# FACTORS DETERMINING ADOPTION OR NON-ADOPTION OF PRECISION AGRICULTURE BY PRODUCERS ACROSS THE COTTON BELT

A Thesis

by

CHRISTOPHER BERNARD LAVERGNE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2004

Major Subject: Agricultural Education

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## ABSTRACT


Factors Determining Adoption or Non-adoption of Precision Agriculture by Producers Across the Cotton Belt. (December 2004)

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The purpose of this study was to determine factors influencing cotton producer adoption of Precision Agriculture in the cotton belt according to members of the American Cotton Producers of the National Cotton Council.

The National Research Council's Board on Agriculture defines Precision Agriculture (PA) as "a management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production." For the purpose of this study, Precision Agriculture technologies included yield monitors, global positioning units, variable rate applicators, and similar components.

Many studies have found that adoption of Precision Agriculture can be profitable for agricultural producers. However, the fact that Precision Agriculture is relatively new and unproven hinders rapid adoption by agricultural producers. According to the National Research Council Board of Agriculture widespread adoption relies on economic gains outweighing the costs of the technology. This study attempted to find the factors associated with adoption of these technologies in the cotton belt.

The sample population consisted of cotton producer representatives from the leading cotton-producing states. A Delphi approach was utilized to establish a consensus of cotton producer perceptions of the advantages of adopting Precision Agriculture technologies. Advantages included more accurate farming (i.e., row spacing, reduced overlap, and cultivation). Barriers to adoption were also documented, questioning employee capability to operate equipment, learning curve, technology complexity, and uncertain return on investment.

# DEDICATION

This thesis is dedicated to my loving family. India, thank you for all you’ve sacrificed to make this degree a reality. From relocation to financial strains, you’ve been a sound nucleus for us all. I’d also like to thank Colby, Noah, and Lucas for putting up with Dad during this busy season. I couldn’t ask for a more loving and supportive family unit. God has truly blessed us.

## ACKNOWLEDGEMENTS

First and foremost, I'd like to give thanks and praise to God. Earning this degree is a far cry from my beginning—welding concrete trowels. We can truly do all things through He who gives us strength!

I must acknowledge my family for supporting my pursuit of this degree. I know it's not over yet, but we are that much closer. India, you are the best wife in the world. To leave the Flint Hills is enough sacrifice, not to mention all that you've endured in the last two years. Thank you, honey. I love you.

To my parents, Linton and Alpha Lavergne, I thank you for teaching me the value of persistence and detail. I'll never forget to check, double check, and triple check.

I would also like to thank Dr. Tracy Rutherford and Dr. Kris Boone (Kansas State University) for igniting my interest in research. Tracy, I doubt we would have come down to A&M without your support and encouragement. Thank you for being such a great resource and friend over the last six years.

To my other graduate committee members—Dr. Gary Wingenbach, Dr. Chris Boleman, and Dr. Robert Lemon—I appreciate your contribution to this research effort and great ideas. Dr. Boleman, KSU will overtake the Aggies one day- mark my words.

Thank you to my colleagues from the Institute of Food Science & Engineering. Dr. Andy Vestal, I appreciate the professional guidance you've provided. Charlie Young, Nancye Penn, Lyne Galloway, and Grace Wilkinson, thank you for helping me to laugh especially in the hectic times. We've perfected firefighting!

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# CHAPTER I

# INTRODUCTION

Technology transfer has been a driving force in crop and livestock management for the past century. Beginning with the advancement from horse and plow production practices in the 1890s to the use of internal combustion systems in tractors during WWI, agricultural technology has advanced at a rapid rate (National Academy of Engineering, 2000). These advances have improved efficiencies in all commodities especially cotton. The evolution of cotton harvesting from handpicked in the 1940s to mechanized cotton pickers thirty years later, revolutionized the industry (Grove, 2000). In fact, the mechanical cotton picker was responsible for expanding the region of heavy cotton production from the Deep South to dryer areas like West Texas (White, 2000).

Producer adoption of agricultural technologies has been well documented. Not since the rapid diffusion of hybrid seed corn in the 1930s (Ryan & Gross, 1943) has there been an agricultural technology with the magnitude and potential of precision agriculture. For the purpose of this study precision agriculture includes the use of global positioning systems (GPS), yield monitors, and other site-specific management technologies. Precision agriculture provides agricultural producers the ability to delineate between productive and non-productive sections of their fields, and manage the variability in soil and mineral distribution.

The responsibility of diffusing agricultural technologies often lies in the hands of

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This thesis follows the style of the *Journal of Agricultural Education*.

the Cooperative Extension Service. The Cooperative Extension Service was built on the premise of educating Americans, primarily rural Americans (Buford, Bedeian, & Lindner, 1995). While the target audience has broadened to reach urban America, farming and ranching still constitutes a large segment of Extension programming.

The adoption of agricultural technologies, from tillage practices to the use of genetically modified crops, has been researched in many regions. Although efforts are currently underway to accommodate producers' precision agriculture needs in various crops (Arnholt, 2001; Roberts, English, & Larson, 2002; Segarra, 2002; Wiebold, Sudduth, & Davis, Shannon, & Kitchen, 1998), little research has been conducted investigating the diffusion of this innovation in cotton.

The target audience for this study consisted of the representatives for the American Cotton Producers (ACP) of the National Cotton Council. This organization was chosen as the expert panel because they are considered opinion leaders for the commodity in the 16 states that constitute "The Cotton Belt."

## Purpose of the Study

The purpose of this study was to determine factors influencing or prohibiting cotton producer adoption of precision agriculture (PA) technologies in the leading cotton-producing states, as perceived by American Cotton Producers of the National Cotton Council representatives.

## Research Objectives

Research objectives were developed to support the purpose of the study:

1. Identify perceived advantages of adoption of PA technologies.
2. Identify perceived barriers to adoption of PA technologies.
3. Identify information sources used by cotton producers to learn about PA technology.

## Significance of the Study

This study will help field practitioners (i.e., Extension specialists and private PA sales personnel) in developing practical PA solutions for cotton producers. The information will provide insight into this particular expert panel of cotton representatives' perceptions of the technology. Kitchen, Snyder, Franzen & Wiebold (2002) commented on the complexity of training individuals to use PA technologies, and recommended that an understanding of explicit producer needs is necessary to provide product research & development and direction for educational objectives. This study will provide insight into the critical issues that help or hinder precision agriculture adoption, according to the selected expert panel of cotton representatives.

## Delimitations

The goal of this study was to build consensus of opinion based on the perceptions of 24 ACP members who represent 16 leading cotton-producing states. While useful in assessing producers' general opinions toward the PA technologies, the results only reflect the perceptions of this particular group.

## Limitations

The target population in this study consisted of active cotton producers responsible for the planning, equipment maintenance, planting, and harvesting duties associated with cotton production. A portion of the data-collection period conflicted with cotton harvest season. This researcher believes participants' commitment to harvesting the crop prohibited a more desirable response rate.

# CHAPTER II

# REVIEW OF LITERATURE

The following review of literature builds a case for the need to gather information regarding the factors associated with the adoption or lack of adoption of precision agriculture technologies among cotton producers in the leading cotton-producing states.

The theoretical foundation for this study consisted of six main themes, which include 1) diffusion of innovation theory; 2) communication and change agents; 2) innovation attributes; 3) precision agriculture (PA) technologies; 4) adoption of PA technologies; and 5) The Cotton Belt. The following sections further explain the theoretical framework guiding this study.

## Diffusion of Innovation Theory

The theoretical base for this study was Rogers' Diffusion of Innovation theory (2003). Rogers' theory of diffusion has been applied successfully and repeatedly to rural sociology research and is widely utilized (Gregor & Jones, 1999). While the theory is well established, in a study critiquing the barriers of adoption, Vanclay and Lawrence (1994) recommended further social research was needed into agricultural producer adoption of environmentally sustainable techniques and strategies.

