SUSTAINABLE AGRICULTURE IN OKLAHOMA: A STUDY OF OKLAHOMA COOPERATIVE EXTENSION SERVICE NEEDS FOR PRECISION AGRICULTURE EDUCATION AND OTHER OBSTACLES IN THE ADOPTION OF PRECISION AGRICULTURE IN OKLAHOMA

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CHAPTER I

INTRODUCTION

Precision agriculture (PA) includes the use of digital soil mapping, geographical information systems, global positioning systems, ground based sensors, remote sensors, variable rate application technologies (including greenseeker technologies), and yield monitoring systems (Cowan, 2000). Using precision agriculture allows the producer to "detect and manage variability for profit" (Butcher, 1998, p. 2). Another benefit of using precision agriculture technology involves less contamination of ground and surface water supplies in the management of fertilizer, herbicides, and lime (Hatfield, 2000, p. 1). Therefore, precision agriculture is important in keeping our water supply as pure as possible. Precision agriculture also allows for less water to be utilized in irrigation systems and fewer chemicals to be used in fertilizer applications, pesticide control, and soil management.

Precision agriculture serves useful purposes in improving farm management including cost reductions, improving returns, and stopping unnecessary pollution. However, the economics of different precision agriculture techniques may not be feasible for some farms (especially smaller farms) considering the return for money spent on the technology. Therefore it is important to evaluate the effects of different precision agriculture techniques on each farm in order to gain maximum benefit from each technology.

It is important for all agriculturalists to know the best way to manage their farms or businesses. The Oklahoma Cooperative Extension Service (OCES) is responsible for providing services to farmers in order to educate and to diagnose problems in farm management. Precision agriculture is a more precise way to manage Oklahoma farm production that could be used to the benefit of the farmer and the sustainability of agriculture in Oklahoma. Therefore, it is important to evaluate problems that extension might perceive in providing precision agriculture services and education to Oklahoma farmers.

Statement of the Problem

The state of precision agriculture services and education in the Oklahoma Cooperative Extension Service (OCES) has gone previously undocumented. In order for OCES to meet precision agriculture needs in Oklahoma farm production, educators must have sufficient education on precision agriculture. The OCES is responsible for helping farmers solve production problems and providing education opportunities and services to help farmers to manage their production practices.

Also undocumented have been the problems the Oklahoma Cooperative Extension Service may be having in providing PA education and services. There is a need to capture the PA education needs of the OCES in order to insure that precision agriculture services and education are provided with competence from the OCES to Oklahoma farmers.

There exists a need in Oklahoma to improve the sustainability of agriculture within the state. Precision agriculture use within the state has the potential to increase the sustainability of Oklahoma agriculture. Evaluation of the current needs of OCES educators to provide precision agriculture services and education to Oklahoma farmers may uncover obstacles in implementing precision agriculture use into Oklahoma agriculture.

Project Objectives

1. Describe what precision agriculture services are provided to Oklahoma farmers through the Oklahoma Cooperative Extension Service by district.
2. Describe problems that Oklahoma Cooperative Extension Service educators have encountered with providing precision agriculture services in Oklahoma.
3. Describe why there may not be precision agriculture services available in some areas of Oklahoma farm production.
4. Describe PA education needs of Oklahoma Cooperative Extension Service educators.
5. Describe the perceptions of selected Oklahoma agricultural service providers regarding precision agriculture.

Limitations of the Study

This study was limited to the state of Oklahoma and included only data from Oklahoma Cooperative Extension Service agriculture educators and purposively selected Oklahoma agriculture service providers.

Basic Assumptions of the Study

This study assumed that data collected through interviews was valid and current. Also, this study assumed that participants were knowledgeable about the PA education and services that OCES provided in their county. Finally, this study assumed that counties within different OCES districts were similar.

Importance of the Study

Describing the current state of precision agriculture in the Oklahoma Cooperative Extension Service determined the needs of extension educators who are charged with providing PA education and services to farmers. Provision of proper precision agriculture services and education to farmers is necessary in order to promote the use of precision agriculture in Oklahoma. Increasing precision agriculture can reduce the costs of fertilizers for farmers while increasing crop yields (Raun & Johnson, 1999).

Also a great need exists in Oklahoma to improve the sustainability of agriculture, considering that agriculture is the number one contributor to the ground water and surface water pollution in the state (Derichsweiler, 1996). PA education can promote the sustainability of agriculture by preventing the over application of fertilizers and other agricultural inputs (Larson, Lamb, Khakural, Ferguson, & Rehm, 1997). Therefore, PA education and activities in the Oklahoma Cooperative Extension Service must be assessed.

Definition of Terms

Digital Soil Mapping- "Fields are divided into grid cells of approximately 2-3 acres defined by a GPS receiver, and soil sample data from each cell are transferred to a digital map that is then used to manage precise input application" (Cowan, 2000, p. 1).

Geographical Information Systems (GIS) – "A combination of computer hardware, software, and geographic data designed to capture, store, manipulate, analyze, and display data that is referenced to specific points on the Earth's surface" (Cowan, 2000, p.1).

Global Positioning System (GPS) - "A radio navigation facility which consists of a network of satellites and earth stations that are controlled by the Department of Defense to determine a radio receiver's position in latitude, longitude and altitude" (McNeill, 2003, p. 3).

Ground Based Sensors- "Sensor-based application of inputs implies that sensors (such as soil nutrient sensors, soil property sensors, and optical plant sensors) on the VRT (variable rate technologies) can measure information in real-time and make the necessary precise adjustments" (Cowan, 2000, p. 1)

Non-Point Source Pollution- "Pollution caused by multiple sources of emissions, each contributing a small portion of the total pollution, as contrasted with point sources such as factories or refineries" (Mirovitskaya & Ascher, 2001, p. 352).

Oklahoma Farmer- Those managing lands for agricultural production within Oklahoma borders.

PA- Precision Agriculture- "Spatial information technology applied to agriculture" (Hatch, Brooks, Mask, & Shaw, 1999, p.1).

Precision Agriculture Techniques- "Digital soil mapping, geographical information systems, global positioning systems, ground based sensors, remote sensors, variable rate application technologies, and yield monitoring systems" (Cowan, 2000, p. 1).

Remote Sensing- "The act of monitoring an object without direct contact between the sensor and object" (McNeill, 2003, p. 3). An example of this is aerial photography.

Variable Rate Application (VRA) - "Adjustment of the amount of crop input such as seed, fertilizer, lime or pesticides to match conditions (yield potential) in a field" (McNeill, 2003, p. 3).

Yield Monitoring Systems- "Electronic device that continuously measures and records crop yields and moisture on-the-go" (McNeill, 2003, p. 3).

CHAPTER II

LITERATURE REVIEW

This chapter will first establish the importance of precision agriculture in Oklahoma, then PA education obstacles and needs for producers and cooperative extension agents found in the literature will be examined.

The sustainability of agriculture in Oklahoma is extremely important for state livelihood. In 2003 the total cash receipts for livestock and crops in Oklahoma were $4,162,186,000.00 (Bloyd, 2004). Seventy-three percent of the 45 million acres of land in Oklahoma is used for farming and ranching (ODAFF, 2004). Therefore the increased sustainability that precision agriculture could bring to Oklahoma agriculture is very important.

The impact and need for PA education can be divided into environmental concerns, producer needs, obstacles to precision agriculture adoption, and educational needs. Precision agriculture can be utilized in order to reduce pollutants in the environment, increase yields, and decrease the costs of farm inputs. The use of these techniques is greatly needed in Oklahoma considering the state of Oklahoma's natural resources and the amount of excess inputs that costs farmers' money and disrupts the environment.

Environmental Concerns

According to a study of the ground and surface waters of Oklahoma, agriculture is the number one contributor to nonpoint source pollution in this state (Derichsweiler, 1996). The United States Environmental Protection Agency states, “agricultural activities that cause nonpoint source pollution include animal facilities, grazing, plowing, pesticide spraying, irrigation, fertilizing, planting, and harvesting” (EPA, 2003, p. 1). A structured approach needs to be taken in order to evaluate the environment in order to define the indication of sustainability in Oklahoma (Walker, 2002). As it stands the standards for sustainability are not being met. Most of these problem sources could be contained with the implementation of precision agriculture practices in Oklahoma.

Sustainability of Agriculture and the Importance of Precision Agriculture

The sustainability of agriculture is imperative to the future of Oklahoma and to the rest of the world. Sustainability includes good stewardship of natural resources such that long-term productivity may be maintained or improved with minimal, if any, adverse impacts on the environment (Pojasek, 1998). If agriculture is to remain sustainable it needs to be environmentally friendly. Therefore, it is important for agricultural educators to find the target audience needed to improve the sustainability of agriculture in Oklahoma.

Currently some farming practices are degrading the conditions of the environment in Oklahoma and the world. "Only 33% of the total nitrogen applied for cereal production in the world is actually removed in the grain" (Raun & Johnson, 1999, p. 357). This means that of every 100 pounds of fertilizer that was applied to the soil, only 33 pounds was actually needed for the production of grain. Excess nitrogen applied to fields can lead to run off and leach into ground water supplies. Agricultural nonpoint source pollution is the leading source of water degradation to Oklahoma's rivers and lakes, and agriculture is also a major contributor to ground water contamination and wetlands degradation (EPA, 2003). Currently agriculture has not met the criteria for sustainability.

In a study in the *Agronomy Journal*, it was found that variable rate application of fertilizers reduced inputs from 12% to 44% (Wittry & Mallarino, 2003). Furthermore, the *Precision Agriculture Journal*, found that the use of variable rate application resulted in a decrease in the amount of leaching as a result of over fertilization (Wang, 2003). Studies have shown that precision agriculture use reduces the amount of residual nitrogen in the soil (Kitchen, Hughes, Sudduth, & Birrell, 1995).

Variable rate application can also be utilized in insecticide application and herbicide application in addition to fertilizer application (Clark & McGuckin, 1996). The use of these variable rate application techniques will decrease water pollution and, in turn, decrease health problems in society (Payne, Keeney, & Rao, 2001). Also, wildlife including fish, birds, and all of the animals that eat fish and birds will be better protected with less use of agricultural chemicals. Urban and rural populations will see decreases in the cleaning costs of drinking water supplies. Drainage costs will be decreased with the use of precision irrigation (Hrubovcak, Vasavada, & Aldy, 1999). Use of precision agriculture has the potential to benefit the farmer, society, and the environment.

The use of precision herbicide application reduced the use of herbicides between 11.5% and 98.0% (Williams, Gerhards, & Mortensen, 2000). A study done by Watkins, Lu, & Haung (1999) found that variable rate irrigation and fertilizer application decreased environmental detriments and increased profits for farmers (Watkins, Lu, &

Haung, 1999). Precision agriculture reduces the pollution of ground and surface waters by reducing excess fertilizers, pesticides, herbicides, irrigation, and lime that are sometimes applied to fields without the use of scientific methodologies in the application of these chemicals (Hrubovcak, Vasavada, & Aldy, 1999). Precision agriculture has been shown to decrease inputs, and therefore, decrease pollution (Larson et al. 1997).

