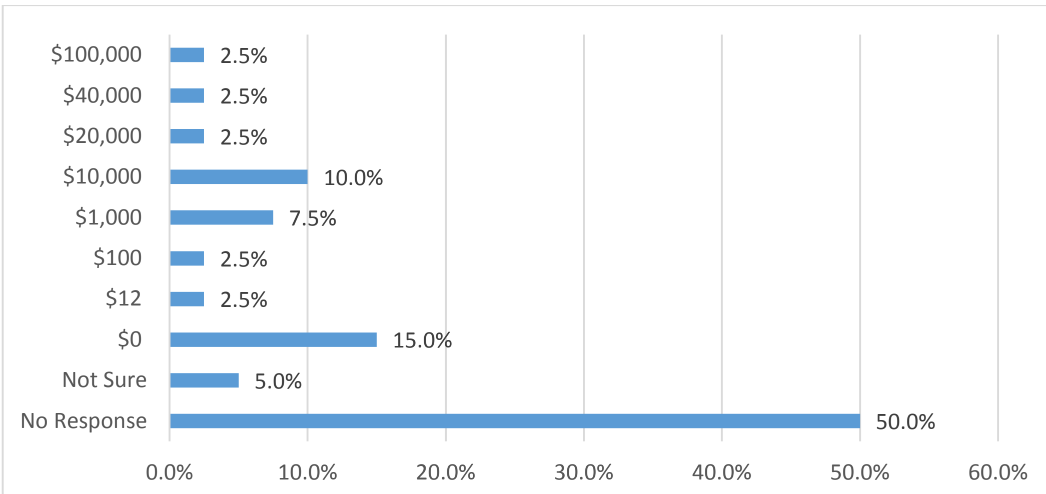
those who first identified using the Mesonet between the year 2010 and the year 2015 provided an average (Q11) rating of 7.54. Further identifying the significance of use, 6 Out of the 7 respondents that were categorized as using the Mesonet before the year 2000 also reported using the Oklahoma Mesonet at least once a week which is considerably higher than the (13) out of (24) respondents, approximately (54%), from the year 2000 and beyond group that also reported using the Oklahoma Mesonet at least once a week.

Figure 10: Year of First Use of the Oklahoma Mesonet



For all survey respondents using the Oklahoma Mesonet there is a clear linear trend that shows an increase in the initial date of use from 1997 to 2016, however, as shown by the correlation coefficient, this does not necessarily translate into higher levels of importance to farm profitability. Therefore, more recent Mesonet users could perceive the Mesonet to be equally important to farm profitability. Question (Q12) retrieved dollar values for the information and data services provided by the Oklahoma Mesonet to a respondent’s farm over the course of a year. Close to half of all survey respondents (45%) provided either a zero or a positive dollar value estimate for the Mesonet information and data being provided to their farm over the course of one year (Figure 11). 60%, or 12 out of the 20 survey respondents who did not provide a response to Q12, indicated that they were using Mesonet information for their farming decisions. Therefore 8 of the 40 respondents, 20%, were not using Mesonet information for their farming decisions and did not provide an answer for the one year values of Oklahoma Mesonet information.

Figure 11: One Year Values for Oklahoma Mesonet Information – Farmers' Estimations



The average value from the 18 respondents, including those who provided a $0 value, is $11,284 and the median is $1,000. The average value, excluding the $0 values, is $16,926 and the median $10,000. The largest value provided by a single respondent was $100,000 and two respondents were unsure of what dollar value the information used at their farm represented. Out of the (10) respondents who provided values over $1,000, (3) had their farms located in Garfield County (Northwest Oklahoma) and (3) in Pawnee County (Northeast Oklahoma). The additional (3) who provided county location had their farms physically located in Caddo County (Southwest Oklahoma), Beaver County (Northwest Oklahoma), and Lincoln County (Eastern Central Oklahoma).

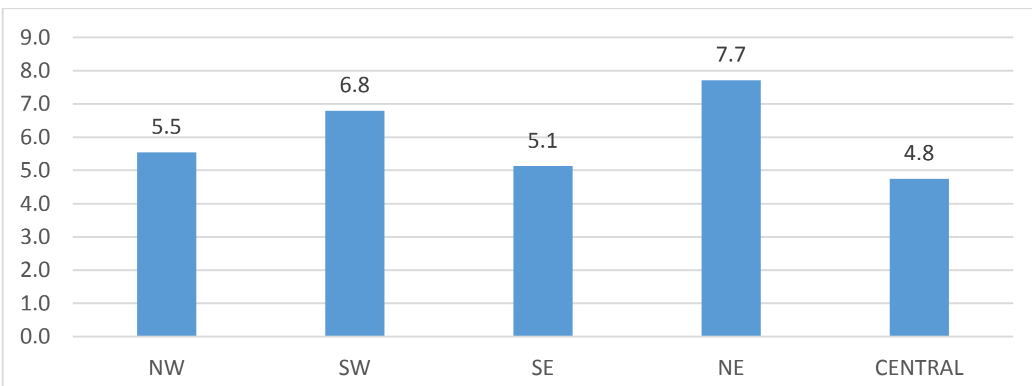
7.2. Farm Characteristics and Weather Monitoring Information