Rogers (2003) defined diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (p. 5). For the purpose of this study, cotton producers in the 16 main cotton-producing states constituted the social system. These states included Alabama, Arkansas, Arizona, California, Florida, Georgia, Kansas, Louisiana, Missouri, Mississippi, North

Carolina, New Mexico, Oklahoma, South Carolina, Tennessee, and Texas. The study attempted to ascertain the primary channel of PA diffusion for the selected population.

Lee, O'Neal, Pruett, and Thomas (1995) defined an innovation as knowledge in the form of an idea, method, or device that differs from current knowledge. Rogers adds that the degree to which an individual perceives an idea or object as "new" determines their initial reaction to this innovation. Precision agriculture was made available commercially to agricultural producers in the early 1990s (Daberkow & McBride, 2003).

Innovation adopters fall into five categories of adoption. Rogers (2003) described these categories as (a) innovator, (b) early-adopter, (c) early majority, (d) late majority, and (e) laggards.

Innovators are defined as venturous and active-information seekers. An example of an innovator is an agricultural producer who develops innovations by adapting current technologies for their specific needs. Innovators take advantage of open lines of communication with land grant university subject matter specialists and industry representatives. They tend to be more affluent than other adopter categories, which allows them to take more risks. Innovators consistently have been found to make adoption decisions in a shorter period of time than other adopter categories. This group makes up the first 2.5% of adopters (Rogers, 2003).

The next 13.5% of adopters are called early adopters. The early adopter is a localite, as opposed to a cosmopolite. Localites work in and among their peers, and are more readily accepted by their peers. Cosmopoliteness is "the degree to which an individual is oriented outside the social system" (Rogers, 2003, p. 290). Innovators generally fall into the cosmopolite category. Opinion leaders are often found in the early-adopter category. Opinion leadership refers to an individual's ability to influence other individuals' attitudes or behaviors (Rogers, 2003). The selected population for this study fit into the early adopter category. Many were state or regional opinion leaders for the cotton industry. Early adopters are willing to take more risks than other adopter categories. The remaining adopters usually look to the early adopter for recommendations and advice. Successful adoption of an innovation sometimes depends on the early adopter's success with the innovation.

AtKisson (1991) referred to the stage after innovator and early adopter buy-in, as "take-off." The initial adopters work as change agents to communicate the innovation benefits to the remaining population.

The early-majority category adopts the innovation just before others rapidly adopt it (Rogers, 2003). This group makes up the next 34% of adopters. They communicate with peers when deciding whether to try an innovation. The early majority generally looks to opinion leaders for reassurance that an innovation is worthwhile. This group also interacts with their peers frequently.

Skepticism is a trait found in most late-majority adopters — the next 34% of adopters. They adopt an innovation after average adoption has taken place. Downey, Holschuh, and Jackson (1999), referred to this group as having a "wait and see attitude" (p. 109). Peer pressure and observation of innovation success is necessary for this group of adopters. Innovation adoption is usually due to economic necessity.

Laggard is the term given to the final 16% of innovation adopters. The traditional laggard category of adopters generally contains no opinion leaders. “Laggards tend to be suspicious of innovations and change agents” (Rogers, 2003, p. 284). Zobbe (2001) posits that laggards generally lose money. A change agent promotes innovations to potential adopters, and attempts to influence adopter decisions in a pre-determined direction. Laggards make decisions at a much slower pace than the other four categories of adopters, and are rarely influenced by change agents.

## Communication and Change Agents

Since the enactment of the Smith Lever Act in 1914, the Cooperative Extension Service has grown through Americans’ need for up-to-date information to improve their quality of life (Astroth & Robbins, 1987). Mandate Although it is not always accomplished, it is important for researchers and change agents to act in the best interest of the client. Technology is generally transferred through a top-down approach where an innovation is developed by researchers, then the innovation is marketed by change agents, this is followed either by adoption or rejection of the innovations by producers (Lanyon, 1994).

Communicating innovative farming techniques and best management practices calls for the change agent to be aware of client needs. The change agent needs to take psychosocial variables into account when diffusing knowledge to potential adopters (Barao, 1992). Traditionally, innovations were developed by scientists and diffused to producers via change agents. Little thought was put into the social or economic attributes of adoption (Vanclay & Lawrence, 1994).

Vanclay and Lawrence (1994) stated:

> Extension agents considered farmers who failed to adopt new techniques to be recalcitrant and irrational. Farmers' attitudes and their lack of knowledge were considered to be the main barriers to adoption. Little consideration was given to farmers' points of view. The idea that resistance or reluctance to change might have some logical basis was never considered. Recent analysis reveals that most 'barriers' have a rational basis and can be categorized as: conflicting information; risk; implementation costs and capital outlay; intellectual outlay; loss of flexibility; complexity; and incompatibility with other aspects of farm management and farm and personal objectives. Social and perceptional issues also affect adoption. (p. 59)

This study attempted to address the stated withdrawn nature of technology transfer by providing the key issues and concerns related to the adoption of precision agriculture as stated by a selected panel of cotton experts.

Cooperative extension agents undoubtedly play a crucial role in agricultural producers’ decision to adopt innovations. Agents and specialists bear the weight of Extension’s original mandate to “aid diffusion among the people of the United States useful and practical information…and to encourage the application of the same (Hildreth & Armbruster, 1981). Barao (1992) stated adoption of agricultural innovations is largely due to Cooperative Extension Service educational programs. Bracewell, Persons, Lakjaa, and Chen (1993) agreed that most of the recent practices and innovations that have been adopted by America’s farmers are a result of educational programs promoted by the Cooperative Extension Service. The Extension model generally calls for effective communication of information between researchers, extension agents, and agricultural producers (O’Connell, 1992). This study attempted to ascertain whether Extension programming answers the precision agriculture demands of producers.

## Innovation Attributes

Rogers (2003) provided specific characteristics of innovations, as perceived by potential adopters. These include (a) relative advantage, (b) compatibility, (c) complexity, (d) trialability, and (e) observability. Table 1 shows common questions asked by agricultural producers when deciding whether to adopt an innovation.

Table 1

*Perceived Attributes of Innovation Questions*

| Attribute | Corresponding Producer Questions[1] |
|---|---|
| (1) Relative Advantage | Is innovation superior to current practice? |
| (2) Compatibility | Is innovation congruent and adaptable with current |
| (3) Complexity | Is innovation difficult to understand or use? |
| (4) Trialability | Can I test the innovation prior to purchase or adoption? |
| (5) Observability | Can others observe positive results? |

[1]Adapted from Rogers (2003) pp. 229-266

These attributes only cover the innovation in question. Other psychosocial and communication factors also play a role in a producer's decision to adopt. King and Rollins (1995) revealed that agricultural producers in Pennsylvania perceived that negative attitudes of change agents stifled farmers' willingness to adopt pre-sidedress nitrogen testing. The authors built their argument on the foundation that (a) communication is crucial to innovation adoption; (b) clear economic aspects are crucial to innovation adoption and (c) failure to adopt is often due to economic cost and time (Bracewell et al., 1993). King and Rollins recommended that, "educators should include information about economic usefulness, and must motivate change agents to promote adoption" (p. 46).

Lack of innovation compatibility with existing equipment is often a deterrent to producer acceptance. McCauley (1999) stated that user-friendly software is a determinant of producer adoption.

Rogers (2003) wrote that the most effective communication between change agents and their clients occurs if the two groups display homophilous characteristics. Homophily is defined as “the degree to which two or more individuals who interact are similar in certain attributes” (Rogers, 2003, p. 19). Change agents are more effective if their clientele perceive them as similar to themselves.

## Precision Agriculture (PA) Technologies

The need and demand for technologies increase as agricultural producers continually look for more efficient ways to grow commodities. Olson (1998) listed increasing equipment complexities, increasing farming and marketing risks, and increasing pressure to lower input costs as factors that cause farmers to increase demand for precise technology and decision-making aids. Recent agricultural market trends — decreased prices, increased input costs, and decreased yields — have led agricultural producers to search for more cost-effective management practices (Watson, 2002). Many producers have implemented PA technologies in their operations to decrease input costs.