The Need for Soil and Water Conservation

According to the Oklahoma Water Resources Board, many communities in Canadian County are in need of a future water supply, and a $500,000 project was initiated in the summer of 2003 in order to assess the use of the Arbuckle-Simpson Aquifer for that purpose (OWRB, 2004). The study stated that 60,000 acre-feet of groundwater from this aquifer would be transferred to the populations in need (OWRB, 2004). This demonstrates the fact that Oklahoma has a water supply problem, and conservation practices must be implemented in order to sustain agriculture as well as the state's population.

Over-irrigation of crops causes many problems to the producer and society including salinization of soil, sodic soil, waterlogging, depletion of water supplies, and drainage costs (Howell, 2001). Salinization of soil, sodic soil, and waterlogging can result in decreased crop yields and eventually a "barren salty landscape" if poor management practices are not remedied (AIS, 2003, p. 2). Most regular irrigation systems have only 40% efficiency, while agriculture is using 80% of the world's water supplies (Howell, 2001).

According to a study conducted by the United States Geological Survey, "irrigation accounted for 96 percent of all use of water from the High Plains (Ogallala)

Aquifer in the Oklahoma portion of the study area in 1992 and 93 percent in 1997" (Luckey & Becker, 1999, p. 2). As a result of this use, the recharge of the aquifer has not been able to keep up with the depletion of water in the aquifer. This has caused a varied decline in the levels of the aquifer including a 100 feet decline in areas of Texas County and a 50 feet decline in areas of Cimarron County (Luckey & Becker, 1999, p. 2).

Even more alarming than the decrease in available water is the decrease in the Ogallala's ability to produce more water. Reductions in groundwater supply in turn decrease the saturated thickness of the aquifer (Kromm & White, 1992). This decrease in saturated thickness has an inverse-square relationship with the recharge of the aquifer (Sweeten & Jordan, 1987). According to Kromm & White, "a 50 percent reduction in saturated thickness could mean that a well will yield only 25 percent of its initial capacity" (Kromm & White, 1992, p. 46). It is very important to maintain the water in the Ogallala in order for future generations to be able to obtain water from this valuable resource.

Consequences already seen due to the degradation of the ground water in Oklahoma include decreased water quality, decreased stream flow, eradication of wetlands and riparian vegetation, and decreased windbreaks and shelterbelts (Kromm & White, 1992). Precision irrigation will reduce the use of water from the Ogallala for agricultural purposes (Watkins, Lu, & Haung, 1999).

Precision Agriculture and Producer Benefits

In a study done by the Oklahoma Agriculture Statistics Service, it was found that "fertilizer, lime, and soil conditioner expenditures in Oklahoma were 54% of all of the outputs used in farm production” (Bloyd, 2004, p. 3). 700 million dollars was spent on these products (Bloyd, 2004, p. 3). Agriculture chemicals, fertilizer, lime, and soil conditioners are some of the largest expenditures on Oklahoma family operations.

Profitability increases due to use of precision agriculture practices have been shown to be as high as 19% (Young, Kwon, Smith, & Young, 2003). Although precision agriculture profit varies from farm to farm according to the technology used and the size of the farm, costly inputs are reduced with the use of this technology (Wang, Prato, Zeyuan, Kitchen, & Sudduth, 2003). Using precision agriculture techniques on farms has proved to produce “higher yields with the same level of inputs, simply redistributed; the same high yield with reduced inputs; or more income and reduced inputs” (Mohamad, Rukunnudin, & Chong, 1999, p. 217).

$15.9 billion dollars was lost in 1999 through unneeded application of nitrogen fertilizer (Raun & Johnson, 1999, p. 357). Inputs cost money. So if the farmer can decrease the amounts of inputs he or she uses and increase yields at the same time, then the farmer will gain an increase in profits.

Because there are so many variables that promote the success of precision agriculture technology, selection of precision agriculture techniques must be done on a case-by case basis. Teaching these differences to wheat farmers who would like PA education will give farmers a better understanding of the best PA techniques to use for their farms. This could be profitable to small farmers by increasing their profits through an increase in yields and also by a decrease in the costs of inputs such as fertilizers, pesticides, lime, herbicides, and irrigation. However, proper education and services must be provided to Oklahoma wheat farmers before precision agriculture is widely accepted and adopted.

Obstacles to Precision Agriculture Adoption

Even though the use of precision agriculture yields numerous benefits to the producer and society, there are many barriers to the adoption of this new technology. Increased returns must be large enough to compensate for the investment in equipment.

In a project done by the Cooperative Extension Service at the University of Kentucky, profitability in investing in precision agriculture equipment for the size of the farm was analyzed and found that fertilizer and lime variable rate application requires an 882-acre farm to breakeven (Hancock, 2003). The use of two fertilizers and lime variable rate application requires 511 acres to be profitable where one fertilizer variable rate application required 1, 060 acres to break even (Hancock, 2003). Different sizes of farms will see different levels of profitability when using precision agriculture techniques. Also, differences in the soil types present in fields and other factors may make some precision agriculture models unsuitable for use on some farms.

According to a report to the North Central Soybean Research Program (1999), different barriers that were identified by adopting and non-adopting producers included: the cost of technology adoption (initial investment, length of time before return, time to learn usage techniques), need for training programs and consultation resources (not having PA education readily available to producers), lack of quality data collection (due to yield monitor residues, uneven ground, defective grain moisture sensors, and loss of data when transferring raw data to an analysis computer), the need for a producer's guide to precision agriculture technologies comparing the advantages and disadvantages of different precision agriculture technologies, and lack of widespread knowledge of environmental benefits of precision agriculture (Wiebold, Sudduth, Shannon, & Kitchen, 1999).

These themes reoccurred in a study (2002), where barriers to precision agriculture adoption included, "accessibility to well-trained, knowledgeable people, and the cost and availability to obtain quality education, training, and products" (Kitchen, Snyder, Franzen, & Weibold, 2002, p. 344). Another study found that precision agriculture adoption barriers include the costs of precision agriculture, lack of technological ability on the part of the producer, lack of availability of basic information in precision agriculture, inadequate data collection, misuse of information, lack of qualified precision agriculture services, and precision machinery technical difficulties (Robert, 2002).

As these studies show, many of the barriers to precision agriculture adoption are directly associated with the PA education needs and responsibilities of the producers, agriculture service providers, and agricultural educators.

Caution in the Use of Precision Agriculture

Caution should be exercised in order to protect the financial status of farmers considering that not all farmers may see compensating returns from large precision agriculture investments.

In a literature review, it was found that of 108 studies investigated, 63% indicated positive net returns for a variety of precision agriculture techniques (Lambert & De-Boer, 2000). Eleven percent of these studies found a negative net return, and 26% found mixed results for returns (Lambert & De-Boer, 2000).

In precision agriculture studies involving wheat, 42% saw an economic benefit from using precision agriculture technology, 33% saw no benefit from using precision agriculture technology, and 25% saw mixed results from using precision agriculture technology (Lambert & De-Boer, 2000). In precision agriculture studies involving corn, 69% saw economic benefits from using precision agriculture technology, 15% did not see benefits, and 17% saw mixed results (Lambert & De-Boer, 2000). Therefore, farmers and Oklahoma Cooperative Extension Service educators should take caution economically in the implementation of precision agriculture in Oklahoma. This demonstrates that Oklahoma Cooperative Extension Service educators need to be educated in order to give proper scientific advice and education concerning the adoption of precision agriculture by farmers.

Education Needs

Understanding producer information needs, in regard to precision agricultural education, is important in establishing the role and needs of cooperative extension educators. In a study conducted by the Precision Agriculture Center at the University of Missouri (1999), producers reported that a barrier to precision agriculture adoption was that sufficient technological training was unavailable to them, and the producers felt unable to use precision agriculture methods to manage their farms (Weibold, Sudduth, Shannon, & Kitchen, 1999). This study concludes that there is a need for additional availability of PA education and training materials in order to encourage the adoption of precision agriculture practices and to sustain farmers who were currently practicing precision agriculture.

In another study, precision agriculture adopters expressed a need for educated personnel for technical advice, an informed agricultural workforce with the ability to help maintain and calibrate their equipment, compatible equipment and software, digitized soil maps on the Internet for GIS use, and precision agricultural training for laborers, agriculture service personnel, and farm owners (Roberts, English, & Larson, 2002). This study concluded precision agricultural education needs of those farmers currently using precision agriculture. In order to bring useable education to Oklahoma farmers, cooperative extension agents must have proper and current PA education and understand the needs of producers who may adopt or have already adopted precision agriculture techniques.

Bringing awareness to Oklahoma producers of the financial and environmental benefits of using precision agriculture is also important in promoting PA education and then use in Oklahoma. In a review of precision agriculture adoption literature, it was found that the top five factors that were involved in producer adoption of precision agriculture were: "1) initial surprise at the degree of within-field variation; 2) belief that better data could be collected for the cropping system; 3) perception that it was an important step toward growing crops at near optimum costs; 4) improved environmental protection; and 5) more efficient fertilizer use" (Murrell, 2003, p. 12). All of these reasons have to do with improving farm efficiency and improving the environment.

If knowledge of these benefits of precision agriculture is made more readily available to Oklahoma producers, then the adoption of precision agriculture may be increased. In the same study, factors that were found to persuade non-adopters of precision agriculture were: "1) demonstration of increased profitability; 2) improved environmental protection; 3) cost/benefit analysis; 4) advice from agronomists; 5) ease of operation; and 6) enough information to interpret the data collected" (Murrell, 2003, p. 12). Also, in terms of keeping current precision agriculture producers from leaving precision agriculture the Murrell study found that current precision agriculture producers need: "1) cost/benefit analyses for the various technologies; 2) a listing of the total costs involved to eliminate unforeseen costs; 3) accuracy of measurement by various technologies; 4) compatibility of software; 5) demonstration of agronomic and environmental benefits; and 6) assessment of the farm size necessary to make precision agriculture profitable" (Murrell, 2003, p. 12).

Informed PA Investment and Management

In the precision agriculture realm there are many different management decisions to be made. For the use of precision agriculture to benefit the agriculturalist and the rest of society, these decisions must be made with a good knowledge base. Knowing how to manage the use of precision agriculture equipment is important in order to collect valid field data. For instance, with the use of yield monitors, it has been shown that the data is significantly more accurate if the harvested segments are long and taken at a constant rate of speed (Arslan & Colvin, 2002).

Understanding the compatibility of different precision agriculture equipment is also important before the adoption of precision agriculture technology occurs (Roberts, English, & Larson, 2002). Another important option to consider is the profitability of investing in precision agriculture machinery versus hiring a company to utilize precision agriculture in order to analyze the within-field variation (Gandonou, Stombaugh, Dillon, & Shearer, 2001). Whatever method is used for that purpose, it is important to note here that the most important thing to realize in precision agriculture use is that each farm must be taken on a case-by case basis. Not all models will fit all farms. Knowing what technologies will help the producer and the proper methods of use is important in PA education and adoption.

The Process of PA education and Adoption

The fundamental principle, which must be appreciated by those producers choosing to adopt precision agriculture practices, is that within-field variability is an important consideration when formulating management plans (Kitchen, Snyder, Franzen, & Weibold, 2002). Precision agriculture uses site-specific management to allow for less inputs and costs by farmers. This means that each area of the field is broken down into small levels in order to apply chemicals only where they are needed.