From the partial farm data information provided by 23 survey respondents, the average total farm size owned and rented in 2015 was 1,167 acres, which is close to the average farm size for farms in Oklahoma with $100,000 to $250,000 in sales and approximately three times as large as the average overall farm size in Oklahoma (Oklahoma Department of Agriculture, Food and Forestry, 2015). Farmers who provided at least partial farm data characteristics were also more likely to provide a positive dollar value estimate for the Mesonet's information and data services used at their farm over the course of one year (9 out of the 12 positive dollar values, 75%, correspond to respondent's who provided farm data characteristics). Out of the 23 survey respondents who provided farm data, 47.8% listed some type of livestock operation with a total average of 212 head of cattle per farming operation. In 2012, from 80,200 farms in the state of Oklahoma, approximately 55,000 farms, 68.6%, held livestock of some type. Largely corresponding to the state of Oklahoma's significant levels of wheat acreage, 10 (43.5%) of the survey respondents who provided farm data, had planted acres of wheat in either 2014 or 2015 compared to only 4 (17.4%) who had planted acres of corn in either 2014 or 2015. 34.8% of the survey respondents who provided farm data listed the type of tillage used at their farm. 75% listed no-till, 12.5% listed mulch-till, and 12.5% listed conventional till. No-till and mulch till are both considered to be conservation tillage methods that, "provide benefits to both producers and society by reducing runoff and erosion (McMurtrey, Chappelle, Daughtery, & Kim, 1993), conserving soil moisture (Hartfield & Stewart, 1993), reducing energy and labor requirements (Guy & Oplinger, 1989), and increasing carbon (West & Post, Vol. 66 (1); pp. 1930-1946)" (Vitale J. D., Godsey, Edwards, &

Taylor, 2011). Possibly indicative of the concerns of the inability of farming activities to earn reasonable rates of return on investment (ROI) (Kelsey et al., 2000), 70.6% of survey respondents indicated that a household member had some type of off-farm employment and only 42.3% of farmers who provided a percentage for farming income to total annual income (Q27) derive over 61% of the total income from farming activities.

The average profitability scores of respondents with farms located in the Northeast and Southwest were considerably higher than for respondents with farms located in the Northwest, Southeast, and Central regions. The Northeast farmers provided an average Mesonet profitability score of 7.7 and the Southwest farmers provided an average Mesonet profitability score of 6.8 (Figure 12). Consistent with the overall results, all regions displayed profitability score averages over 5.

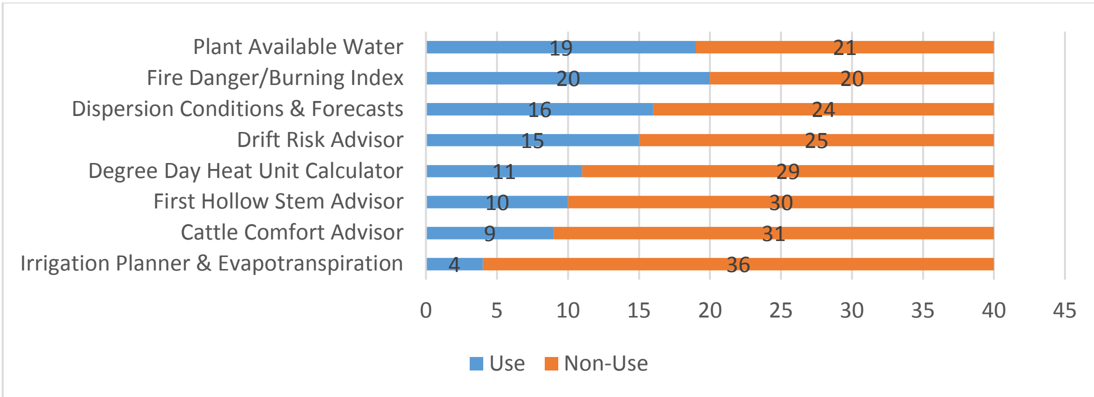
Figure 12: Average Mesonet Profitability Score based on Geographic Region