The National Research Council (1997) defines precision agriculture as “a management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production" (p. 2). Precision agriculture is comprised of three categories, (a) capture of data at an appropriate scale and time; (b) interpretation and analysis of that data to support a range of management decisions; and (c) implementation of a management response at an appropriate scale and time. Precision agriculture uses information-technology-based instruments to manage site-soil spatial and temporal variability in fields (Segarra, 2001).

Zhang, Wang, and Wang (2002) categorized variability in agricultural production into six groups (a) yield variability: defined as historical and present yield distributions, (b) field variability: elevation, slope, terrace, proximity to field boundaries and streams; (c) soil variability: fertility, amount of essential and nonessential minerals; (d) crop variability: density, height, and biomass; (e) anomalous factor variability: weed, insect, and disease infestation; and (f) management variability: tillage practice, crop seeding rate, and fertilizer application. Precision agriculture technologies address these variabilities, in turn, increasing profits for agricultural producers.

The accuracy of precision agriculture has been well documented (Atherton, Morgan, Shearer, Stombaugh & Ward, 1999). In developing a cotton yield monitor, the three-year field evaluation at the University of Tennessee Milan Experiment Station, resulted in an average absolute error for the monitor to be less than 4% (Wilkerson, 2001). Wilkerson soundly endorsed the benefits of applying precision agriculture to cotton production.

Wilkerson (2001) stated:

> Delineating within a field between areas that consistently return a profit and areas that consistently lose money is a good starting point for site-specific field management. A cotton yield monitor with a GPS receiver is necessary technology for generating detail profit/loss maps. (p. 2)

Atherton, et al., (1999) noted that site-specific farming holds potential increases in profitability and production by focusing on improved management. Precision agriculture enables agricultural producers to adjust chemical application levels to adapt to the variable and temporal nature of cropland. Precision agriculture utilizes rapidly evolving electronic information technologies to modify land management in a site-specific manner as conditions change spatially and temporally (Schilfgaarde, 1999).

Although the technical benefits of precision agriculture have been well received, producers overlook these advantages if there is no tangible impact to the producer's bottom line. Kitchen, et al. (2002) said producers must see value in absolute dollar terms for the successful adoption to occur. Arnholt (2001) surveyed Ohio crop producers who used precision agriculture technologies and concluded the main incentive for adoption was potential increased profits by making better management decisions. The respondents used precision agriculture to clarify the crop yield variability in their fields, and to identify soil pH and nutrition. The majority of respondents (71%) felt the benefits of precision agriculture outweighed the costs. In summation, clear economic benefits must be communicated to the potential adopter before consideration of adopting the innovation is taken seriously. Arnholt also found that according to his agricultural producer sample, the yield monitor was the most important precision agriculture component.

The aim of precision agriculture is to "improve management to increase profitability, increase crop productivity, sustain the soil-plant-water environment, and/or reduce detrimental environmental impacts" (Atherton et al., 1999, p. 455). While much research has been conducted on the economics of precision agriculture, little has been documented on profit potential or adoption trends for cotton, or in the southern United States (Roberts, English & Larson, 2002). Research on PA application in non-grain or non-combine harvested crops is relatively new (Plant, 2001; Wallace, 1999). Wallace poses that a lack of suitable yield monitors in cotton is responsible for minimal PA application in this commodity.

**Adoption of PA Technologies**

As stated, a large determinant in agricultural producer adoption of precision agriculture innovations is found in a cost/benefit analysis, with tangible proof of economic advantage (Roberts, English & Mahajanashetti, 2000; Plant, 2001). In an econometric forecast analysis, the researchers found that use of precision farming services has the potential to increase profits via increased yield averages and input reduction. Roberts, English, and Larson (2002) also found that farmers decided to invest in precision farming technology based on the technologies' potential to earn a profit.

Depending on the region and farm size, precision agriculture has been found to be profitable for many producers. Research conducted at Kansas State University indicated that crop producers who adopted technology one year ahead of their neighbors gained approximately $10/acre advantage (Staggenborg, 2002).

Education and outreach have played a vital role in producer adoption of technologies. Daberkow and McBride (2003) stated that low-precision agriculture adoption was potentially due to lack of awareness of the technologies. In 1998, Daberkow and McBride conducted a nationwide survey of more than 8,400 producers, and found that almost 70% of respondents were unaware of precision agriculture technology.

Size of operation has been found to be a factor in both promoting and prohibiting the adoption of agricultural technologies. Batte and Van Buren (1999) found that farm size and economies of scale played a role in producers' decisions to adopt precision agriculture in Ohio. Economies of scale is the degree of advantage large farms possess due to their ability to achieve lower costs and higher returns (Knutson, Penn, & Boehm, 1995). Feder and Slade (1984) agreed that producers farming more acreage invested more resources to acquire information, which in turn, provided higher levels of data in their decision to adopt technologies. This was further proven by Roberts, English, Larson, Cochran, Goodman, Larkin, Marra, Martin, Reeves, and Shurley (2002), who found that generally, adopters of precision agriculture owned 1,063 acres and rented 399 acres in cotton.

Daberkow and McBride (2003) concluded that farm size, computer literacy, full-time farming status, farm type, and location all determine producer adoption of precision agriculture.

Roberts, English, Larson, et al. (2002) noted "the future of precision agriculture in cotton production depends on how producers view this set of technologies and how willing they are to improve current management practices" (p. 2).

Wiebold, Sudduth, Davis, Shannon, and Kitchen (1999) conducted a similar study to determine barriers of precision agriculture adoption in soybeans, using focus groups. The researchers concluded that start-up cost, lack of expertise and time, inadequate training resources, operator age, and farm size to be obstacles to precision agriculture adoption. Wiebold et al., recommended an increase in producer education efforts, including written materials and face-to-face training schools.

This cotton study investigated how producer perception contributes to the adoption of precision agriculture. Assessing the needs of cotton producers in the top-producing states contributes to the programming effectiveness of change agents responsible for diffusing these technologies.

## The Cotton Belt

The adoption of precision agriculture technologies has been shown to vary depending on region. Daberkow & McBride (2003) noted "location factors, such as soil fertility, climate, and availability or access to information can influence the profitability of different technologies across different farms" (p. 167). Gathering information from producers in heterogeneous regions provided insight into the perceived benefits and barriers in different cotton-producing areas. Different environmental factors determine the advantage or disadvantage of using PA in agricultural production, including precipitation percentage, yield average, method of harvest (i.e., stripper, picker), and topography. Table 2 provides 2003 cotton yield and economic data from the states represented in this study.

Table 2.

*2003 Cotton Belt: Area Planted, Harvested and Cash Receipts*[2]

| State | 2003 Acres Planted | 2003 Acres | 2003 Production |
|---|---|---|---|
| Arizona | 218,000 | 216,000 | $186,010,000 |
| Arkansas | 980,000 | 945,000 | $560,736,000 |
| California | 700,000 | 694,000 | $556,560,000 |
| Florida | 94,000 | 92,000 | $40,872,000 |
| Georgia | 1,300,000 | 1290,000 | $618,912,000 |
| Kansas | 90,000 | 80,000 | $29,280,000 |
| Louisiana | 525,000 | 510,000 | $298,654,000 |
| Mississippi | 1,110,000 | 1,090,000 | $612,864,000 |
| Missouri | 400,000 | 390,000 | $211,296,000 |
| North Carolina | 810,000 | 770,000 | $341,616,000 |
| New Mexico | 62,100 | 48,000 | $22,752,000 |
| Oklahoma | 180,000 | 170,000 | $61,488,000 |
| South Carolina | 220,000 | 218,000 | $98,683,000 |
| Tennessee | 560,000 | 530,000 | $249,060,000 |
| Texas | 5,620,000 | 4,420,000 | $1,187,280,000 |
| Virginia | 89,000 | 85,000 | $36,922,000 |

[2]From USDA National Agricultural Statistics Service Crop Values Summary February 2004.