Another important part of the education and adoption process for precision agriculture is learning to use proper sampling techniques (Kitchen, Snyder, Franzen, & Weibold, 2002). This is important in order to have accurate data to make a proper diagnosis. Also learning to use a computer and programs such as GIS is essential in learning to use different techniques in precision agriculture (Kitchen, Snyder, Franzen, & Weibold, 2002).

The ability to develop plans to manage the farm site specifically is also important in the development in precision agriculture management (Kitchen, Snyder, Franzen, & Weibold, 2002). These processes in the PA education evolution are important in the analysis of precision agriculture adoption because today farmers find precision agriculture support services to back and further PA education insufficient (Fountas, 1998; Weibold, Sudduth, Shannon, & Kitchen, 1999). Therefore, PA education and support service providers need more solidity and increased commitment to precision agriculture in order to increase the trust of the farmer in precision agriculture. Also on-farm demonstrations by OCES may increase trust in precision agriculture use.

According to a study titled "The Education Needs of Precision Agriculture," on-farm trials may be utilized in order to further develop the decision process in PA education and adoption (Kitchen, Snyder, Franzen, & Weibold, 2002). Having good precision agriculture support services has been very important in areas where precision agriculture has flourished (Weibold, Sudduth, Shannon, & Kitchen, 1999).

In areas where precision agriculture support services are lacking, early adopters feel as though they are alone when technical or diagnostic problems arise (Weibold, Sudduth, Shannon, & Kitchen, 1999). Therefore, in encouraging precision agriculture adoption and ensuring continuing precision agriculture use, it is very important to provide a good education and service base in Oklahoma farm production. The Oklahoma Cooperative Extension Service could be an important element in improving Oklahoma agricultural production through PA education.

Oklahoma Cooperative Extension Service

The Oklahoma Cooperative Extension Service (OCES) is involved in servicing many farmer needs in Oklahoma. The OCES is responsible for the transfer of information from the university to Oklahoma agricultural producers. Service programs in Cooperative Extension "focus on increasing opportunities for agricultural enterprises, natural resources and environmental management, food nutrition health and safety education, and youth, family, and community development" (OCES, 2004, p. 1). Futhermore, in a study of Mississippi cotton producers, it was shown that cooperative extension educators were considered an important source to producers for precision farming information (Martin & Cooke, 2002). According to a study in Iowa, cooperative extension agents were considered the second most important human resource for agricultural information following the Soil Conservation Service (Bruening & Martin, 1992). The Oklahoma Cooperative Extension Service has access to resources and the responsibility to educate farmers and help them to solve problems associated with agricultural production. Therefore, the Oklahoma Cooperative Extension Service is an important source of information for Oklahoma farm producers.

Summary of Literature Review

In Oklahoma, agriculture contributes to most non-point source pollution in the state (Derichsweiler, 2003). The sustainability of agriculture can be increased with the use of precision agriculture techniques in Oklahoma in order to decrease the inputs for this non-point source pollution (Larson et al.1997). Much of previous literature has found that obstacles to precision agriculture adoption include a need for a producer's guide to precision agriculture technologies comparing the advantages and disadvantages of different precision agriculture technologies, lack of widespread knowledge of environmental benefits of precision agriculture, lack of well trained educators, lack of PA education programs, lack of technological ability on the part of the producer, lack of availability of basic information in precision agriculture, inadequate data collection, misuse of information, lack of qualified precision agriculture services, and precision machinery technical difficulties (Kitchen, Snyder, Franzen, & Weibold, 2002), (Robert, 2002), (Wiebold, Sudduth, Shannon, & Kitchen, 1999). These studies suggest that PA education is very important in promoting and sustaining precision agriculture technology adoption (Weibold, Sudduth, Shannon, & Kitchen, 1999). The OCES is responsible for the education of farmers in Oklahoma. Therefore, it is important to evaluate the PA education needs of OCES educators in order to ensure their capacity to educate Oklahoma farmers.

Theoretical Framework

The theory base for this study was derived from three theories of technological change in social science. One theory (a macro-level theory) focuses on the education and instruction processes of institutions and individuals that surround the adoption of a technology (Sherry, Billig, Tavalin, & Gibson, 2000). This theory of technological change is referred to as the Integrated Technology Adoption and Diffusion Model (Figure 1).

The Integrated Technology Adoption and Diffusion Model describes the evolution of educators from learners (about the technology) to adopters of the innovation. Then, in the model, the educator is transformed from a co-learner in the education setting to an acceptor or rejecter of the innovation. This theory demonstrates the importance of innovation education among facilitators of learning, and it presents the process that must be promoted in order investigate the benefits of new technologies in different areas.

However, the applied lessons from this theory also show that there is an added element in the successful adoption of a technology. As Sherry, Billig, Tavalin, and Gibson, (2000) stated about the adoption of new technologies, “it is through community participation, not simply through individual agency or perceptions, that the total identity of the system is shaped and sustained” (Sherry, Billig, Tavalin, & Gibson, 2000, p. 47). Thus enters the need for community facilitators such as cooperative extension agents to be educated in order to promote the adoption and continued use of precision agriculture techniques.

The Integrated Technology Adoption and Diffusion Model is useful in describing educators’ progress in adopting innovations. This model will be used in the conclusions and recommendations of this study in order to describe OCES agricultural educators. In order to make progress, it is important to understand where OCES agricultural educators currently are in the Integrated Technology Adoption and Diffusion Model regarding precision agriculture.

Integrated Technology Adoption and Diffusion Model

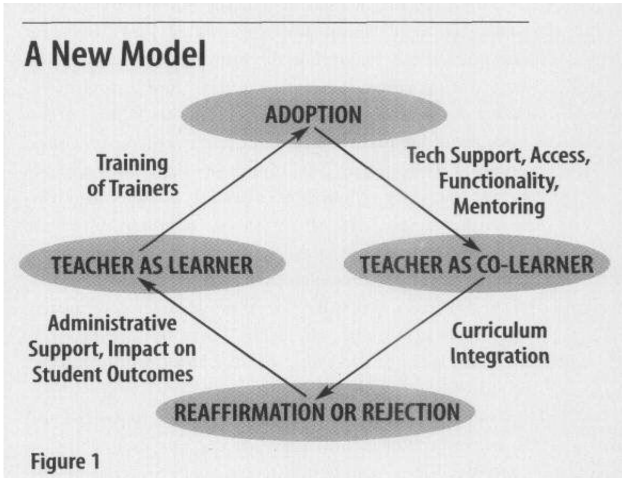

Figure 1.

Note. Taken from Sherry, Billig, Tavalin, & Gibson, 2000, p. 46.

The second theory base for this study was derived from Everett Rogers' *Diffusion of Innovations*model. The Perceived Attributes Theory by Rogers can be considered a micro-level theory or macro-level theory depending on context (Rogers, 2003). This theory states that the characteristics considered in the adoption of an innovation include trialability (being able to use the technology on a trial basis), observability (being able to decipher results), relative advantage (ability to identify the difference with the use of the innovation), complexity (how steep the learning curve is), and compatibility (ability to integrate the innovation into the current system of operation) (Rogers, 2003).

Grounding the need for precision agriculture literacy in OCES, the Perceived Attributes Theory is important because Oklahoma Cooperative Extension educators can address all of these considerations in order to promote the use of precision agriculture in farm production. Trialability, relative advantage, and complexity can be addressed in precision agriculture workshops. Observability can be created by OCES through demonstration farms. Compatibility should be considered on a case-by case basis by OCES in order to discover if precision agriculture would be financially productive for the producer based on diagnosed needs and size of the farm. Also, this theory demonstrates some of the obstacles that OCES educators must face in facilitating the adoption of precision agriculture among Oklahoma farmers.

The Perceived Attributes Theory is also useful in describing the adoptability of an innovation. In order for precision agriculture to be adopted, the trialability, relative advantage, observability, and compatability of the technology must be apparent to the producer. In the conclusions of this study, the precision agriculture technology that will best fit the Perceived Attributes Theory according to OCES agricultural educator perceptions will be described. Also this theory will be revisited in the recommendations of this study in order to describe PA education needs of OCES agricultural educators.

The third theory is the Innovation-Decision Process theory presented by Rogers. This is a five-stage model, which outlines the process of the adoption of an innovation (Rogers, 2003). In this model the stages include knowledge, persuasion, decision, implementation, and confirmation.

In the knowledge stage, the adopter begins learning about the innovation. The persuasion stage includes a person forming an opinion about the innovation through interaction with others. In the decision stage, a person accepts or rejects the innovation. At the implementation phase a person integrates the innovation into their system of operation. Finally, in the confirmation stage the person evaluates continuing the use of the innovation.

This model is very similar to the Integrated Adoption and Diffusion Model with the exception that Rogers' model is aimed toward the adopter and not the educator. Throughout this model, knowledge acquisition is important in moving through the different stages (Wilson, Sherry, Dobrovolny, Batty, & Ryder, 2000). The analysis of this model demonstrates the importance of educators in the distribution of knowledge in order for the adoption of technology to take place.

In this study, the current stage of Oklahoma farmers in the Innovation-Decision Process will be described by OCES participant descriptions of farmers. This theory will be used in making conclusions about the current stage of farmers. Also, recommendations concerning future research will be described in terms of the Innovation-Decision Process.

CHAPTER III

METHODOLOGY

This chapter describes the methods and procedures used in this study. The study was conducted in July of 2004 involving interviews of Oklahoma Cooperative Extension Service agricultural educators in 70 counties in Oklahoma. The data was collected from cooperative extension educators via telephone. Information was gathered in order to accomplish the purposes of describing the state of PA education in Oklahoma agricultural production and also needs for PA educational training in the Oklahoma Cooperative Extension Service. In addition, information was gathered to determine obstacles in the adoption of precision agriculture and obstacles in the dissemination of precision agriculture information in Oklahoma.

Objectives of the Study

1. Describe what precision agriculture services are provided to Oklahoma farmers through the Oklahoma Cooperative Extension Service by district.
2. Describe problems that Oklahoma Cooperative Extension Service educators have encountered with providing precision agriculture services in Oklahoma.
3. Describe why there may not be precision agriculture services available in some

areas of Oklahoma farm production.

4. Describe PA education needs of Oklahoma Cooperative Extension Service educators.
5. Describe the perceptions of selected Oklahoma agricultural service providers regarding precision agriculture.

Institutional Review Board (IRB)

According to Oklahoma State University's Statement of Assurance with the Department of Health and Human Service, the institutional review board must approve all research involving human subjects (OSU IRB Guide, 2004). The study acquired IRB approval in order to confirm respect for persons, beneficence, and justice in all contact with human subjects (IRB #AG053). Human subject contacts included telephone interviews with Oklahoma Cooperative Extension Service educators and telephone interviews with agricultural service providers.

The Study Population

The populations described in the study included Oklahoma Cooperative Extension Service educators and agricultural service providers. The study attempted a census of Oklahoma Cooperative Extension Service educators with a specialty in agriculture. There were 70 county level agricultural educators in Oklahoma cooperative extension as of July 20, 2004. The researcher obtained the population of Oklahoma Cooperative Extension Service agricultural educators through the Division of Agricultural Sciences and Natural Resources (DASNR) Personnel Directory.