7.3. Use Factors of the Oklahoma Mesonet

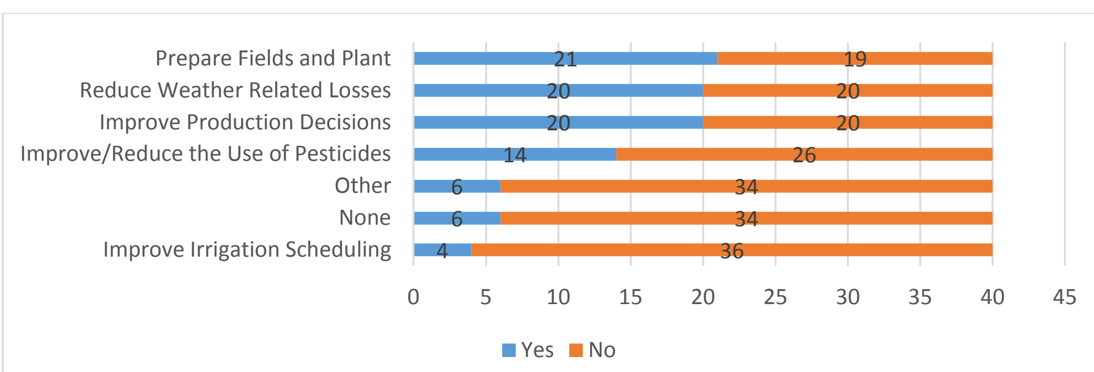
The two Mesonet observational products identified by survey respondents as the most used in any of the previous planting, growing, and harvesting season were the ‘Fire Danger/Burning Index’ and the ‘Plant Available Water’ (PAW) advisor (Figure 13) with corresponding usage rates of 50.0% and 47.5%. The two least used Mesonet observational products were the ‘Cattle Comfort Advisor’ and the ‘Irrigation Planner and Evapotranspiration’ tool with corresponding usage rates of 22.5% and 10%. Out of the only four survey respondents who identified the use of the ‘Irrigation Planner and Evapotranspiration’ tool, two were located in the Central to Eastern counties of Pottawatomie County and Seminole County that are characterized as transitional regions from the Central Great Plains to the more irregular terrain of Southeastern Oklahoma (Oklahoma Climatological Survey, 2016), and one was located in Caddo County which has some of the best agricultural land in Oklahoma (The Oklahoma Climatological Survey, 2016). The 2013 Farm and Ranch Irrigation Survey (FRIS) indicated that Oklahoma has 1,672 farms that contain irrigated lands for a total of 426,602 actual irrigated acres which is just over 1% of the 34,400,000 total farmland acres in the state (Taghvaeian, 2013). The average level of importance given to the Mesonet’s impact to profitability by farmers who used the ‘First Hollow Stem Advisor’ was 8.6, the highest of all the Mesonet observational products. It was followed by the average of farmers who recognized using the ‘Drift Risk Advisor’ with 8.53 and with the average of farmers who recognized using the ‘Cattle Comfort Advisor’ with 8.4. The lowest average levels of importance given to the Mesonet’s impact to profitability based on observational product used in the 2015 planting, growing and harvesting season were by farmers who recognized using the ‘Fire Danger and Burning Index’ with 5.9 and by farmers who recognized using the ‘Irrigation Planner and Evapotranspiration’ tool with 6.25.

Figure 13: Mesonet Agricultural Decisions Aids Used in 2015 Season



Mesonet observations are primarily used to prepare fields and plant (52.5%), to reduce weather related losses (50%), and to improve production decisions (50%) (Figure 14). The observations are less often utilized to improve or reduce the use of pesticides (35%) and to improve irrigation scheduling (10%). The significant correlations with the Mesonet's importance to farm profitability (i.e. correlation coefficients larger than 0.50) were found in field preparation and planting with a 0.54 correlation coefficient, improving production decisions with 0.54, reducing weather related losses with 0.52, and improving or reducing the use of pesticide inputs with 0.50. Improving irrigation scheduling, other, and none had no significant correlations.

Figure 14: Farming Decisions where Mesonet Observations are utilized



7.4. Valuation of the Oklahoma Mesonet

In the Kenkel & Norris (1995) study, it was determined that producers were willing to pay a mean of $5.83 per month for raw weather data and a mean of $6.55 per month for raw data and value-added information. In order to calculate aggregate values, a conservative assumption (implying a zero WTP for non-respondents) and an optimistic assumption (non-respondents have the same WTP as respondents) were calculated to generate results of $29,942 and $186,364 per month ($359,304 and $2,236,368 per year). At the time of the WTP study, overall Oklahoma Mesonet system costs were expected to be around $500,000 to $700,000 per year ($41,666 – $58,333 per month), current yearly operating costs are closer to $1.8 million (Klockow & McPherson, 2010). By bringing the Kenkel and Norris (1995) monthly WTP aggregate value to present day value by adjusting for an average yearly inflation rate from 1994 to 2016 of approximately 2.24% based on the U.S. Bureau of Labor Statistics' CPI Inflation Calculator (United States Department of Labor, 2016), the expected $359,304 and $2,236,368 yearly value would currently represent $580,077 and $3,610,496. Klockow & McPherson (2010) estimated that the realized annual savings from a reduction in 2007 chemical spraying costs by farmers using the Oklahoma Mesonet could be anywhere from $160,000 to $1.6 million. Similarly, annual savings in irrigation costs by way of the Oklahoma Mesonet irrigation planner were estimated at anywhere between $130,000 and $1.3 million while reductions in fertilizer applications by farmers using the Greenseeker decision support tool, which uses Mesonet information in its fertilizer application models, were estimated to save approximately $2.5 to $5 million annually . The sum of all estimated direct annual savings was thus placed at $2.8 to $5.4 million