Texas was the largest cotton-producing state represented in this sample. Two specific Texas regions together are responsible for 4 to 5.5 million acres annually. The Texas Southern High Plains (SHP) is a region synonymous with agricultural production. Terrell, Johnson, and Segarra (2002) suggested that the region relies on agriculture for economic stability and concluded, “cotton is king in the SHP region and should be regarded as the crop of choice for producers.” Cotton is the most affluent crop in this region. (p.42) Optimal production conditions produce more than 60 percent of the state’s cotton acreage, 3 to 4 million acres. This region produced an average of 500 to 1,500 pounds of lint/acre under irrigation and 270 pounds/acre in dry-land situations (Sansone, Isakeit, Lemon & Warrick, 2002).

The Rolling Hills has fewer irrigated acres, yielding 250 to 315 pounds of lint/acre (Sansone et al., 2002). Cotton was the fourth highest-grossing Texas agricultural commodity in 2001, accounting for 20.2% of all state cash receipts (USDA, Economic Research Service, 2002).

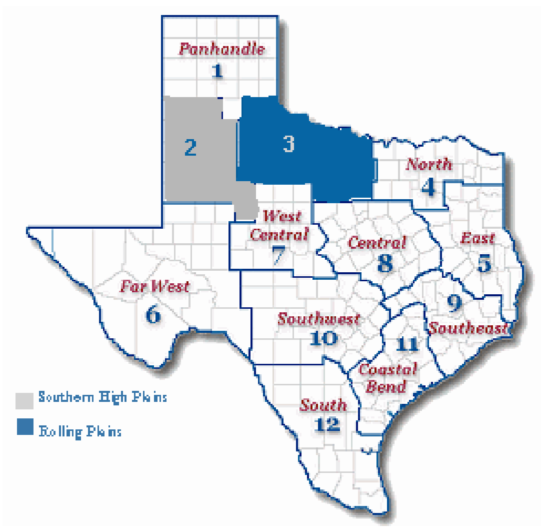


Figure 1. Texas Cotton Regions (Texas Cooperative Extension, 2002)

**West Texas Precision Agriculture Producer Adoption**

The use of precision agricultural components in the High Plains of Texas is still in its infancy stage. Researchers (Batte & VaBuren, 1999; Roberts, English, & Mahajanshetti, 2000; Maohua, 2001; Yu, 2000) foresaw this as a promising technology. Yu (2000) stated that advantages of precision agriculture included an increased efficiency of input use, potential profit increase, and potential reduction in negative environmental impact caused by excessive chemical application. Figure 1 depicts these high-yielding regions.

Segarra (2001) concluded that precision agriculture can be used in the Texas Southern High Plains to benefit cotton producers. Segarra writes:

> Precision farming can be economically enhancing for producers in the Texas High Plains, if adoption costs are reasonably low. Depending on the specific location, the crop being analyzed, and input and output price scenarios, net increases of profits of 2 to 5% per acre could be expected from the adoption of precision farming practices. (p. 2).

Agricultural change agents in Texas can potentially benefit from the results of this study due to the high economic impact of cotton in this state.

## Delphi Methodology

This study utilized the Delphi methodology to solicit a consensus of expert opinion regarding the advantages and barriers to adopting precision agriculture in cotton production. Delphi techniques seek to explore ideas or produce suitable data to make decisions (Adler & Ziglio, 1996; Rowe & Wright, 1999). A Delphi is a procedure used to “obtain the most reliable consensus of opinion in a group of experts… by a series of intensive questionnaires interspersed with controlled opinion feedback” (Dalkey & Helmer, 1963, p. 458). Strauss and Zeigler (1975) found the methodology also effective in identifying divergence of opinion.

Dalkey and Helmer (1963) posited that systematically exploring factors that influence the judgment of the individual expert makes correcting misconceptions regarding empirical factors or theoretical assumptions possible. Dalkey and Helmer stated that presenting other expert opinion helps draw attention to other factors that may have been overlooked.

Traditionally, the Delphi methodology was thought to be solely applicable to forecasting studies (Twiss, 1992; Rowe & Wright, 1999), but over the years the applications have grown. Martino (1983) argued that Delphi could be used “for any purpose for which a committee can be used” (p. 16). The group communication strategy has been applied successfully to strategic planning, community needs assessment, and policy development. Linstone and Turoff (1974) defined the Delphi as an effective method for assembling group communication to solve a complex issue.

Many agricultural researchers have used the Delphi technique to forecast future trends as well as generate a consensus for making decisions (Boyd, 2004; Shinn & Smith, 1999; Harris, Lasaux, & Kocher, 2000). Martin and Frick (1998) conducted an exhaustive literature review of the *Journal of Agricultural Education*, *Journal of Extension*, *Journal of Vocational Education Research*, and the Summaries of Research and Development Activities in Agricultural Education between 1984 and 1998. The researchers found that 19 manuscripts reported using the Delphi technique for forecasting, evaluation, and curriculum planning purposes. The researchers concluded that the Delphi technique was a highly acceptable research methodology.

Linstone and Taroff (1974) stated that Delphi was an effective method for “distinguishing and clarifying real and perceived human motivations” (p. 4). Linstone and Taroff also asserted:

> Delphi attempts to design a structure which allows many "informed" individuals in different disciplines or specialties to contribute information or judgments to a problem area which is much broader in scope than the knowledge that any one of the individuals possesses”.

## History of the Delphi

Dalkey and Helmer (1963) developed the technique in the 1950s in a Rand Corporation project sponsored by the U.S. Air Force. The seminal study conducted a review using seven weapons experts. The objective was to construct a consensus of the perceived effects of strategic bombing of industrial targets in the United States given a hypothetical attack on the United States by the Soviet Union. The researchers used five rounds of questionnaires to develop consensus. Over the last 50 years, researchers have refined the Delphi process and have found that three rounds of questionnaire administration is sufficient for making valid conclusions.

The second and third Delphi round for this study utilized electronic Web-based resources to provide feedback to participants. Many studies have been conducted to assess agricultural producer use of computers and the Internet (Gabriele, 2004; Goe & Kenney, 2003, Peña, 1999). While the rate of adoption has not mirrored that of the general population, the number of producers online has notably increased. Producers use the Internet to check electronic mail, monitor commodity markets and weather conditions, and even purchase livestock and machinery. The United States Department of Agriculture reported that 48% of U.S. farms have Internet access (United States Department o Agriculture National Agricultural Statistics Service, 2003). Fifty-four percent of farms were found to own computers. In the leading cotton-producing states, an average of 52.7% of farms had computer access.

Ladner, Wingenbach, and Raven (2002) found Web-based and traditional paper-based survey methodologies were equally valid and reliable for social science research.

The researchers found differences in the aggregate response rate between the two groups. The Web-based group's response rate exceeded the traditional group, 72 to 7, within the first week of data collection. This study provides strong evidence for using Web-based surveying methods in social science research.

**Components of Delphi**

There are three key elements in the Delphi methodology. These elements include anonymous response, iteration with controlled feedback, and statistical aggregation of group response (Martino, 1983). Martino stated that anonymity is crucial to removing social pressures, and recommended using mail questionnaires. For this study, all correspondence with participants emphasized their anonymity.

The Merriam-Webster Dictionary defines iteration as "a procedure in which repetition of a sequence of operations yields results successively closer to a desired result." This condition of the Delphi technique is accomplished by conducting a minimum of three rounds of communication with the respondents (Renzelman, 1982; Ludwig, 1997).

Controlling feedback provides participants with an update of the panel's responses. The researcher monitors the summary data disseminated to the anonymous participants. Martino (1983) stated controlled feedback reduces the monotony of repetitive arguments, which are found in traditional face-to-face panels (p. 17). This element is used also to reinforce the fact that participants' opinions are important to the study.