Information for agricultural service providers was gathered via telephone interview. In order to satisfy objective five, a total of nine agricultural service providers who served in counties in Oklahoma were interviewed. These agricultural service providers were purposively selected (Creswell, Plano, Guttman, & Hanson, 2003). The researcher selected agriculture service providers in areas where the counties seemed different than the counties around them. Differences were found in answers to questions including why no precision agriculture services were provided in the county, what obstacles were encountered when providing precision agriculture services, why farmers may have stopped using precision agriculture, if there was a lack of interest in precision agriculture on the part of the producers in the county, and if there were enough precision agricultural companies to provide technical support in the county. The researcher chose ten agriculture service providers from farm net services at http://www.farmnetservices.com/ok/elevators/index.asp and at http://www.farmnetservices.com/ok/implement/index.asp. Of these ten, nine agriculture service providers participated. The agriculture service providers provided services in 18 different counties in Oklahoma. Service providers were located in eleven counties in the Northwest District. Most of the service providers were chosen in this district because of the great differences in the Northwest District compared to the rest of the state. One agriculture service provider provided services in the Southeast District and one provided services in the Northeast District. Finally, five agriculture service providers provided services in the Southwest District. Several of the agriculture service providers provided services in more than one county.

Sampling Procedure

The total population of cooperative extension educators was obtained through the DASNR list of the State of Oklahoma employees. From that list, each OCES agricultural educator was identified for the telephone interview. Of the 70 OCES agricultural educators, 90 percent participated in the study (n=63). Ten agriculture service providers were purposively sampled in order to triangulate data collected from OCES educators. Ninety percent of the service providers participated in the study (n=9). The data from these service providers was compared to data collected from Oklahoma Cooperative Extension Service educators located in service areas of the participating agricultural service providers.

Data Analysis

This was a descriptive study that attempted a census of a population. The study described what precision agriculture services are provided to Oklahoma farmers through the Oklahoma Cooperative Extension Service by district. Also, the study described problems that Oklahoma Cooperative Extension Service educators have encountered with providing precision agriculture services to Oklahoma farmers. Describing why there may not be precision agriculture services available in regions of Oklahoma and describing education needs of Oklahoma Cooperative Extension Service educators were also key dimensions of the study. Finally, the study described a representation of agricultural industry perceptions in regard to precision agriculture.

Therefore, descriptive statistics were utilized in describing the results of the study. After codes were identified, a binary system of evaluation was established using

Microsoft Excel in Windows XP in order to organize the data and to perform statistical analysis of the data. Significance testing was not performed in the study because the study was an attempted census that did not get data from every person in the population. Therefore, the study was based on a nonrandom sample (Grossnickle & Oliver, 2001). Significance testing is not appropriate in nonrandom samples (Henkel, 1976). Service providers were purposively sampled, and therefore significance testing was also not preformed on the findings obtained from that group.

Statistical analysis for this study was performed using *Microsoft Excel* The data analysis included means, modes, ranges, standard deviations, frequencies, and percentages.

Research Design

The survey used a mixed methods approach to answering the research questions (Creswell et al. 2003). A mixed methods study is one that "employs at least one method of quantitative and qualitative research" (Creswell et al., 2003). As of July 20, 2004, there existed 70 cooperative extension educators in Oklahoma with a specialty in agriculture. A census of this population was attempted via telephone interview in order to collect the data. Data from this population was triangulated with a telephone interview of agricultural service providers. The original telephone survey schedules were developed and pilot tested. Data collected during telephone interviews was both quantitative and qualitative. Data collected from service providers was compared to information gathered from cooperative extension educators located in the service area of the agricultural service providers.

Developing the Survey Instruments

Development of the study's questionnaires focused on ensuring validity and reliability. The content for the surveys was derived from an extensive literature review.

In order to discover Oklahoma precision agriculture issues and OCES education needs, interviews were conducted. Information regarding OCES educational needs and possible terminology problems were discovered through conversations with the Interim Associate Director for the Oklahoma Cooperative Extension Service and a group meeting with District OCES supervisors. Also, additional Oklahoma precision agriculture issues were discovered through conversations with leaders of precision agriculture companies located in Stillwater, Oklahoma. Content validity for the study was established through a panel of experts in both precision agriculture and agricultural education. In order to establish reliability of the instruments, pilot testing was performed. Validity measures "whether the measurement tool actually captures what we want it to" (Greeno, 2003). Reliability describes the "ability of the measurement tool to get the correct measurement" (Greeno, 2003). It is important to establish the existence of these measures in social science in order to discover if the research procedures accurately and precisely represent the phenomenon (Creswell et al. 2003).

Panel of Experts

The researcher selected a panel of experts for their ability to evaluate the content validity of the study's questionnaires based on their experience in research design, precision agriculture, education, cooperative extension, and technological change (Table 1). The panel of experts rated the instruments for precision agriculture technical accuracy, face validity, and content validity. The researcher made revisions to the questionnaires based on the experts' recommendations.

Table 1

Panel of Experts

Panel expert	Position	Expertise
Dr. Kathleen Kelsey	Agricultural Education, Associate Professor	Research Design, Adoption of Innovation, Evaluation
Dr. William Raun	Plant and Soil Sciences, Professor	Precision Agriculture
Dr. William Weeks	Agricultural Education, Professor	Education, Cooperative Extension
Dr. Michael Craig Edwards	Agricultural Education, Associate Professor	Technological Change

Pilot Testing

In the pilot test for the cooperative extension evaluation questionnaire, the researcher interviewed ten Kansas cooperative extension educators, who were not a part of the study. These cooperative extension educators were interviewed via telephone after being notified over the Internet of the impending pilot test. The researcher did not use the data gathered from these pilot tests in the study.

In the pilot test for the agricultural service provider questionnaire the researcher interviewed three Oklahoma agricultural service providers who were not part of the study.

The researcher revised the pilot instruments after analysis of each pilot test was conducted. Revisions included making more of the interview questions open-ended and using more specific language to clarify the intended questions.

Cooperative Extension Instrument Content

The content of the instrument used in this study addressed the objectives of the study.

The first portion of the instrument included ten questions in which the researcher asked Oklahoma Cooperative Extension Service agriculture educators about precision agriculture activities and educational programs provided in their county. The researcher asked all OCES participants to describe the precision agriculture work or activities that they were doing in their county. The researcher also asked all OCES participants if they provided PA educational programs in their county. The researcher asked those participants that provided PA education services if they provided pamphlets, seminars, workshops, technical support, precision agriculture profitability analysis, or technical training in their counties. PA educational topics including Global Positioning System (GPS) use, variable rate application, yield monitoring, and grid soil sampling, were explored. In addition, the researcher investigated Oklahoma Cooperative Extension Service education programs including questions about the provision of technical training, precision agriculture seminars, pamphlets, and workshops.

The second portion of the questionnaire gathered information about problems that the OCES agricultural educators had encountered when providing PA educational programs and services. The problems investigated included use of precision agriculture in diagnosing soil and other farm management problems, farmer obstacles in using precision agriculture in production, farmer opinions of precision agriculture, and other problems with precision agriculture use and adoption in their county.

The third objective was useful in counties where there existed no precision agriculture services provided by the OCES. The researcher used this objective to surface all obstacles for Oklahoma Cooperative Extension Service educators in providing PA education and services to Oklahoma farmers. The researcher asked OCES agriculture educators why they did not provide PA educational programs and services in their counties. The researcher assessed obstacles such as lack of precision agriculture dealerships or companies, lack of available funding, lack of farmer PA education need, and lack of farmer interest in precision agriculture.

The fourth section of the instrument was utilized to discover the PA education needs of Oklahoma Cooperative Extension Service educators. Cooperative extension educators must be provided with proper education in order to solve problems and to provide education in areas of production need. The purpose of this portion of the instrument was to evaluate the need for precision agriculture training programs for OCES educators.

The researcher asked all OCES agriculture educators if they would benefit from an inservice PA education program. If educators replied that they would benefit from PA education inservice programming, then they were also asked on what precision agriculture topic they would prefer education. Also, the researcher asked OCES educators what would be the best method of educating OCES educators. Later on in the interview, the researcher asked OCES participants if they had received PA education in the past. Also, in this section of the instrument, selected characteristics of the participants were gathered. See Appendix B for a copy of the survey.

Agriculture Service Provider Instrument Content

The purpose of the agricultural service provider questionnaire was to triangulate data obtained from Oklahoma Cooperative Extension Service educators. Triangulation is useful in order to "confirm, cross-validate, or corroborate finding within a single study" (Creswell, Plano, Guttman, & Hanson, 2000, p. 3). This was important in establishing the validity of data collected regarding the current state of precision agriculture in the counties that agriculture industry providers serviced. Comparison of agricultural service provider responses provided evidence of the validity of OCES educator comments (Stage & Russell, 1992). It is important to triangulate data in social science research in order to gather a complete picture of the noumena utilizing different viewpoints (LeBlanc, 2002). Objective five allowed for a more clarified view of the state of precision agricultural education in Oklahoma.

An interview was completed with nine agriculture service providers representing 18 counties in Oklahoma. Information triangulated via the agricultural service provider interviews included why no precision agriculture services were provided in the county, what obstacles were encountered when providing precision agriculture services, why farmers may have stopped using precision agriculture, and if there was a lack of interest in precision agriculture on the part of producers in that county. Also, in their interviews, agricultural service providers were asked if they were interested in receiving PA education or technical training. This was done to potentially identify a target audience for PA education delivered via the Oklahoma Cooperative Extension Service.

Increasing the Accuracy of Data

All of the interviews for this study were recorded in order to increase the accuracy of the data collected. The interviews were then transcribed and coded for unifying themes. Then, the data were organized in *Microsoft Excel XP* and statistical analysis was performed.

Response Rate

In this study, the Interim Associate Director for the Oklahoma Cooperative Extension Service asked OCES district members to advise their county agriculture educators of the up-coming interview in order to increase response rate. The response rate for the OCES agriculture educator survey was 90%. At the time of this study, seven counties in Oklahoma did not have OCES agriculture educators. Seven agriculture educators declined to participate. Thus, the total useable responses totaled 63 participants out of the 70 agricultural educators in the OCES.

CHAPTER IV

RESULTS AND CONCLUSIONS

The purpose of this chapter is to describe the results and conclusions of the study. Conclusions based on the data gathered for each objective are described immediately following each finding or objective.

Selected Characteristics of the Participants

Selected characteristics are described in order to provide a complete description of the population of Oklahoma Cooperative Extension Service educators and to describe the agriculture service providers who were used to triangulate data. Information was gathered in this portion of the OCES instrument including respondent characteristics such as age, gender, ethnicity, respondent college major and degree attained, university background of OCES participants, respondent experience in extension, and previous PA education of participating OCES agricultural educators.

Respondent Characteristics

Table 2 contains the statistical information for the age of Oklahoma Cooperative Extension Service participants.

Table 2

Oklahoma Cooperative Extension Service Participant Age Statistics (n=63)

Statistic	Age
Mean	42.67
Median	44
Mode	42
Standard Deviation	7.56
Range	25-56

Respondent Gender

All of the agricultural educators in the Oklahoma Cooperative Extension Service are male. Therefore, 100% of the study population is male (Table 3).

Table 3

Gender of Oklahoma Cooperative Extension Service Participants (n=63)

Gender	% OCES Participants
Male	100
Female	0
Total	100

Respondent Ethnicity

Table 4 described the ethnicity of OCES participants.