Although this study's survey did not directly apply the WTP method, it nonetheless was still able to calculate the value provided to farmers by Mesonet information over the course of one year with question Q12. The overall average from the 18 respondents who provided values, including the $0 value respondents, totaled to $11,948 with a median of $1,000. When the $0 response values were excluded, the average inched up to $16,926 with a higher median of $10,000. With the exclusion of the single $100,000 outlier value and the $0 values, the average totals $11,852 with a median of $5,500. By making the assumption that non-respondents see no value in the data and services provided by the Mesonet, descriptive statistics on all 40 respondents provided a mean of $5,078 and a standard deviation of $17,075.73. A data set with a large standard deviation is generally representative of values being far from the mean. The aggregate one year value for the Oklahoma Mesonet, from the $5,078 mean and the assumption that the same proportion of respondents that provided a positive value (30% of the population) stands true for the 79,600 farms in the state (Oklahoma Department of Agriculture, Food and Forestry, 2015), was estimated at $121,262,640.

8. Conclusion

This study provides insight into the importance of weather monitoring networks and into what factors contribute to differences in value judgments by agricultural producers for weather monitoring networks by analyzing the Oklahoma Mesonet. On the improvement to farm profitability scaled question from (0) to (10), all respondents either provided a (0) value or a value higher than (5), and only one of the respondents actively using the Mesonet for their farming decisions provided a (0) value, the rest had values higher than (5). This data therefore suggests that there is an overall positive contribution to farm profitability perceived from using the Mesonet weather information and data for farming decisions. In other words, no active Mesonet user finds that the Mesonet's contribution to farm profitability falls within the 1-4 scale which would indicate that, although the information is being actively used, it does not provide much added value. Further delving into the results, it was determined that the consistent use of weather monitoring information from the Oklahoma Mesonet by individual farmers led to higher levels of importance being placed on the Mesonet information's contribution to farm profitability. This is demonstrated with the high level of correlation between the results of both Q9 and Q11 and with the significant increase in the average level of importance given to Mesonet observations by active users who indicated using the Mesonet every day. There was no conclusive statistical relationship or correlation found between the level of importance of Mesonet information and a number of the hypothesized factors such as experience with weather related losses, educational levels, cattle operations, and farmer age. There was however a somewhat significant to significant positive correlation of over 0.50 found between the consistency of use and with users who identified having first used the Oklahoma Mesonet in the 1990's. There was also a positive relationship found with farmers who indicated using the 'First Hollow Stem Advisor', the 'Cattle Comfort Advisor', and the 'Drift Risk Advisor.' The 'Cattle Comfort Advisor' and the 'First Hollow Stem Advisor' were second and third to last in terms of overall identified use to non-use by survey respondents. This indicates that the small group of farmers who indicated using one of the two tools believe that the Oklahoma Mesonet highly contributes to their farm profitability. This finding can allow Mesonet operators to further assess the impact to perceived profitability of specific tools and to further communicate the perceived benefits to potential users of tools that have been identified by current users as having a high perceived impact to farm profitability. Significant Mesonet levels of importance to profitability correlations were found between users who identified the use of observations to either improve production decisions, reduce weather related losses, or for field preparation and planting. No significant correlations were found for the use of observations to improve irrigation scheduling or to improve the use of pesticide inputs. The study's findings imply that the actual decision to use Mesonet observations is to improve production decisions, reduce weather related losses, and prepare fields and plant. However, the findings do not necessarily imply that farmers are not achieving an improved use of pesticide inputs or a reduction in irrigation use because it is not identified as a direct use of Mesonet observations by the survey respondents. For example, farmers may still be reaping the benefits of a reduced use of pesticide inputs as a result of their decision to use Mesonet observations for field preparation and planting

When specifically evaluating the table results (Q18) a few interesting conclusions were determined from the statistical analysis. For one, the more farm acres owned, the higher the values provided for the Mesonet's contribution to the farm over the course of one year (correlation coefficient of 0.55). It was also determined, from the respondents who elected to provide farm data on cattle, that having cattle operations correlates with the use of the Mesonet (73% of respondents), however, it does not indicate a higher level of importance given to the Mesonet's observations impact to profitability (average: 6.4) when compared to the overall average of 6. This may be attributed to the non-users of the 'Cattle Comfort Index' since the identified users provided a level of importance value of 8.4. In the overall survey data that were a couple of gaps found, particularly in regards to respondent's knowledge of the Oklahoma Mesonet and the use of the Oklahoma Mesonet for farming decisions. This study's data shows that, in addition to the (15%) of respondents who have no knowledge of the Oklahoma Mesonet's existence, there is an additional (15%) of respondents who are aware of the Mesonet's existence but consciously decide to not use the information and data for their farming decisions. This gap may indicate that there are still opportunities to communicate the perceived positive impacts to farm profitability of the Mesonet by current users based on specific use decisions and specific observational tools.