The final round is generally followed by a statistical group response summary, including the majority of responses, and minority views with the degree of spread from the majority opinion.

Webber (1995) presented many advantages to the Delphi technique including: (1) the provision of opportunity for large numbers of people to participate; (2) anonymity for participants, which makes the contribution of ideas a safe activity; (3) lack of social pressures, personality influences, and dominance by individuals; (4) provision of opportunities for participants to reconsider their opinions; (5) allows information sharing and reasoning among participants; (6) conducive to independent thinking and gradual formulation; (7) provides a varied and well-selected respondent panel; (8) can be used to reach a consensus among hostile groups, and finally (9) the process is inexpensive.

Cyphert and Gant (1970) concluded that “virtually all (99%) of respondents’ changes in opinion occurred in questionnaire III” (p. 109), and posited that implementing more than three rounds should be questioned by researchers. Martino stated that round four could be eliminated if the investigator has no need for rebuttals to the arguments presented in round three. Given these conclusions, coupled with an attempt to reduce the risk of participant attrition, three rounds were used in this study.

## Disadvantages of the Delphi

While the Delphi technique holds advantages when seeking data that are not readily available, Webber (1995) also noted disadvantages to the process including the amount of time needed to conduct multiple rounds, complex data analyses, attrition, and the difficulty of keeping statements clearly defined. Ibery, Maye, Kneadsey, Jenkins, and Walkley (2003) found that retaining participation throughout the iterative process was a weakness in the Delphi technique. Regarding this cotton research project, a definite concern was the lack of on-site contact with participants. Gamon (1991) noted lack of stimulation from face-to-face contact to be a limitation of the methodology. Gamon also found weakness in the length of time required to perform the multiple rounds.

# CHAPTER III

# METHODS AND PROCEDURES

The purpose of this study was to determine factors influencing cotton producer adoption of precision agriculture technologies in the leading cotton-producing states. This chapter explains the research techniques and procedures used to execute this purpose.

## Research Design

A Delphi approach was used to solicit agreement on factors that enhance or inhibit precision agriculture adoption. The target population consisted of the American Cotton Producers of the National Cotton Council of America, a 24-member association elected by their peers across the Cotton Belt. This organization represents cotton producers in the 16-leading cotton producing states including Alabama, Arkansas, Arizona, California, Florida, Georgia, Kansas, Louisiana, Missouri, Mississippi, North Carolina, New Mexico, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. The members are responsible for developing recommendations on all matters affecting the production sector. A consensus of the panel was gathered to identify perceived advantages and barriers to cotton producer adoption of precision agriculture technologies.

## Procedures

All 24 American Cotton Producer representatives were offered the opportunity to participate in the study at an annual meeting held in Dallas, Texas on April 15, 2004.

Round one of the Delphi was conducted at the meeting. Participant's anonymity was ensured to thwart group influence, a threat to internal validity (Weatherman & Swenson, 1974).

The chosen participants represented all cotton producers involved with the National Cotton Council of America in their respective states, establishing their validity as an expert panel.

Round one consisted of an open-ended preliminary questionnaire designed to elicit responses concerning the broad problem: lack of adoption of precision agriculture by cotton producers (Schoeman & Mahajan, 1977). The participants were asked three questions:

1. List at least three advantages of adopting precision agriculture technologies in cotton production.
2. List at least three barriers to adopting precision agriculture technologies in cotton production.
3. List three sources for precision agriculture technology information.

Round two provided participants the opportunity to rank the relative importance of the statements established in round one. A four-point importance scale of 1= *Not Important* through 4= *Very Important*, was used to assess the perceived importance of round one-derived advantages and barriers.

A round three instrument was developed using statistical aggregation of round two results. A 4-point Likert scale of 1= *Strongly Disagree* through 4= *Strongly Agree* was used to gather participants' level of agreement with advantage and barrier statements.

Participants were provided with mean scores for each variable statement to adhere to the controlled feedback requisite of the Delphi.

Participant attrition, a weakness of Delphi, was expected. Reminder emails were sent throughout the Delphi process to encourage participant response. While Dalkey (1969) found that expert groups in excess of 13 satisfactorily met process reliability requirements with a mean correlation greater than .80, Adams (2001) reported that validity and reliability does not improve when using more than 30 experts. In the original Rand Delphi study, Murphy, et al. (1998) concluded that a larger group of participants yielded higher reliability, but added reliability above 12 is subject to diminishing returns, and does not rapidly decline until the sample number is less than six respondents. For this study, multiple reminder emails were sent to participants to ensure at least six responses per round.

In summary, the procedure for this Delphi study was:

(1) Described, in person, the nature of the study, solicited participation, and explained the Delphi process; (2) administered the first round instrument to participants; (3) summarized responses from round one and developed round two instrument; (4) administered the second round instrument to participants electronically; (5) summarized responses from round two and developed round three questionnaire; (6) electronically mailed participants round three questionnaire; (7) summarized consensus of responses and notified participants of results.

# CHAPTER IV

## RESEARCH FINDINGS AND DISCUSSION

According to the USDA National Agricultural Statistics Service (2002), the average age of the U.S. farmer is 55.3 years of age. This sample group fit this statistic. All respondents on the expert panel were male, and held substantial experience in years involved in cotton production, ranging from 7 to 32 years, with a mean of 23.9 years of cotton production experience.

Round one provided 13 completed questionnaires. In this round the following open-ended questions were posed:

1. List at least three advantages of adopting precision agriculture technologies in cotton production.
2. List at least three barriers to adopting precision agriculture technologies in cotton production.
3. List three sources used for precision agriculture technology information.

### Results

Following round one, the open-ended questions produced 21 advantage statements and 21 barrier statements from the expert panel. The states represented in the response pool included Alabama (n=1), Arizona (n=1), California (n=2), Georgia (n=1), Louisiana (n=1), Oklahoma (n=2), Texas (n=4), and Virginia (n=1). Table 3 provides both the advantages and barriers of adopting precision agriculture in cotton production, as identified by the expert panel. In both categories, the panel provided statements that closely mirrored Roger's perceived attributes of innovations. For example, participants named relative advantage variables, such as better fiber quality, establishing realistic yield goals, and decreasing driver fatigue, as important factors when deciding whether or not to adopt precision agriculture in cotton.

The perception that utilizing precision agriculture technologies is too complex has been documented barrier in many studies (Wiebold, et al., 1999; Kitchen, et al., 2002). When listing barriers to adoption in this study, participants agreed that incompatibility, questionable data, and untested equipment as important factors to consider, which all related to components of Roger's diffusion model (2003), specifically complexity and compatibility attributes. Fichman & Kemerer (1999) stated the complexity attribute of innovations is generally fixed, and that it largely determines the rate and level of adoption.

Other perceived barriers included questionable benefits in smaller operations, inconsistencies between cotton and grain yield data, initial cost, operator unfamiliarity with equipment, lack of industry support, technological unfamiliarity, and producer resistance to change. These barrier variables are not unique to cotton, but found in literature documenting other commodities.