Table 4

Ethnicity of Oklahoma Cooperative Extension Service Participants (n=63)

Ethnicity	% OCES Participants
Native American	11.11
African American	3.18
Caucasian	82.53
Native American and Caucasian	3.18
Total	100

Respondent College Major and Degree Attained

In evaluating current needs in precision agriculture in the Oklahoma Cooperative Extension Service, past education emphasis is an important consideration. College major and degree attained are described in Tables 5 and 6.

Table 5

Bachelor's Degrees and Majors of Oklahoma Cooperative Extension Service Participants (n=63)

Degree and Major	% OCES Participants
Bachelor's: Animal Science	38.09
Bachelor's: Agricultural Education	38.09
Bachelor's: Double Major in Animal Science and Agricultural Education	11.11
Bachelor's: Agronomy	6.35
Bachelor's: Plant and Soil Science	3.18
Bachelor's: Agriculture Economics	1.59
Bachelor's: Agriculture Business	1.59
Total	100

Table 6

Master's Degrees and Majors of Oklahoma Cooperative Extension Service Participants (n=45)

Degree and Major	Frequency of OCES Participants
Agricultural Education	23
Animal Science	4
Plant and Soil Sciences	3
Education	3
Agronomy	2
Agriculture Business	1
Entomology	1
Personnel Services	1
School Administration	1
Agriculture Economics	1
Public Information	1
Business	1
Education	3

Note. Some OCES participants did not have a Master's Degree.

University Background of OCES participants

The researcher examined the university background of all of the Oklahoma Cooperative Extension Service participants in order to further describe the population (Tables 7 and 8).

Table 7

University Attended for Bachelor's Degree for Oklahoma Cooperative Extension Service Participants (n=63)

Degree and University	Frequency of OCES Participants
Refused	1.59
Oklahoma State University	80.94
Panhandle State University	3.17
Texas Tech University	3.17
Iowa State University	1.59
Kansas State University	1.59
South Dakota State University	1.59
Northeastern Oklahoma State University	1.59
Northwestern Oklahoma State University	1.59
Eastern Oklahoma State College	1.59
University of Illinois	1.59
Total	100

Table 8

University Attended for Master's Degree for Oklahoma Cooperative Extension Service Participants (n=45)

Degree and University	Frequency of OCES Participants
Oklahoma State University	32
Louisiana State University	2
Panhandle State University	2
Northwestern Oklahoma State University	2
Texas A&M University	1
Kansas State University	1
South Dakota State University	1
Southeastern Oklahoma State University	1
Oklahoma University	1
Oklahoma City University	1
East Central Oklahoma State University	1

Respondent Experience in Extension

Addressed in this portion of the survey was the issue of beginning educators who were not aware of the activities and educational programs that their county has to offer.

This information is found in Table 9. Participants' extension experience in other states is addressed in the next section.

Table 9

Years Oklahoma Cooperative Extension Service Participant Served as a County Educator (n=63)

Statistics	Years Served as OCES County Educator
Mean	14.92
Median	15
Mode	23
Standard Deviation	8.33
Range	.2 - 30

OCES Participant Extension Work in Other States

Of the OCES agricultural educators who participated in the study 7.94% had worked in Extension in other states. However, these participants had worked in OCES at least two months and were aware of their county's activities.

Objective 1

The first objective of this study was to describe what precision agriculture services are provided to Oklahoma farmers through the Oklahoma Cooperative Extension Service by district. Precision agriculture services that were identified in this study included activities (such as one-on-one work) and PA education provided to the farmers in the county. Precision agriculture activities were considered a separate entity from PA education because activities would include work in OCES that would not necessarily be considered the dissemination of university research. Precision agriculture activities are those that aid current use of precision agriculture, test the usefulness of precision agriculture, and demonstrate the positive or negative effects of using precision agriculture in production. PA educational programs aid in the dissemination of information from the university to the farmers in regard to the use of precision agriculture.

Precision Agriculture Activities in Oklahoma

The precision agriculture activities that Oklahoma Cooperative Extension Service educators took part in with farmers are presented by district and for all participants in Table 10.

Table 10

Precision Agriculture Activities in the Oklahoma Cooperative Extension Service (n=63)

Activity	Frequency Northwest District	Frequency Northeast District	Frequency Southeast District	Frequency Southwest District	Frequency All Counties
No activities	2	7	9	7	25
One-on-one work	8	3	2	5	18
Test Plots	7	4	0	6	17
Greenseeker demonstrations	8	2	0	3	13
GPS work	5	3	1	4	13
N rich strip work with farmers	5	2	0	3	10
Yield monitor Data	2	4	1	0	7
Subsurface irrigation work	2	0	0	0	2
Precision seeding-cotton	0	0	0	1	1

Note. More than one activity was used in some counties.

Precision Agriculture Activities in Oklahoma Conclusions

Different precision agriculture activities included work with global positioning systems, nitrogen rich strip work with farmers, yield monitor work, greenseeker technology demonstrations, subsurface irrigation work, one-on-one precision agriculture work with farmers, precision agriculture test plots, and precision seeding in cotton production.

Test plots were the most common activity for all OCES participants. In the Northwest District, precision agriculture one-on-one work with farmers was the most common activity. Yield monitor work and test plots were the most common activities in the Northeast District. One-on-one work was the most common activity in the Southeast District. Test plots were the most common activity in the Southwest District. The high number of demonstration or test plot activities in Oklahoma may indicate that Oklahoma is still in a testing mode in regard to precision agriculture.

In terms of the Integrated Technology Adoption and Diffusion Model, Oklahoma is still in stage one of the technology adoption process. Educators are still learning about precision agriculture themselves and most are not currently adopters of the innovation (especially in the Southeast District of Oklahoma). This is especially evident in the Northeast, Southeast, and Southwest OCES Districts of Oklahoma where most of the counties do not provide precision agriculture activities, education, or any other service and most of the participants in these districts would like additional PA education.

Some educators, especially in the Northwest District of OCES were in the third stage as a co-learner in the education setting and were moving to accept or reject precision agriculture as a useful innovation. This is evident in the high use of PA education and activities in these counties and the high number of counties that would like additional PA education. This difference in adoption stages should be used to develop different education strategies for OCES educators in each district in Oklahoma.

Northwest District educators need education to focus on the best types of precision agriculture technology for their district. Other districts need both broad and focused information to decide what precision agriculture practices may be useful in their counties.

According to Rogers' Perceived Attributes Theory, OCES agricultural educators are doing the best job of promoting trialability (being able to use the technology on a trial basis) and observability (being able to decipher results) in moving towards the adoption of precision agriculture in Oklahoma. However, more work needs to be done in this area to transition to the next levels of the Integrated Technology Adoption and Diffusion Model (Sherry et al., 2000).

PA education Services Available Through OCES

Table 11 describes OCES PA educational programs provided to farmers.

Table 11

PA education Provided Through the Oklahoma Cooperative Extension Service

PA education provided	% Northwest District (n=14)	% Northeast District (n=17)	% Southeast District (n=14)	% Southwest District (n=18)	% All Counties (n=63)
Yes	78.57	41.18	14.28	38.89	42.86
No	21.43	58.82	85.72	61.11	57.14
Total	100	100	100	100	100

PA education Services Available Through OCES Conclusions

PA education topics included precision agriculture database use, digital soil sampling, global positioning systems, variable rate application, yield monitor use, and subsurface irrigation efficiency. In all counties, global positioning systems and variable rate application were the most common types of education. The majority of the

Northwest district taught about variable rate application. PA education in the Northeast District was mostly regarding global positioning systems. Database use was the most common form of education in the Southeast. Global positioning system education was the most common form of PA education in the Southwest District.

This pattern of global positioning systems being the most common form of education in the Northeast and Southwest districts of OCES is notable. Many educators had volunteered during the interviews that farmers were using GPS systems to prevent overlap in their fields. Thus it could be applied to many more fields and pasture land where fertilizer is applied. This could be a form of precision agriculture that, according to the Perceived Attributes Theory, may provide a good relative advantage (ability to identify the difference with the use of the innovation), low complexity (how steep the learning curve is), and good compatibility (ability to integrate the innovation into the current system of operation) for may different types of cropping systems in Oklahoma.

PA education Methods Employed by Oklahoma Cooperative Extension Service Educators

Many Oklahoma Cooperative Extension Service agricultural educators utilized more than one method of PA education. These methods are described in Table 12.

Table 12

PA education Methods Employed by the Oklahoma Cooperative Extension Service (n=63)

Method of Educating	Frequency Northwest District	Frequency Northeast District	Frequency Southeast District	Frequency Southwest District	Frequency All Counties
None	3	10	12	11	36
Demonstrations	9	6	0	6	21
Meetings	7	3	2	6	18
Newsletters	7	5	2	4	18
Workshops	7	5	2	4	18

Note. Many Oklahoma Cooperative Extension Service agricultural educators utilized more than one method of PA education.

PA education Methods Employed by Oklahoma Cooperative Extension Service Educators Conclusions

Most of the agricultural educators did not provide PA education in their county. Demonstrations were the most common tool for educating farmers. OCES agricultural educators found hands-on methods of distributing information an effective way to teach and learn. This tendency was also found in OCES agricultural educators' own preference for education (Table 23).

Types of Precision Agriculture Information Provided in all Counties

Table 13 describes the types of precision agriculture information taught in OCES counties. Some educators provided more than one type of precision agriculture information.

Table 13

Types of Precision Agriculture Information Provided in All Counties (n=27)

PA education Subject	Frequency Northwest District	Frequency Northeast District	Frequency Southeast District	Frequency Southwest District	Frequency All Counties
GPS	6	4	0	6	16
Variable rate application	9	3	0	4	16
Database use	3	1	2	4	10
Digital soil sampling	0	3	0	4	7
Yield monitors	3	1	1	0	5
Subsurface irrigation	2	0	0	0	2

Objective 1 Conclusions

Objective one of this study was to describe what precision agriculture services were provided to Oklahoma farmers through OCES. Most of the Northwest District provided precision agriculture activities. However, in the Northeast, Southeast, and Southwest Districts, the majority of each district did not provide PA education through OCES. Most of the Southeast District does not provide precision agriculture services. This difference in Oklahoma regions may be due to different cropping systems. For instance, some of the participants stated that the reason that they did not provide precision agriculture services in their county was because their county farms were mostly pasturelands. No Northwestern District counties stated this as a reason for not having PA education programs.

Objective 2

The second objective of this study was to describe problems that Oklahoma Cooperative Extension Service educators encountered with providing precision agriculture services (education and activities) in Oklahoma. The purpose of this objective was to identify those factors that may be inhibiting the adoption of precision agriculture in Oklahoma. This objective was accomplished by asking questions of those OCES agriculture educators who currently provided agriculture education services in their county.

OCES use of Precision Agriculture to Diagnose Farm Problems

The researcher asked OCES participants who provided PA education services (n=27), "Do you use precision agriculture in diagnosing soil or other farm management problems for the farmers in your county?" The expected response was a "yes" or a "no." However some educators replied that they did not use precision agriculture to diagnose farm problems because they did not have precision agriculture equipment to do so. Therefore, an extra category was created to further describe those counties who did not use precision agriculture to diagnose farm problems. This category is titled, "Could not because there is no equipment available" (Table 11). This data is included in county data that did not use precision agriculture to diagnose farm problems. Only OCES educators that provided PA education services in their county were asked this question. The data for this question is found in Table 14.