The estimated economic loss to agricultural production of the 2012 drought represented approximately 6% of the total agricultural products sold in the state of Oklahoma in 2012. The potential for economic losses from weather is demonstrated by the 77% of survey respondents who indicated that in the past 10 years they have experienced very significant to somewhat significant weather related losses. This study showed that consistent users of the Oklahoma Mesonet value the network's ability to assist in field preparation, planting, and reduction of weather related losses. Previous studies had similarly indicated that producers who suffer larger weather related crop losses have a higher WTP for weather data. Even with the legitimacy of the Mesonet's capabilities, there are still agricultural producers that are consciously objecting to the use of the Oklahoma Mesonet for farming decisions (30%).

Studies have indicated that producers with irrigated acres are also expected to pay more for weather data due to the more intensively managed nature of irrigated crops. "In 2013, Oklahoma producers spent more than $22 million in energy expenses to power 5,351 pumps" (Taghvaeian, 2013) that either raise groundwater or pressurize surface water for its distribution. This study found that respondents who described the importance of timely and accurate weather information to irrigation scheduling moderately important to very important (N=12) provided an average score of (4.75) out of (10) to the improvement of farm profitability as a result of Mesonet observations, lower than the total average of (6) for all respondents and (7.82) for active Mesonet users. Furthermore, only (3) of the (12) provided values for information and data provided by the Oklahoma Mesonet over the course of one year, which averaged to $33.33. Considering the costs of irrigation and the increased need for groundwater use efficiency due to overdraft from the Ogallala aquifer (Walbridge, 2008), the value and impact to profitability from the improved weather data provided by the Oklahoma Mesonet should be significantly higher. The Water for 2060 report identified the need to develop an Oklahoma crop irrigation best practices guide that would better leverage Mesonet data and identify water use benchmarks for crop irrigation. The estimated cost for developing this guide is $300,000, which is approximately 1% of the $22 million spent by agricultural producers in energy expenses to irrigate their fields in 2013. This study can help convince state officials that providing funding to better leverage Oklahoma Mesonet irrigation decisions aids tied to on-farm irrigation technology and best practices is a cost effective and required tool that will significantly improve the state's chances of meeting the Water for 2060 goal and of irrigating farms sustainability.

This study analyzed differences in farmer perceptions about their potential benefits from using the Oklahoma Mesonet to make production decisions throughout the growing, planting, and harvesting process. The literature demonstrated that improved weather monitoring information can contribute to the application of conservation tillage and to a reduction in pesticide, fertilizer, and irrigated water use. Previous studies have also described the potential for reduced fuel use, soil erosion, and production costs with the expanded use of conservation tillage (Vitale et al., 2011). The unpredictability of climate in Oklahoma, characterized by a long growing season and a short summer window for potentially double cropping, has been cited as one of the challenges to the increased adoption of conservation tillage in a state that has heavily relied on a winter wheat monoculture system. Survey respondents of this study indicated that timely and accurate weather information is most important for field preparation and planting management decisions and that Mesonet observations are mostly used to prepare fields and plant thereby indicating its ability to assist farmers with a mixed-crop farming system and conservation tillage methods. 7 survey respondents indicated some type of conservation tillage being used at their farm. Clearly demonstrating the contribution of Mesonet to the application of conservation tillage, the 5 respondents who use Mesonet information for their farming decisions and apply conservation tillage indicated an average level of importance to farm profitability score of 8.2 and an average yearly value of the Mesonet of $8,220. Literature has shown that farmers in Oklahoma have been much slower in their adoption of conservation tillage, future research could look at assessing the ecosystem benefits potentially capable with the increased adoption of conservation tillage practices and how the Oklahoma Mesonet would contribute to these benefits while helping to preserve yields and farmer profitability. If the added ecosystem benefits were more easily quantified, federal and state government incentives or subsidies that help induce the adoption of such practices, could be more easily justified by government officials.