Table 3

*Advantages/Barriers of Adopting Precision Agriculture in Cotton Production (n=13)*

| Advantages | Barriers |
|---|---|
| 1. Ability to get precise acreage and field size. | 1. Accuracy of data questionable. |
| 2. Assistance in maneuvering larger equipment. | 2. Adapting new implements to older equipment. |
| 3. Better fiber quality. | 3. Adequate benefits may be questionable in smaller operations. |
| 4. Conserve chemicals and inputs. | 4. Adequate benefits may be questionable in smaller operations. |
| 5. Cutting costs of overall production. | 5. Data not as believable as it is in grain production. |
| 6. Decrease driver fatigue. | 6. Different brands of equipment not functioning together. |
| 7. Identify low pH, low fertility areas. | 7. Employee capability to operate equipment questionable |
| 8. Increased production. | 8. Farmers slow to change. |
| 9. Increase profitability on overall farm by increased efficiencies and production. | 9. Few suppliers with technical experience. |
| 10. Leads to fewer tons of chemical and nutrients to the environment. | 10. Initial cost. |
| 11. Identify high and low-yielding areas. | 11. Lack of “hi-tech” talent to meet potential demand. |
| 12. Less waste of equipment – time, labor, fuel. | 12. Lack of support from industry. |
| 13. Maximize inputs (fertilizer, herbicides, etc.) | 13. Learning curve. |
| 14. More accurate farming (row spacing, reduced overlap, and cultivation). | 14. No accurate yield monitor for cotton strippers. |
| 15. Operate in all weather conditions (fog, night, dust, etc.). | 15. Return to investment questionable. |
| 16. Record keeping. | 16. Software problems and incompatibility. |
| 17. Self guidance. | 17. Suppliers not geared up with application equipment. |
| 18. Variable rate application, especially lime. | 18. The ability to manipulate data for better results. |
| 19. Variable seeding rate. | 19. Too complex for older laborers. |
| 20. Yield monitor – establish realistic yield goals. | 20. Unfamiliar with technology. |
| 21. Yield result for better-input control on different field & soil types in each field. | 21. Untested equipment. |

Upon receipt of the round one results, a second round instrument was formulated using participants’ responses from round one data collection. Redundant variables were collapsed, but no responses were eliminated. A team of agricultural education faculty assisted in condensing and combining initial responses into statements without altering their original meanings. A panel of experts from agricultural education and soil and crop sciences reviewed the instrument for face validity.

The second round was administered via a secured Internet Web site to gather participants' independent and anonymous responses to the round one panel summary. The electronic announcement was sent to participants on May 24, 2004. In the second round, participants reviewed the summarized statements from round one and used a four-point importance scale of 1= *Not Important* through 4= *Very Important* to rate their agreement levels with each statement.

Round two was closed on July 20, 2004 after three reminder emails were sent to participants. The round results were based on 10 responses. These responses came from representatives of California (n=2), Virginia (n=1), Missouri (n=1), Texas (n=3), Georgia (n=1), Oklahoma (n=1), and Alabama (n=1).

The third and final round was also administered electronically. The announcement for the round was sent to participants on July 21, 2004. Three reminder emails were sent to participants, and the round was closed on September 10, 2004 after receiving 6 responses. Responses came from representatives of Alabama (n=1), California (n=2), Georgia (n=1), and Texas (n=2). Incidentally, the USDA-National Statistics Service, reported a large window for planting and harvesting. Much of the study interval overlapped optimal planting times. This overlap might explain participant attrition. Table 4 displays the usual planting dates for cotton planting and harvested, by state.

Table 4
*Usual Planting and Harvesting Dates, by State*[3]

| State | Begin Planting | Most Active | End Planting | Begin Harvest | Most Active | End Harvest |
|---|---|---|---|---|---|---|
| AL | Apr 12 | April 24-May 24 | June 6 | Sept 22 | Sept 20 | Dec 15 |
| AZ | Mar 15 | April 1-April 30 | May 15 | Sept 15 | Oct 10 | Dec 25 |
| AR | Apr 24 | May 1-May 24 | May 31 | Sept 22 | Oct 6 | Nov 24 |
| CA | Apr 1 | April 15-May 30 | May 15 | Oct 1 | Oct 15 | Nov 15 |
| FL | Apr 1 | April 15-May 15 | June 15 | Sept 15 | Oct 1 | Dec 1 |
| GA | Apr 20 | April 25-May 25 | June 5 | Sept 20 | Oct 5 | Dec 15 |
| LA | Apr 17 | April 26-May 16 | June 2 | Sept 15 | Sept 28 | Nov 13 |
| MS | Apr 14 | April 28-May 28 | June 9 | Sept 15 | Oct 6 | Nov 17 |
| MO | Apr 25 | May 5-May 20 | June 1 | Sept 20 | Oct 5 | Nov 20 |
| NM | Apr 10 | April 20-May 10 | May 20 | Oct 10 | Oct25 | Dec 20 |
| NC | Apr 21 | May 1-May 20 | June 8 | Sept 27 | Oct 7 | Dec 15 |
| OK | May 6 | May 20-June 12 | June 29 | Oct 11 | Nov 4 | Dec 15 |
| SC | Apr 24 | May 1-May 20 | June 1 | Sept 23 | Oct 15 | Dec 5 |
| TN | Apr 25 | May 5-June 6 | June 5 | Sept 20 | Oct 5 | Nov 25 |
| TX | Mar 10 | May 5-June 6 | June 30 | Aug 10 | Oct 1 | Dec 28 |
| VA | Apr 10 | April 20-May 10 | May 20 | Sept 30 | Oct 25 | Dec 10 |

[3]From USDA National Agricultural Statistics Service.

The third round explored divergence and summarized the consensus of factors that promote or prohibit producer adoption of precision agriculture. Descriptive statistics were used to compare round two and round three advantages and barriers to adopting precision agriculture technologies to verify the variable statements were sufficiently narrowed to form an accurate consensus.

A large component of producers’ decisions to adopt innovations were linked to the level of information available.

Table 5 lists the primary sources used for precision agriculture information, as well as respondent frequencies. Respondents were asked to list more than one source. According to these data, precision agriculture dealers were the most often utilized source of information, followed by agricultural publications.

Table 5

*Identified Precision Agriculture Information Sources*

| Source | *f* |
|---|---|
| Dealers | 9 |
| Agricultural Publications | 6 |
| Beltwide Cotton Conference | 4 |
| Extension Service | 4 |
| Peer Farmers | 4 |
| University | 3 |
| Internet | 2 |
| Consultants | 2 |
| National Cotton Council | 1 |
| Trade Shows | 1 |
| Total | 36 |

## Advantages to Adoption

To accomplish research question one, descriptive statistics were used to record convergence of opinion. Table 6 illustrates that four of the 21 advantages received a very important ranking ($M= \geq 3.51$). Respondents agreed most with variables that were production-and economically oriented. For example, accuracy of row spacing, reduced overlap, and increased profitability were rated highest, as a group of priorities, than any other importance grouping. Conversely, “maneuvering large equipment” and “operating in all weather conditions” were rated least preferable among all variables.

Table 6

*Round 2 Descriptive Statistics for Advantages to PA Adoption*

| Statements | Round Two (*n* = 10) | |
|---|---|---|
| Advantages | *M* | *SD* |
| More accurate farming (row spacing, reduced overlap, and cultivation) | 3.80 | .42 |
| Increased profitability on overall farm by increased efficiencies and production | 3.80 | .42 |
| Cutting costs of overall production | 3.60 | .52 |
| Increased production | 3.67 | .71 |
| Less waste of equipment – time, labor, fuel | 3.60 | .52 |
| Yield monitor – establish realistic yield goals | 3.40 | .52 |
| Conserve chemicals and inputs | 3.40 | .70 |
| Yield result for better input control on different field & soil types in each field | 3.50 | .71 |
| Identify high and low yielding areas | 3.30 | .82 |
| Maximize inputs (fertilizer, herbicides, etc.) | 3.50 | .85 |
| Self guidance | 3.10 | .99 |
| Decrease driver fatigue | 3.20 | .63 |
| Leads to fewer tons of chemical and nutrients to the environment | 3.20 | .63 |
| Ability to get precise acres and field size | 3.10 | .88 |
| Record keeping | 3.00 | .82 |
| Identify low pH, low fertility areas | 2.90 | .88 |
| Variable seeding rate | 2.70 | .95 |
| Better fiber quality | 2.80 | .42 |
| Variable rate application, especially lime | 2.70 | 1.16 |
| Assistance in maneuvering larger equipment | 2.60 | .84 |
| Operate in all weather conditions (fog, night, dust, etc.) | 2.80 | .79 |

Scale: 1 through 4, where 1= *Not Important* 4= *Very Important*

Emphasis on the potential economic benefits of precision agriculture is consistent with the Atherton, et al., (1999), conclusion that precision agriculture fosters potential increases in profitability and production by focusing on improved management.