Table 14

OCES Use of Precision Agriculture to Diagnose Farm Problems in Counties Where Precision Agriculture Services are Located (n=27)

Diagnose with Precision Agriculture	Frequency All Counties
Yes	10
No	17

Note. Only 27 of the participants answered this question.

Conclusions From OCES Participants who Diagnose Farm Problems with Precision Agriculture in Counties Where PA education Services are Located

Most of the OCES educators who provided precision agriculture services in their county did not diagnose farm problems with the use of precision agriculture. Some of the OCES educators volunteered that they could not use precision agriculture to diagnose farm problems because of the lack of available equipment. Lack of equipment for OCES educators is one obstacle in precision agriculture adoption in Oklahoma.

Participants Perceptions of Obstacles in Farmer use of Precision Agriculture in Oklahoma

The researcher asked OCES agricultural educators who provided PA education programs (n=27) to describe obstacles that they had encountered with farmers using precision agriculture in production (Table 15).

Table 15

Participants' Perceptions of Obstacles in Farmer use of Precision Agriculture in Oklahoma (n=27)

Farmer Obstacles in Using PA	Frequency Northwest District	Frequency Northeast District	Frequency Southeast District	Frequency Southwest District	Frequency All Counties
None	2	7	1	4	14
Cost	3	1	0	4	8
Technical	5	1	1	1	8
Production	1	0	0	0	1
Available Equipment	0	1	0	1	2
Not able to interpret data	2	1	1	1	5

Note: Some OCES educators described more than one obstacle.

Conclusions from Farmer Obstacles in the Adoption of Precision Agriculture in Oklahoma

The majority of OCES agricultural educators stated that there were no obstacles that they had encountered with farmers using precision agriculture in their county. There could be a few different explanations for this. First, the farmers could be getting help from a different source other than OCES agricultural educators. Second, the farmers that use precision agriculture currently may be advanced enough to not need help. Finally, most of the farmers may not currently use precision agriculture, and so they would not encounter any problems in that area. If this were the case, then it would suggest that in terms of the Innovation-Decision Process (Rogers, 2003) the farmers are still in either the Knowledge Stage or the Persuasion Stage of the process of adopting precision agriculture. This would mean that there is a great need for farmer education. Therefore, interviews of the farmers should be done to determine if the farmers are currently using precision agriculture, what they think of precision agriculture, and where they get their production information.

The cost of precision agriculture was cited as the most common adoption problem for farmers to adopt precision agriculture in Oklahoma. There was a common association in this category with high initial costs of precision agriculture and farmers who were about to retire or turn their ground to native range. This problem revealed that OCES educators should receive PA education including topics on inexpensive forms of precision agriculture (e.g. infrared aerial photography, precision agriculture databases, and attachable GPS units). Another option would be to initiate incentive programs for the use of precision agriculture.

Technical problems were an obstacle for adopters of precision agriculture in Oklahoma. Many educators cited some sort of technical issue that farmers had with using precision agriculture in production from the learning curve of technical precision agriculture to having “black spots” (misinformation locations on the map) on GPS readings. This information suggests that farmers who have adopted or will adopt precision agriculture in the future in Oklahoma, need or will need technical assistance from educators if not provided from some other source.

Farmers’ not being able to interpret data was an obstacle for farmer adoption in Oklahoma. In the Northwest, where precision agriculture was most readily used, more OCES agricultural educators described this as an obstacle than any other district. The Southeast District, where the least PA education in the state and the least precision agriculture activities occurred, had the second highest percent of farmers not being able to interpret data. Also, the Northeast District participants and the Southwest district participants described farmers who had trouble interpreting data. There is a need for additional farmer PA education in all districts, especially the Southeast District.

Available equipment problems in farmer adoption of precision agriculture existed in the Northeast and Southwest Districts. This problem suggests that there may be a need to initiate incentive programs for farmers to be able to invest in precision agriculture equipment. This also may promote the recruitment of precision implement dealers to these areas or encourage cooperatives to invest in the machinery and provide custom precision agriculture application.

Production problems were cited only in one instance in the Northwest District. This problem probably occurred in this district because there are a larger number of producers using precision agriculture in this region, and so there is larger room for error. In OCES participants there was only one case where the farmer discontinued precision agriculture use. This was because the use of precision agriculture was in demonstration plots and the cost was too great for the farmer to continue use of the technique in production. Therefore, once farmers invest in precision agriculture techniques, they seem to continue use.

Participants' Perceptions of What Farmers Think of Precision Agriculture in Oklahoma

In this study, the purpose of documenting precision agriculture educators' perceptions on farmer thoughts of precision agriculture was to discover any additional obstacles in the adoption of precision agriculture in Oklahoma. The researcher asked OCES agriculture educators who provided PA education in their county how farmers perceived precision agriculture (Table 16).

Table 16

Participants' Perceptions of What Farmers Think of Precision Agriculture (n=27)

Farmers' thoughts	Frequency Northwest District	Frequency Northeast District	Frequency Southeast District	Frequency Southwest District	Frequency All Counties
Initial costs are too high	4	3	0	1	8
Use commercial applicators	1	0	0	0	1
Precision agriculture is for the future…not now	5	1	0	3	9
Precision agriculture is not practical	2	3	0	2	7
Unsure of precision agriculture	2	2	1	2	7
Precision agriculture is useful	3	4	0	1	8
Not educated enough about precision agriculture to have an opinion	0	0	1	3	4
Not interested	0	1	1	0	2

Note: Many of the OCES educators who provided PA education described more than one perception of what farmers thought about precision agriculture.

Participants' Perceptions of Farmers' Thoughts on Precision Agriculture Conclusion

When asked what farmers in the area thought about precision agriculture, the greatest number of OCES educators claimed that farmers thought that precision agriculture was for the future and not a technology for now. Most of these counties were surprisingly in the Northwest District. Also, much of the participating Northeast District, Southeast District, and Southwest District claimed that farmers thought precision agriculture was for the future and not for the present. Others claimed farmers' thoughts included that the initial costs of precision agriculture are too high, precision agriculture is useful, precision agriculture is not practical, farmers were unsure about precision agriculture, farmers did not have enough PA education to have an opinion, farmers were not interested in precision agriculture, and farmers preferred to use commercial applicators when it came to precision agriculture.

Considering this data and the Perceived Attributes Theory (Rogers, 2003), counties need education where farmers think that precision agriculture is not practical, farmers were unsure about precision agriculture, and farmers did not have enough PA education to have an opinion. Education is needed to evaluate precision agriculture's trialability (being able to use the technology on a trial basis), observability (being able to decipher results), relative advantage (ability to identify the difference with the use of the innovation), complexity (how steep the learning curve is), and compatibility (ability to integrate the innovation into the current system of operation) in the counties, (Rogers, 2003). This may help to alleviate these obstacles in farmer adoption of precision agriculture in Oklahoma.

Participants' Perceptions of Other Problems Associated with Precision Agriculture

The researcher asked OCES agricultural educators who provided PA education in their county an open-ended question about describing any additional problems that OCES agricultural educators may have encountered with precision agriculture in Oklahoma (Table 17).

Table 17

Participants' Perceptions of Other Problems Associated with Precision Agriculture in Oklahoma (n=27)

Problems	Frequency
Cost	2
Lack of OCES training	3
Lack of awareness in OCES	3
No additional comments	19

Conclusions From Other Problems with Precision Agriculture

The data from the question of other problems with precision agriculture in Oklahoma provides additional evidence that OCES educators think that there is a need for PA education in the OCES. Cost, lack of OCES training, and lack of awareness in OCES were the responses from this question.

Objective 3

The third objective of this study was to describe why there might not be precision agriculture services available in some areas of Oklahoma farm production. The purpose of this objective was to describe OCES obstacles in the dissemination of precision agriculture information. All OCES agricultural educators who did not provide agricultural education were asked why there were no precision agriculture services in their county (Table 18).

Table 18

Participants' Perceptions of Why There are no Precision Agriculture Services and Education in Some Districts in Oklahoma (n=36)

Why no PA education and services	Frequency Northwest District	Frequency Northeast District	Frequency Southeast District	Frequency Southwest District	Frequency All Counties
Pasture lands	0	6	8	1	15
Not enough equipment through OCES	3	0	0	6	9
Farmers not interested	2	2	4	1	9
OCES educator training needs	1	2	1	0	4
Small farms	0	0	2	1	3
Producers lack knowledge about	1	0	0	2	3
Cost	0	0	0	2	2
Vacancies in OCES	1	0	1	0	2
Mostly trees in county	0	1	0	0	1
I have not got around to doing it.	0	1	0	0	1
Urban county	0	0	0	1	1
Dry land wheat	1	0	0	0	1

Note. Some OCES educators gave more than one response.

Conclusions for Obstacles in the Dissemination of Precision Agriculture Information

When asked why no PA education or services were offered in their county most of the participants said that most of the county that they served was pasture land. Of the Northwest District participants, no educators said this. A mostly pasture land county was the most common reason for no PA education in most of the participating Northeast District, Southeast District, and Southwest District. Providing OCES educators with information on different precision agriculture techniques that could be used on pasture land may increase PA education programs in Oklahoma.

Another reason given for no PA education and services in Oklahoma was that there was not enough equipment available through OCES. This was again a problem in the Northwest and also in the Southwest Districts of Oklahoma. Since this problem is reoccurring in these districts for both educators who did and who did not provide PA education and services to Oklahoma farmers, the Northwest and Southwest Districts described a need for more equipment in order to aid OCES educators in improving agriculture in Oklahoma.

Objective 4

The fourth objective of this study was to describe the PA education needs of Oklahoma Cooperative Extension Service educators. In order to accomplish this objective, the researcher asked all educators if they would benefit from an inservice PA education program (Table 21). Also the researcher asked all OCES agriculture educators on what precision agriculture topics (Table 22) they would prefer training and how they wished to receive this training (Table 23). In addition to this, the researcher documented previous PA education of OCES agriculture educators (Table 19). Also the researcher documented the method of their previous education (Table 20).

Table 19

Participation of Oklahoma Cooperative Extension Service Educators in Previous PA education (n=63)

PA education	% OCES participants
Little education	19.05
Yes	57.14
No	23.81
Total	100

Previous OCES PA education Conclusions

When the researcher asked OCES agricultural educators if they had previous PA education, most stated that they had previously received PA education. However, because a large number of OCES agricultural educators who stated that they had received little or no previous PA education, there is a definite need for precision agriculture inservice training in the OCES. Also, considering that most of the educators had attended inservice training, and many of these educators stated that they had received “a little” PA education. There is a need for more in-depth inservice training.

Method of Previous OCES Participant PA education

All OCES agriculture educator participants were asked by what method they were previously educated. The results of this question are presented in Table 20.

Table 20

Method by Which Oklahoma Cooperative Extension Service County Educator Received Previous PA education (n=48)

Method of PA education	Frequency of OCES participants
Inservice training	39
Certified crop advisor training	5
Oklahoma State University class	2
Oklahoma State University wheat field trial	1
Through demonstrations and hands-on work	6
Newsletters	1
Self-taught	5

Note. *Some participants (5) had received PA education by more than one method.*

Conclusions From Method of Previous OCES Participant PA education

Most OCES agriculture educators had attended inservice training from Oklahoma State University in order to receive PA education. Obtaining PA education through demonstrations followed this. Most OCES PA education comes from inservice training opportunities.