This study provided a quantitative analysis that makes the argument for the continued investment in the Oklahoma Mesonet due to the level of positive impact it has on the profitability of farmers from different backgrounds, with different farm sizes, and different levels of education. There are significant percentages of farmers turning to part time work to supplement the low returns of farming businesses. This study's results showed that the Oklahoma Mesonet provides a valuable service to the increasingly large percentage of part-time farmers who are typically in small community based rural farming operations. Survey respondents who relied on some type of off-farm employment by a household member were more likely to perceive a higher level of importance for the Oklahoma Mesonet's contribution to farm profitability (average value of 6.8) compared to the those who did not rely on off-farm employment (average value of 3.4). Another apparent determinant to the level of positive impact to profitability appears to be geographic location, the highest level of impacts were given in the NE and in the SW, 7.7 and 6.8 respectively. The lowest level of impacts were given in the Central, SE, and NW regions. This result indicates that in the NE and SW more value is given to the Mesonet's impact on profitability possibly because of the larger variability in precipitation that these regions exhibit. The result also demonstrates that, possibly due to the use of irrigation systems, the highly agricultural NW region does not place as high a score as the NE and SW regions. As groundwater levels become stressed and farms become more reliant on the efficient use of irrigation systems mixed with precipitation, the value placed on accurate weather monitoring systems would be likely to increase. The SE region averages the most precipitation throughout the state and it experiences the longest average growing season which typically allows farmers to diversify their crops. This geographic characteristic could possibly explain the lower average Mesonet profitability score. It may be possible to focus on the regions exhibiting a lower average score to communicate the additional benefits provided by the Oklahoma Mesonet that better address these unique geographical differences.

The ultimate value of the Oklahoma Mesonet to Oklahoma taxpayers and constituents is not just attributed to the potential impact it has on individual farm profitability but also on the potential environmental benefits that can come about as a direct result of reduced producer inputs, and improved conservation of water and soil conditions. One such example is that of the Mesonet's fire prescription planner and its ability to assist with prescribed burning practices that are aimed at cutting down the growth of the Eastern Red Cedar tree. The Eastern Red Cedar tree has been responsible for an estimated $447 million in losses attributed to wildfires, reduced cattle forage, and water yields among other negative effects. As farmers, landowners, and state lawmakers recognize the value of applying the Mesonet's fire prescription planner to enhance prescribed burning practices, a specific statewide economic value could be applied to the Oklahoma Mesonet's contribution to water conservation, wildfire control, and pollen allergy control. Literature has generally shown that the CV method is an able tool to assist policymakers in understanding the public's WTP for environmental goods and even with its deficiencies, the method itself has been endorsed by Nobel economic laureates Kenneth Arrow and Robert Solow. Applying the contingent valuation method to determine the general public's WTP for the environmental benefits possible because of the publicly funded weather monitoring network, such as its capability to assist landowners in controlling the Eastern Red Cedar tree, is an area of potential future research. The potential study's results could provide government officials with the justification to fund or defund weather monitoring network operations based on the public's value of the network's ultimate results in agriculture. Most studies that focus on the agricultural adoption of technology or weather monitoring stations apply the stated preference CVM approach to determine the 'use value.' Further looking into the 'non-use values' potentially achieved because of the benefits derived from user adoption of these technologies is an area that requires further research.

The level of uncertainty and risk inherent in agricultural production was mentioned in literature as an important factor in the determination of value for weather monitoring information. This study reinforced the idea that quality, accurate, and consistent weather monitoring information provides agricultural producers with some of the reassurances needed to make informed decisions that better prepare them for adverse conditions or that better allow them to take advantage of favorable conditions. However, future research could focus on identifying differences in the levels of risk being taken by agricultural producers who highly value weather monitoring information from a statewide monitoring network and agricultural producers who disregard weather monitoring information and apply more conservative strategies.

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10. APPENDIX A: SURVEY PARTICIPANT ADDITIONAL COMMENTS

FARMER ID	COMMENT
42	You can predict the weather but doing something about it is another story. Forecasts are good but 90% of the time it's the wrong forecast
36	Many questions don't pertain to us since we are not a sole proprietorship.
29	Survey was incomplete for the farming that most SDLFR that I work with. - Smallest Detectable Leakage Flow Rate?
17	We lease out the majority of our farmable acreage to a neighboring farmer who is a traditional type farmer. We also have some bees that some people have placed near our veggie garden. We have livestock, but you didn't ask about them: Goats (milk), Chickens (egg-layers), Water is a huge problem for us because after the 3 or 4 years of drought, our local rural water provider (Payne County Rural Water District No. 4) decided to implement emergency pricing and the cost of water went up to about 2 to 3 times more than before. After the drought, they decided to KEEP the pricing high in order to provide for replacement water delivery piping... Whereas our water bill had been about $40 / month on average, it went up to $70 to $150 and one month it was $630 due to a water leak! We need help with inexpensive ideas on how to build a large capacity rainwater catchment system.
15	One acre garden under Plasticulture program. Heavy loss due to DEER, not due to weather.
12	This survey doesn't fit very well with my farming methods (agro-ecological) which are deemed radical here. These methods are also de-desertification, soil remediation, etc. and include composting, organic minerals, and fish/kelp. The rain fall skips around and is very unpredictable in recent years. I believe my neighbors who till several times a year and use chemicals have little or no soil organic matter and have removed most trees. I think their practices help create wind and ongoing droughts.
10	I utilize OK Mesonet resources for conducting RX fire on my place. I currently am building my pastures through RX fire and spot treatment for invasive plants. Our goal is to build our native range plants and utilize a grazing animal (Beef) to maintain the native plant system. We raise chickens, and two pigs for our own consumption. I have used OK Mesonet when conducting prescribed fires on my property as well as helping neighbors conduct RX fires. Of our 15 ac., 75% is native grass 25% is cross timbers hardwood vegetation. I burn at different intervals each year and rotate the whole 15 ac. through multiple burns per season. Not each unit is burned each year.