Round three presented participants the opportunity to rank their level of agreement with variable statements. Only one statement, “more accurate farming, i.e., row spacing, reduced overlap, and cultivation," was strongly agreed upon as an important variable in considering precision agriculture adoption (Table 7). Managing these production aspects reduces costs. This producer perception was congruent with Arnholt's (2001) conclusions that economic incentive was a key incentive for adoption.

Table 7

*Round 3 Descriptive Statistics for Advantages to PA Adoption*

| Statements | Round Three ($n$ = 6) | |
|---|---|---|
| Advantages | *M* | *SD* |
| More accurate farming (row spacing, reduced overlap, and cultivation) | 3.83 | .41 |
| Increased profitability on overall farm by increased efficiencies and production | 3.50 | .55 |
| Cutting costs of overall production | 3.50 | .55 |
| Increased production | 3.33 | .52 |
| Less waste of equipment – time, labor, fuel | 3.33 | .52 |
| Yield monitor – establish realistic yield goals | 3.67 | .52 |
| Conserve chemicals and inputs | 3.50 | .55 |
| Yield result for better input control on different field & soil types in each field | 3.33 | .52 |
| Identify high and low yielding areas | 3.50 | .55 |
| Maximize inputs (fertilizer, herbicides, etc.) | 3.17 | .75 |
| Self guidance | 3.67 | .52 |
| Decrease driver fatigue | 3.33 | .52 |
| Leads to fewer tons of chemical and nutrients to the environment | 3.33 | .52 |
| Ability to get precise acres and field size | 3.33 | .52 |
| Record keeping | 3.50 | .55 |
| Identify low pH, low fertility areas | 3.50 | .55 |
| Variable seeding rate | 3.17 | .75 |
| Better fiber quality | 2.83 | .41 |
| Variable rate application, especially lime | 2.67 | 1.03 |
| Assistance in maneuvering larger equipment | 2.67 | .52 |
| Operate in all weather conditions (fog, night, dust, etc.) | 2.33 | .52 |

Scale: 1 through 4, where 1= *Strongly Disagree* 4=*Strongly Agree*

Round three advantage results (Table 7) show that respondents moderately agreed with all 16 advantages variables that were carried over from round two. Consensus was built around strategies to reduce input costs.

## Barriers to Adoption

Round two showed that respondents found only two of the 21 barriers to adoption very important, "initial cost" (*M*=3.80), and "employee capability to operate equipment questionable," (*M*=3.70), while they found the other 19 barriers important (Table 8). The barrier receiving the lowest ranking was "no accurate yield monitor for cotton strippers" (*M*=2.30). This can be explained by reviewing the states represented in round two. Cotton strippers are primarily used in the Texas High Plains. The remaining states most likely utilize cotton pickers for harvesting.

Respondents agreed that complexity and compatibility were the most influential barriers to precision agriculture adoption. The respondents expressed concern that employee capability to operate equipment was questionable, technical learning curve was too great, technology was too complex for older operators, and adapting new implements to older equipment was a problem.

Table 8

*Round 2 Descriptive Statistics for Barriers to PA Adoption*

| Barriers | Round Two ($n$ = 10) *M* | *SD* |
|---|---|---|
| Initial cost | 3.80 | .42 |
| Employee capability to operate equipment questionable | 3.70 | .48 |
| Different brands of equipment not functioning together | 3.50 | .71 |
| Learning curve | 3.40 | .52 |
| Software problems and incompatibility | 3.40 | .52 |
| Lack of “hi-tech” talent to meet potential demand | 3.40 | .52 |
| Too complex for older laborers | 3.30 | .82 |
| Few suppliers with technical experience | 3.30 | .48 |
| Suppliers not geared up with application equipment | 3.30 | 1.06 |
| Lack of support from industry | 3.30 | .48 |
| Return to investment questionable | 3.22 | .44 |
| Adapting new implements to older equipment | 3.10 | .99 |
| Confidence to know what factors vary | 3.10 | .57 |
| Accuracy of data questionable | 3.10 | .88 |
| Data not as believable as it is in grain production | 3.00 | .94 |
| Unfamiliar with technology | 2.90 | .32 |
| Untested equipment | 2.90 | .57 |
| The ability to manipulate data for better results | 2.90 | .88 |
| Adequate benefits may be questionable in smaller operations | 2.80 | 1.14 |
| Farmers slow to change | 2.40 | .97 |
| No accurate yield monitor for cotton strippers | 2.30 | 1.42 |

Scale: 1 through 4, where 1= *Not Important* 4=*Very Important*

No barrier statements were strongly agreed upon in round three (Table 9). However, the expert panel agreed with 8 of the 21 statements, ranging from concerns of “lack of hi-tech talent to meet demand” to “employee capability to operate equipment”.

Table 9

*Round 3 Descriptive Statistics for Barriers to PA Adoption*

| | Round Three ($n$ = 6) | |
|---|---|---|
| Barriers | *M* | *SD* |
| Employee capability to operate equipment questionable | 3.50 | .55 |
| Learning Curve | 3.50 | .55 |
| Too Complex for older laborers | 3.50 | .84 |
| Adapting new implements to older equipment | 3.50 | .55 |
| Confidence to know what factors vary | 3.33 | .52 |
| Unfamiliar with technology | 3.33 | .52 |
| No accurate yield monitor for cotton strippers | 3.25 | .50 |
| Lack of “hi-tech” talent to meet potential demand | 3.17 | .41 |
| Initial cost | 3.00 | .63 |
| Software problems and incompatibility | 3.00 | .00 |
| Data not as believable as it is in grain production | 3.00 | .00 |
| Untested equipment | 3.00 | .63 |
| Farmers slow to change | 3.00 | .89 |
| Different brands of equipment not functioning together | 2.83 | .41 |
| The ability to manipulate data for better results | 2.80 | .45 |
| Few suppliers with technical experience | 2.67 | .82 |
| Suppliers not geared up with application equipment | 2.67 | .82 |
| Accuracy of data questionable | 2.67 | .52 |
| Return to investment questionable | 2.67 | .52 |
| Adequate benefits may be questionable in smaller operations | 2.67 | .52 |
| Lack of support from industry | 2.33 | .52 |

Scale: 1 through 4, where 1= *Strongly Disagree* 4=*Strongly Agree*

In summary, the expert panel found consensus in variables related to relative advantage and compatibility when deciding whether to adopt or not adopt precision agriculture technologies in cotton.

# CHAPTER V

## CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to determine factors influencing cotton producer adoption of precision agriculture in the cotton belt, according to American Cotton Producers of the National Cotton Council representatives. The following questions were administered to an expert panel to accomplish this purpose:

1. List at least three advantages of adopting precision agriculture technologies in cotton production.
2. List at least three barriers to adopting precision agriculture technologies in cotton production.
3. List three sources used for precision agriculture technology information.

The study was used a three-round Delphi methodology. It was developed to define critical concerns cotton producers face when deciding whether or not to adopt precision agriculture technologies for their farm operations.

The selected expert panel was comprised of the American Cotton Producers of the National Cotton Council, a 24-member organization that represent cotton producers in the 16-leading cotton-producing states.

Controlled feedback was used to provide participants with the opportunity to modify answers each round and view peer responses. This helped develop a clear convergence of the expert panelist's opinion. Data were collected using both paper-based and electronic means.

Thirteen of the 24-member organization responded to the first round questionnaire. This was followed by 10 responses and 6 responses, in the second and third round, respectively. Although some literature (Dalkey, 1969) recommends at least 13 respondents for each round, this conflicts more recent empirical literature (Murphy, et al., 1998), which states with respondent numbers above 12, reliability enhancement is subject to diminishing returns. Murphy also posited that reliability is highly dependent on the application of the method. For the purpose of this study, the number of respondents was found to be a sufficient cross section of the sample group.