Need for PA education

In the survey, the researcher asked OCES agricultural educators if they would benefit from an inservice precision agriculture program. All participants were asked this question (Table 21).

Table 21

Oklahoma Cooperative Extension Service Educator's Perceived Need for PA education in Each District (n=63)

Would you benefit from more PA education?	Northwest District%	Northeast District%	Southeast District%	Southwest District%	All %
Yes	92.86	94.12	78.57	88.89	88.89
No	7.14	5.88	21.43	11.11	11.11
Total	100	100	100	100	100

Need for PA education Conclusions

A great majority of the OCES agriculture educator participants thought that they would benefit from more inservice PA education.

Precision Agriculture Subjects on Which OCES Participants Wished to Receive Education

All OCES educator participants were asked what subject they would prefer to receive education on in terms of precision agriculture. Participants were told that they could choose from a list consisting of the economic benefits of precision agriculture, environmental benefits of precision agriculture, societal benefits of precision agriculture, and technical training in precision agriculture, or they could describe another aspect of precision agriculture on which they would like education (Table 22).

Table 22

Precision Agriculture Subjects on which Oklahoma Cooperative Extension Service Educators Wished to Receive Education (n=56*)*

Subject in Precision Agriculture	Frequency Northwest District	Frequency Northeast District	Frequency Southeast District	Frequency Southwest District	Frequency All Counties
Economic benefits	12	13	9	14	48
Technical training	10	8	7	8	33
Environmental benefits	5	6	5	9	25
Kinds of PA available	4	3	2	4	13
Indicated that economics is the most important	3	4	2	2	11
Societal benefit	3	1	1	2	7
Grazing land uses	0	4	1	2	7

Note. Some of the OCES agricultural educators chose more the one subject, and some did not think that they would benefit from PA education.

Precision Agriculture Subject Conclusions

Most OCES agriculture educators would like education on the advantages and disadvantages of different precision agriculture practices. Also, the data shows that OCES educators would like to have technical training in precision agriculture. Education on the environmental benefits of precision agriculture was important to many of the participants. Many of these educators indicated that the environmental aspect of precision agriculture might be a driving force for adoption in the future. Finally, some participants volunteered that they would prefer education on grazing land uses for precision agriculture. Considering the frequencies of similar requests in all of these PA education categories, all of these subjects should be taught through OCES inservices. This is with one exception. The Northwest District did not have any participants who requested pastureland PA education. Therefore, this district may not benefit from grazing land precision agriculture information.

Preferred Method for Receipt of PA education for OCES Educators

The researcher asked all participating OCES agricultural educators who thought they would benefit from PA education and what method was best for educating agricultural educators in OCES. Some participants chose more than one method of education, and some participants of the study did not want an inservice PA education program (Table 23).

Table 23

Preferred Method for Receipt of PA education for Oklahoma Cooperative Extension Service Educators (n=56)

Method	Frequency Northwest District	Frequency Northeast District	Frequency Southeast District	Frequency Southwest District	Frequency All Counties
Hands-on	11	10	6	4	31
Demonstrations	4	7	2	4	17
Inservice	1	0	1	6	8
Email updates	1	0	4	1	6
District meetings	1	1	3	1	6
Classroom	1	1	1	2	5
With specialists	0	0	0	2	2
Short course	0	0	1	1	2
Printed material	0	0	1	0	1

Note. Not all OCES agriculture educators thought that they would benefit from precision agriculture education, and some chose more than one method of education.

Preferred Method for Receipt of PA education for OCES Educators Conclusions

Most of the OCES agricultural educators preferred hands-on training in precision agriculture. The participants preferred demonstrations second to hands-on training. Additionally, Email updates were requested by some of OCES educators. Therefore, future PA education OCES inservices should include hands-on work and demonstrations. Also Email updates should be sent between inservices.

Objective 5

The fifth objective of this study was to describe agricultural industry perceptions in regard to precision agriculture. Also, the researcher gathered data on the PA education needs of agricultural service providers. Nine agriculture service providers were interviewed via telephone. One agriculture industry provider declined to participate. Five agriculture service participants were farmer cooperatives and four were implement dealers. The agriculture service providers conducted business in 18 counties in Oklahoma. It was found that OCES agriculture educator data and agriculture industry perceptions were very similar. Four out of nine interviewees did not provide precision agriculture services. Of these four, the reasons for not providing PA education services included not being familiar with precision agriculture (one agriculture service provider), not interested in precision agriculture (one agriculture service provider), and not usually buying precision agriculture equipment (two agriculture service providers).

Five out of the nine agriculture service providers provided precision agriculture equipment or services. Three out of the nine agriculture service providers used precision agriculture services in custom applications. Three provided soil-sampling services. Four agriculture industry providers provided GPS units in different types of equipment including “rigs,” combines, and gators. Two agriculture service providers provided equipment with GPS guidance systems in tractors.

The researcher compared data between agriculture industry professionals and OCES agriculture educators. The data was consistent. In the four counties where a service provider did not provide PA education services, corresponding OCES educators indicated that there were no precision agriculture dealerships or companies to provide precision agriculture technical support in the county. In all other counties where precision agriculture services were provided by the OCES agricultural educator, the researcher did not ask OCES agriculture educators if there were precision agriculture service providers or equipment dealers in their county because PA education and services were provided through OCES.

All agriculture service providers who had precision agriculture customers said that they had never experienced a farmer discontinuing use of precision agriculture. This is consistent with data from cooperative extension educators. Only one OCES participant indicated that a farmer discontinued the use of precision agriculture. This was because the use of precision agriculture was in demonstration plots and the cost was too great for the farmer to continue its use.

Two out of the nine agriculture service providers stated that they did not know if farmers in the area were interested in precision agriculture. Three out of nine agriculture service providers indicated that farmers were not interested in precision agriculture. Four out of nine agriculture service providers perceived that farmers were interested in precision agriculture. Finally, it was found that five out of nine service providers indicated that they would prefer additional PA education for their company.

Objective 5 Conclusions

The fifth objective of this study was to describe agricultural industry perceptions in regard to precision agriculture. The purpose of this objective was to triangulate data gathered from OCES agriculture educators. Also data was gathered on the PA education needs of agriculture service providers. It was found that OCES agriculture educator data and agriculture industry perceptions were very similar. This suggests that the data collected was valid.

CHAPTER V

SUMMARY AND RECOMMENDATIONS FOR PRACTICE

In this chapter a summary of the study is presented. Also, recommendations as a result of the conclusions are described.

Purpose of the Study

Describing the current state of PA education and services in the Oklahoma Cooperative Extension Service and discovering obstacles in the adoption of precision agriculture in Oklahoma was the two-fold purpose of the study. This description was necessary in order to determine the needs of extension educators who are charged with providing PA education and services to farmers in Oklahoma. This information could be used in order to promote PA education in Oklahoma. This is not to say that precision agriculture is practical for every farm. However, education must be provided so that OCES educators and farmers can make informed decisions about the best precision agriculture techniques to optimize production and improve environmental sustainability. Recommendations from this study should be implemented into inservice programs in the Oklahoma Cooperative Extension Service to ensure that OCES educators may provide precision agriculture services and education to farmers with competence.

Objectives of the Study

In order to fulfill the purpose of the study, five objectives were created. These objectives included:

1. Describe what precision agriculture services are provided to Oklahoma farmers through the Oklahoma Cooperative Extension Service by district.
2. Describe problems that Oklahoma Cooperative Extension Service educators have encountered with providing precision agriculture services in Oklahoma.
3. Describe why there may not be precision agriculture services available in some areas of Oklahoma farm production.
4. Describe PA education needs of Oklahoma Cooperative Extension Service educators.
5. Describe the perceptions of selected Oklahoma agricultural service providers regarding precision agriculture.

Scope of the Study

This study was a descriptive study of Oklahoma Cooperative Extension Service agricultural educators. An attempted census resulted in 63 participants out of 70 OCES agricultural educators. Claims are only made in reference to participants in this survey. Extending or generalizing these findings beyond this group of participants is not advisable.

Summary of Methods and Procedures

This survey used a mixed methods approach to answer the research questions. As of July 20, 2004, there were 70 cooperative extension educators in Oklahoma with a specialty in agriculture. A census of this population was attempted via telephone interview in order to collect the data. Data from this population was triangulated with a telephone interview of agricultural service providers. Data collected during telephone interviews was both quantitative and qualitative. The researcher compared data collected from nine agricultural industry service providers to information gathered from OCES educators located in the service area of the agricultural service provider. This was done in order to triangulate data from Oklahoma Cooperative Extension Service educators.

Sampling Procedure

The researcher obtained the total population of cooperative extension educators through the Division of Agricultural Sciences and Natural Resources personnel directory of the State of Oklahoma employees. From that list, the researcher identified each OCES agricultural educator for a telephone interview. The researcher purposively selected ten agriculture service providers from the Farm Service Website. Ninety percent of these agriculture service providers participated in the study. The data from these service providers was compared to the data collected from OCES educators located in the service area of that agricultural service provider.

Statistical Analysis

Statistical analysis for this study was performed utilizing *Microsoft Word Excel*. The data analysis included calculation of means, standard deviations, frequencies, and percentages. No tests of significance were performed because participant groups in the study were nonrandom samples.

Recommendations Based on Major Findings

The major findings of the study were described in terms of the objective(s) supported by the finding.

1) Global positioning system use in Oklahoma may provide a good relative advantage (ability to identify the difference with the use of the innovation), low complexity (how steep the learning curve is), and good compatibility (ability to integrate the innovation into the current system of operation) (Rogers, 2003) for many different types of cropping systems in Oklahoma. Therefore, OCES should provide inservice training on the use of global positioning systems.
2) OCES educators should receive PA education including topics on inexpensive forms of precision agriculture (e.g. infrared aerial photography, precision agriculture databases, and attachable GPS units).
3) Northwest and Southwest Districts should be provided with more precision agriculture equipment in order to allow OCES agricultural educators to diagnose soil or other farm management problems with precision.
4) OCES should make more precision agriculture tools available for all OCES agriculture educators in order to provide hands-on PA education to farmers.
5) There is a need for additional farmer PA education in all districts, especially the Southeast District based on farmer data interpretation problems. Therefore, OCES should increase the number of PA education services provided to farmers in Oklahoma.
6) Because many participating OCES agriculture educators received little or no previous PA education, there seems to be a definite need for precision

agriculture inservice training in the OCES.

7) Most OCES agricultural educators reported that they would benefit from additional PA education. Therefore in-depth inservices in precision agriculture should be implemented for OCES agricultural educators.
8) Training is needed in order to be able to evaluate precision agriculture's trialability (being able to use the technology on a trial basis), observability (being able to decipher results), relative advantage (ability to identify the difference with the use of the innovation), complexity (how steep the learning curve is), and compatibility (ability to integrate the innovation into the current system of operation) in each county (Rogers, 2003). Therefore, precision agriculture demonstrations should be increased.
9) OCES educators should receive information on different precision agriculture techniques that may be used on pasture land Oklahoma. However, the Northwest district may not benefit from grazing land precision agriculture information considering that no educators requested this type of training.
10) Future OCES inservice training should focus on the economic advantages and disadvantages of different precision agriculture practices.
11) Future OCES inservice training should also include technical training, what kinds of precision agriculture technology is currently available, pasture and grazing land uses for precision agriculture, and environmental benefits of precision agriculture.
12) Future PA education OCES inservices should include training methods

that emphasize hands-on work and demonstrations.