11. APPENDIX B: SURVEY

The Value of Environmental Monitoring Information
University of Oklahoma Research Study - The Value of Environmental Monitoring Information

I am Dr. Jad Ziolkowska from the Department of Geography and Environmental Sustainability at the University of Oklahoma and I invite you to participate in our research project entitled "The Value of Environmental Monitoring Information." This research is being conducted by anonymous online surveys. You were selected as a possible participant because an agricultural extension officer provided us with your email information or you provided us with your email address at the Enid Agrifest on Friday, January 8th. You must be at least 18 years of age to participate in this study. Please read this document and contact me to ask any questions that you may have BEFORE agreeing to take part in our research.

What is the purpose of this research? The purpose of this research is to assess the information value and environmental savings (and prevented losses) of improved farmers' decision making from using Oklahoma Mesonet information. The analysis will help understand the value of environmental monitoring information for agricultural producers of traditional and specialty crops in Oklahoma.

How many participants will be in this research? About 358 people will take part in this research.

What will I be asked to do? If you agree to be in this research, you will be asked to answer a 28 question survey regarding farm operations, decision-making processes, and use of the Oklahoma Mesonet information

How long will this take? Your participation will take approximately 20 minutes to complete the survey.

What are the risks and/or benefits if I participate? There are no risks and no benefits from being in this research.

Will I be compensated for participating? You will not be reimbursed for your time and participation in this research.

Who will see my information? In research reports, there will be no information that will make it possible to identify you. Research records will be stored securely and only approved researchers and the OU Institution Review Board will have access to the records.

Do I have to participate? No. If you do not participate, you will not be penalized or lose benefits or services unrelated to the research. If you decide to participate, you don't have to answer any question and can stop participating at any time.

Who do I contact with questions, concerns or complaints? If you have questions, concerns or complaints about the research or have experienced a research-related injury, contact Dr. Jad Ziolkowska at (405) 325-9862 or jziolkowska@ou.edu You can also contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu if you have questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than the researcher(s) or if you cannot reach the researcher(s). Please print this document for your records.

By providing information to the researcher(s), I am agreeing to participate in this research. This research has been approved by the University of Oklahoma, Norman Campus IRB. IRB Number: 6339 Approval date: 01/21/2016

- I agree to participate (click should connect to the survey)
- I do not want to participate (click should connect to a Thank You for considering page)

Q1: Please rank the following agricultural management issues in order of importance to your farm operations

	Low Importance (1)	Slightly Important (2)	Neutral (3)	Moderately Important (4)	Very Important (5)
Soil quality (1)	❍	❍	❍	❍	❍
Access to water (2)	❍	❍	❍	❍	❍
Labor costs (3)	❍	❍	❍	❍	❍
Fertilizer and pesticide costs (4)	❍	❍	❍	❍	❍
Weather events (5)	❍	❍	❍	❍	❍
USDA Federal Assistance programs and/or price support (6)	❍	❍	❍	❍	❍
Crop insurance (7)	❍	❍	❍	❍	❍
Other (8)	❍	❍	❍	❍	❍

Q2: Please rank the importance of timely and accurate weather information to your farm operations for the following agricultural management decisions?

	Low Importance (1)	Slightly Important (2)	Neutral (3)	Moderately Important (4)	Very Important (5)
Field preparation and planting (1)	❍	❍	❍	❍	❍
Pest/Disease Control (3)	❍	❍	❍	❍	❍
Irrigation Scheduling (4)	❍	❍	❍	❍	❍
Crop Harvesting (5)	❍	❍	❍	❍	❍
Other (6)	❍	❍	❍	❍	❍

Q3: Do you or anyone in the production process use services/information from the Oklahoma Cooperative Extension Service at Oklahoma State University for your farming decisions?

❍ Yes (1)
❍ No (2)

Q4: Do you or anyone in the production process have knowledge of the Oklahoma Mesonet Network?

❍ Yes (1)
❍ No (2)

Q5: Are you using Mesonet information for your farming decisions?

❍ Yes (1)
❍ No (2)

Q6: In what year did you start using Mesonet?

Q7: Which of the following Mesonet observation products have you used in any of the previous planting, growing, or harvesting seasons? (Please check all that apply)

- ❑ Degree-day Heat Unit Calculator (1)
- ❑ Drift Risk Advisor (2)
- ❑ Irrigation Planner and Evapotranspiration (3)
- ❑ Plant Available Water (4)
- ❑ Fire Danger or Burning Index (5)
- ❑ First Hollow Stem Advisor (6)
- ❑ Cattle Comfort Advisor (7)
- ❑ Dispersion Conditions & Forecasts (8)

Q8: Do you currently follow the Mesonet Facebook page or Twitter account?

- ❍ Yes (1)
- ❍ No (2)

Q9: How often do you use Mesonet information for decision-making on your farm?

- ❍ Every day (1)
- ❍ Times per week (2) ____________________
- ❍ Times per month (3) ____________________
- ❍ Times per year (4) ____________________
- ❍ Never (5)

Q10: For which of the following are Mesonet observations used at your farm? (Please check all that apply)

- ❑ To improve production decisions (1)
- ❑ To Improve irrigation scheduling or reduce irrigation use (2)
- ❑ To improve or reduce the use of pesticide inputs (3)
- ❑ To reduce weather related losses (4)
- ❑ For field preparation and planting (5)
- ❑ Other: (6) ____________________
- ❑ None of the above (7)

Q11: Are Mesonet observations helping improve your farm profitability?

- 0 (0)
- 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- 6 (6)
- 7 (7)
- 8 (8)
- 9 (9)
- 10 (10)

Q12: What value Mesonet information and data provide to your farm/ range over the course of one year?

$/ year (1)

Q13: Are you currently using any non-Mesonet weather data services (e.g., DTN/DuPont Weather Service, Climate Corp, John Deere Field Connect, etc.)?

- Yes (1)
- No (2)

Q14: Are you currently using any farmer reports or regional agricultural news services?

- Yes (1)
- No (2)

Q15: If so, please provide the name of the farmers report and/or weather data service and the monthly subscription fee (if any)

Weather Data Service (Name) (1)
Weather Data Service (Fee) (2)
Farmers Report (Name) (3)
Farmers Report (Fee) (4)
Other (Name) (5)
Other (Fee) (6)

Q16: How many years have you been in farming?

Q17: Have you ever taken part in prescribed burning practices to protect grassland?

- Yes (1)
- No (2)

Q18 Farm Data: Please provide the closest estimates of average crop land use and agricultural production in the following time spans: (2001-2005), (2006-2010), (2011-2014), and 2015				
	2001 - 2005	**2006 - 2010**	**2011 - 2014**	**2015**
Total Farm Acres (Owned and Rented)				
Total Annual Production (bushels)				
Total Annual Revenue ($)				
Total Production Costs ($)				
Losses due to Weather Event (Acres)				
Fertilizers Used (tons)				
Pesticides Used (gal)				
Water Used (acre feet)				
Type of tillage: No till (direct seed), Ridge till, Mulch till, Conventional till				
Other (please describe)				
Irrigated Acres				
Planted Acres of Wheat				
Planted Acres of Corn				
Planted Acres of Hay				
Planted Acres of Soybeans				

Planted Acres of Sorghum				
Planted Acres of Cotton				
Planted Acres of Pecans				
Planted Acres of Peanuts				
Planted Acres of Oats				
Planted Acres of Rye				
Planted Acres of Specialty Crops				
Planted Acres of Other Crops				
All Cattle Livestock (head)				
All Hogs and Pigs (head)				

Q19: In the past 10 years, have you experienced any weather related losses? If so, how significant was the loss?

- ❍ Very Significant (1)
- ❍ Somewhat Significant (2)
- ❍ Neither Significant or Insignificant (3)
- ❍ Somewhat Insignificant (4)
- ❍ Very Insignificant (5)

Q20: Please select the USDA Federal Farm Programs that you have previously enrolled in? (Select all that apply)

- ❑ Non-Insured Crop Disaster Assistance Program (NAP) (1)
- ❑ Livestock Indemnity Program (LIP) (2)
- ❑ Tree Assistance Program (TAP) (3)
- ❑ Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish Program (ELAP) (4)
- ❑ Emergency Loan Program (5)
- ❑ Emergency Conservation Program (ECP) (6)
- ❑ Conservation Reserve Program (CRP) (7)
- ❑ Other (8) ____________________
- ❑ None (9)

Q21: In what county is your farm located?

Q22: How many people live in your household?

Q23: What is your age?

Q24: Are you male or female?

- ❍ Male (1)
- ❍ Female (2)

Q25: What is the highest level of school you have completed or the highest degree you have received?

- ❍ Less than high school degree (1)
- ❍ High school degree or equivalent (e.g., GED) (2)
- ❍ Some college but no degree (3)
- ❍ Associate degree (4)
- ❍ Bachelor degree (5)
- ❍ Graduate degree or higher (6)
- ❍ Other (7)

Q26: Do you or any of your household members have any type of off-farm employment?

- ❍ Yes (1) ____________________
- ❍ No (2)

Q27: What is the percent of farming in your total annual income?

Q28: Additional comments