13) Email updates should be sent between precision agriculture inservices.

Summary of Recommendations

Precision agriculture services and education must be readily available to encourage Oklahoma farmers to evaluate implementing the use of precision agriculture technology into their production systems. Also, OCES PA education and services should be made available to aid those producers that have already adopted precision agriculture techniques. Precision agriculture is a tool that could improve the lives of Oklahomans. There are several steps to the PA education and adoption process that could be furthered by OCES. Therefore, educators must be competent in their ability to provide accurate PA education and services to Oklahoma farmers. In-depth precision agriculture inservices should be offered to OCES agricultural educators in order to better serve Oklahoma farmers and to further the precision agriculture adoption process in the state. In addition, OCES should increase PA education and activities provided for farmers in Oklahoma.

Recommendations for Further Study

Further research is needed in several areas of precision agriculture adoption in Oklahoma. More research should be done to document farmer perceptions of precision agriculture in order to describe the interest in precision agriculture in Oklahoma.

Future research needs to document via farmer interviews the actual use of precision agriculture in Oklahoma by farmers. Also future research should document the satisfaction and problems with precision agriculture as perceived by farmers.

Also, the progress of the Oklahoma Cooperative Extension Service in terms of obtaining and distributing PA education should be researched further at a later date in order to document the progress in this organization.

In addition, farmers' potential use of incentive programs for precision agriculture should be investigated, (e.g. via farmer interviews). This would build a solid investigation for future incentive program needs.

Also, the farmer stage of the Innovation-Decision Process Theory (Rogers, 2003) should be investigated further, (e.g. via farmer interview). Objectives of this research should include describing farmers who are currently using precision agriculture, describing what farmers think of precision agriculture, and describing where farmers get their production information.

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APPENDICES

APPENDIX A

IRB APPROVAL

Oklahoma State University Institutional Review Board

Date: Friday, August 13, 2004

IRB Application No AG053

Proposal Title: Sustainable Agriculture in Oklahoma: A Study of Oklahoma Cooperative Extension Needs for Precision Agriculture Education and Other Obstacles in the Adoption of Precision Agriculre in Oklahoma

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved **Protocol Expires: 8/12/2005**

Principal Investigator(s):

Beth Crumpler
3227 Raintree
Stillwater, OK 74074

Kathleen Kelsey
466 Ag Hall
Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

[X] The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact me in 415 Whitehurst (phone: 405-744-1676, colson@okstate.edu).

Sincerely,

Carol Olson, Chair
Institutional Review Board

APPENDIX B

SURVEY INSTRUMENTS

Oklahoma Cooperative Extension Service Telephone Interview Instrument

Thank you for participating in the study. I appreciate your help.

I. (Ask all)

1. How would you describe the concept, idea, or practice of precision agriculture?

    - Informational software bases
    - Digital soil mapping
    - Geographical information systems
    - Global positioning systems
    - Ground based sensors
    - Remote sensing technologies
    - Variable rate application technologies
    - Yield monitoring systems

Ok, I will use your concept of precision agriculture for the rest of this interview.

2. Can you describe to me any work and/or activities you may be doing with these precision agriculture practices?
    - This is what I will be asking you about in this interview.

3. Are there any precision agriculture 1.services, 2. activities, or 3. educational programs offered in your county by OCES?
    a. Tell me about PA education or services offered.
    b. Is technical support provided through OCES?
    c. Do you have a place of referral for precision agriculture technical support?
    d. (The following three questions are yes or no answers) Do you provide information to farmers about precision agriculture through:
        1. Pamphlets?
        (If yes), on what precision agriculture practices?
        2. Seminars?
        (If yes), on what precision agriculture practices?
        3. Workshops?
        (If yes), on what precision agriculture practices?
        4. Precision Agriculture Farm Profitability Analysis?
        (If yes), on what precision agriculture practices?
        5. Precision Agriculture Technical Training?
        (If yes), on what precision agriculture practices?

4. Tell me about work you may have done with precision agriculture databases in working with Oklahoma farmers.
    i. Have farmers had any difficulties with these products?
        1. Can you describe these difficulties?

B. Tell me about any difficulties you may have come across in dealing with precision agriculture databases.

5. Tell me about any work you may have done with digital soil sampling.

6. Tell me about any work you may have done with GPS (global positioning systems).

7. Tell me about any work you may have done with Variable Rate Application.

    - Farm yield problems?
    - Herbicide control problems?
    - A need for decreased use of irrigation?
    - Pesticide control problems?

8. Tell me about yield monitor work OCES has done in your county.

9. Is there anything else to add about precision agriculture 1. services, 2. activities, or 3. education provided in your county?

10. Are you aware of greenseeker technology?
    A. How did you become aware of greenseeker technology?

11. Have any of the farmers in your area expressed interest in greenseeker technology?

12. Do you know of anyone in your area that currently uses greenseeker technology?
    A. Have they had any difficulties with the product?
    B. Can you describe these difficulties?
    C.Have they achieved increased yields with the product?

II. (Ask if yes on objective I.)

1. Do you use precision agriculture in diagnosing soil or other farm management problems for the farmers in your county?
   A. What precision agriculture practices do you use?
   B. Have you encountered any difficulties in using precision agriculture to diagnose farm problems?
   C. What were these difficulties?

2. Tell me about any obstacles that you have encountered with farmers using precision agriculture in production.
   - Technical support issues
   - Decreased production issues
   - Other obstacles

3. Tell me about any experience you may have had with farmers that have stopped using precision agriculture.

- What precision agriculture practices were they previously using?
- Why did they stop?
- How many farmers would you estimate have stopped using this technique?
- Have you had experience with any other farmers discontinuing any other techniques in precision agriculture?
- What techniques were these?
- Why did they stop?

4. What do farmers in your county think about precision agriculture?

5. Have you encountered any problems with farmers not being able to interpret data?

6. Is there anything else to add about problems that you may have encountered with precision agriculture in your county?

III. (Ask if no on objective I.)

1. Why do you think that there are no OCES precision agriculture services available in your county?

2. Do you know of any farmers in your area who use precision agriculture?

    i. Can you describe these farmers?
    ii. How many farmers would you say use precision agriculture in your county?

3. Are there enough precision agriculture companies to provide precision agriculture technical support in your area?

4. Are there any precision agriculture dealerships in your county?

5. Is there a topography problem with utilizing precision agriculture in your area such as mountains?

6. Do farmers in the area express any interest in precision agriculture to you?
    i. Tell me about the farmers' interests.

7. Does OSU make funding available for PA education and services in your county?

8. Do you think that farmers in your county need PA education and services?
    A. Why?

9. Is there any other reason for not having precision agriculture services in your county?

IV. (Ask all)

1. Do you think that you would benefit from an in-service PA education program?
    a. What would you like education on?
        i. Economic benefits of precision agriculture
        ii. Environmental benefits of precision agriculture
        iii. Societal benefits of precision agriculture
        iv. Technical training in precision agriculture

    b. Tell me what you might use precision agriculture technical training for in your work as an OCES educator?

    c. What is the best method of PA education for OCES educators?

2. How long have you worked in extension?
    a. Have you worked in any other states?
    b. How long have you worked in the Oklahoma Cooperative Extension Service?

3. What is your educational background? (For instance college major, degree attained, ect.)

4. What institution did you graduate from?

5. Have you had PA education in the past?
    a. How did you receive this PA education?

6. How old are you?

7. Do you consider yourself:
   White
   Black
   Asian
   Hispanic
   Mixed-race

8. Are you male or female?

That is the end of the questions. Thank you for your help.

Oklahoma Agriculture Service Provider Telephone Interview Instrument

Thank you for participating in the study. I appreciate your help.

I. (Ask all)

4. How would you describe the word precision agriculture?

    - Informational software bases
    - Digital soil mapping
    - Geographical information systems
    - Global positioning systems
    - Ground based sensors
    - Remote sensing technologies
    - Variable rate application technologies
    - Yield monitoring systems

Ok, I will use your concept of precision agriculture for the rest of this interview.

5. Can you describe to me any work and/or activities you may be doing with these precision agriculture practices?
    - This is what I will be asking you about in this interview.

6. In what counties in Oklahoma does your company usually provide agricultural services?

7. Tell me about precision agriculture equipment that your company may make available in your service area.
    A. About how many farmers in the area would you say use this equipment?

8. Tell me about any precision agriculture database software that your company may make available to Oklahoma farmers.

9. Tell me about any digital soil sampling practices or equipment that your company may provide in your area.

10. Does your company provide assistance in using precision agriculture practices in your area?
    - Can you describe this assistance?
    - For what precision agriculture techniques do you provide assistance?

II. If yes on any 5-8

1. Tell me about precision agriculture mechanical or software technical support that your company may provide in your service area.
    - For what precision agriculture practices do you provide technical support?

2. Have you had any farmers discontinue the use of any precision agriculture

    practices?

    A. Why?
    B. What type of precision agriculture was being used?

3. Tell me about any difficulties farmers may have had with using precision agriculture in your area.
    - Difficulties with machinery or data interpretation
    - Production problems

4. Do any employees have problems helping farmers to interpret data?

III. (if no on all 5-8)

1. Why do you think that your company does not offer precision agriculture services?

2. How do the producers in your area feel about precision agriculture?

IV. (Ask all)

1. What PA education would your company be interested in?

2. Have you heard of greenseeker technology?

3. Have any of the farmers in your area expressed interest in greenseeker technology?

4. Do you know of anyone in your area that currently uses greenseeker technology?

A. Have they had any difficulties with the product?
B. Have they achieved increased yields with the product?

5. How many farmers would you say utilize your company's services?

6. How many people does your company employ?

7. How would you describe your company?

VITA

Beth Elaine Crumpler

Candidate for the Degree of

Master of Science

Thesis: SUSTAINABLE AGRICULTURE IN OKLAHOMA: A STUDY OF OKLAHOMA COOPERATIVE EXTENSION NEEDS FOR PRECISION AGRICULTURE EDUCATION AND OTHER OBSTACLES IN THE ADOPTION OF PRECISION AGRICULTURE IN OKLAHOMA

Major Field: Agricultural Education

Biographical:

Personal Data: Born in Oklahoma City, Oklahoma on September 18, 1978, the daughter of Cecil J. and Betty E. Tomlinson.

Education: Graduated from Chisholm High School, Enid, OK in May 1996; received Bachelor of Science degree in Animal Science from Oklahoma State University, Stillwater Oklahoma in May 2001. Completed the requirements for the Master of Science Degree with a major in Agricultural Education, Communications, and 4-H Youth Development at Oklahoma State University in December 2004.

Experience: Worked as a research intern for Seaboard Farms in Rolla, Kansas from May 2000 to August 2000. Worked as an undergraduate research assistant at Oklahoma State University in Stillwater, Oklahoma from February 2000 to May 2001. Worked as a swine production management trainee at Murphy Farms in Laverne, Oklahoma from May 2001 to August 2001. Worked as a substitute teacher in Enid, Oklahoma and Stillwater, OK from August 2001 to March 2002. Worked as a graduate research assistant for Oklahoma State University in Stillwater, Oklahoma from January 2004 to December 2004.