## Conclusions: Research Question One

The objective of research question one was to describe the perceived advantages of adopting precision agriculture technologies in cotton production. In round 3, the highest-ranking advantage variable (*M*=3.83) was “more accurate farming (row spacing, reduced overlap, and cultivation)”. These relative advantages are consistent previous findings related to precision agriculture in other crops (Arnholt, 2001; Kitchen, et al., 2002). The lowest-ranked variable (*M*=2.33) was “operate in all weather conditions (fog, night, dust, etc.)”. This obviously was not seen as an applicable advantage of the technology. It is concluded that producers choose to adopt innovations that are profitable. Therefore, the expert panel perceived that implementing precision agriculture components that reduce input costs translates into increased profit margin.

## Conclusions: Research Question Two

The objective of research question two was to describe the perceived barriers to adopting precision agriculture technologies in cotton production. The highest-ranking barrier variable (*M*=3.50) was “employee capability to operate equipment”. This can be explained in Roger’s complexity attribute (2003, p. 257), which is negatively correlated with innovation adoption. The lowest-perceived barrier (*M*=2.33) was “lack of support from industry”. The producer participants perceive commercial industry as key resource for precision agriculture information. This finding is reiterated in question three results.

## Conclusions: Research Question Three

The objective of research question three was to describe the most popular sources of precision agriculture information. The expert panel named 10 different information sources. Precision agriculture dealers was the most frequently named source; the Extension service, and agricultural publications were also used by a number of respondents.

## Recommendations

Based on the findings and conclusions presented in this study, recommendations have been made in three specific areas. These are 1) recommendations to change agents (i.e., Cooperative Extension and commercial dealer personnel), and 2) recommendations regarding Delphi method application in social agricultural research, and 3) recommendations for further research.

Recommendations for change agents developed from this study are as follows:

1. Agricultural change agents should take agricultural producers needs into account when developing innovation dissemination models, namely the complexity,

compatibility, and realistic economic benefits of the innovation. This can be accomplished by developing a comprehensive needs assessment component with the plan of work.

2. It is recommended that Cooperative Extension specialists and agents collaborate with the personnel at Agricultural Experiment Stations sooner in the innovation development and testing stage. Including producer needs, as seen by the Extension service, will help develop more effective diffusion strategies, support more successful adoption, and mitigate the "top-down" approach (Lanyon, 1994) synonymous with the innovation-diffusion process.

Recommendations regarding Delphi method application in social agricultural research are to:

1. The Delphi methodology is an effective means of developing consensus among a group of experts.

2. Participant attrition is a weakness of the methodology, but can be managed by establishing sufficient producer "buy-in" for the study purpose. Again, a needs assessment can effectively identify issues significant to agricultural producers. Providing incentive to participants may also be effective in minimizing attrition.

3. Attention should be given to the time of year study is conducted. This particular study conflicted with times in which production prohibited participation in a multiple-round study.

4. The Delphi methodology should be replicated in studies using other commodity producers (i.e., corn, livestock, fruits and vegetable growers). Developing consensus

among expert producers can provide useful insight for change agents, and help commodity groups determine critical issues.

Recommendations as a result of this study for further research are as follows:

1. It is recommended that another study be conducted investigating precision agriculture adoption in cotton using a larger sample. This study provided expert perceptions using representatives from "The Cotton Belt". A larger study surveying cotton producer in different cotton-producing areas will provide specific regional advantages and barriers to precision agriculture adoption in cotton production. Results will support change agent diffusion of these promising technologies.

2. It is also recommended that studies investigating the relationship between Roger's Diffusion Theory and farm size, age, education level, level of participation in farm subsidy programs.

3. A study should be conducted to further investigate information sources, and how much impact different sources have on agricultural producer management practices.

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## APPENDIX A

### CONSENT FORM

# FACTORS DETERMINING ADOPTION OR NON-ADOPTION OF PRECISION AGRICULTURE BY PRODUCERS ACROSS THE COTTON BELT

## CONSENT FORM

I have been asked to participate in a research study designed to assess the benefits and barriers to adopting precision agriculture in cotton production. I was selected to be a potential participant because I represent cotton producers from my home state. A total of 24 people have been asked to participate in this study. The purpose of this study is to provide producer perspectives of critical issues that hinder precision agriculture adoption by cotton producers. This information will help public agricultural organizations to more effectively meet producer needs.

If I agree to be in this study, I will be asked to provide my honest opinion and participate in this study for its duration. This study will only take approximately 25 minutes, which will be divided into three rounds each lasting six or seven minutes.

The risks associated with this study are minimal. The benefits of participation include providing Cooperative Extension, Land Grant University, and commercial organizations with crucial insight into producer needs.

This study is confidential. The records of this study will be kept private. No identifiers linking me to the study will be included in any sort of report that might be published. Research records will be stored securely and only Christopher Lavergne, master's candidate; Tracy Rutherford, Ph.D.; Gary Wingenbach, Ph.D.; and Robert Lemon, Ph.D. will have access to the records.

My decision whether or not to participate will not affect my current or future relations with Texas A&M University. If I decide to participate, I am free to refuse to answer any of the questions that may make me uncomfortable. I can withdraw at any time. I can contact Chris Lavergne, (979) 458-0947 or Tracy Rutherford, (979) 458-2744 with any questions about this study.

This research study has been reviewed by the Institutional Review Board- Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, I can contact the Institutional Review Board through Dr. Michael W. Buckley, Director of Research Compliance, Office of Vice President for Research at (979) 845-8585 (mwbuckley@tamu.edu).

I have read the above information. I have asked questions and have received answers to my satisfaction. I have been given a copy of this consent document for my records. By signing this document, I consent to participate in the study.

Signature: ____________________________________________________

Date: __________________

Signature of Investigator: ______________________________________________

Date: ____________________

# APPENDIX B

## FIRST ROUND INSTRUMENT

## FACTORS DETERMINING ADOPTION OR NON-ADOPTION OF PRECISION AGRICULTURE BY PRODUCERS ACROSS THE COTTON BELT

Thank you for participating in this research project. The purpose of this study is to determine factors influencing cotton producer adoption of precision agriculture technologies in the leading cotton-producing states. You have been chosen because of your knowledge of the commodity, and your position representing cotton producers in your region. Your honest opinion is valued.

Region/State ___________ Years in cotton production _________________

Email or Postal Address ___________________________________________

1. What are the benefits of adopting precision agriculture technologies in cotton production?

2. What are the barriers to adopting precision agriculture technologies in cotton production?

# APPENDIX C

## SECOND ROUND NOTIFICATION AND INSTRUMENT

**From:** lavergne@tamu.edu
**Subject:** **American Cotton Producers Precision Agriculture Study**
**Date:** May 24, 2004 12:13:02 PM CDT
**To:** (First Name)(Last Name)@cotton.com

(First Name),
I am following up on the precision agriculture study you participated in at the American Cotton Producers Meeting in Dallas, TX on April 14/15. As indicated in the consent form, I am attempting to form a consensus among cotton experts, concerning adoption or non-adoption of precision agriculture in the cotton belt. Thank you for your original comments.

The responses provided by you and your peers have been compiled into 21 advantages and 21 barriers. The following link http://www.ag-communicators.org/surveys/cotton.asp will allow you to indicate the relative importance of the responses.

The results of this survey will be compiled and you will be contacted to complete one more short survey. The final survey provides the opportunity to reach consensus with your peers. I truly appreciate your assistance in this master's thesis study and I will disseminate the results to all ACP members. The conclusions reached provide state Extension agencies with producers' perspectives on this matter.

Thank you for your participation in this study.

Kindest regards,

Chris

Christopher Lavergne
Texas A&M University
Phone: 979.458.0947
lavergne@tamu.edu

## *Factors Determining Adoption or Non-adoption of Precision Agriculture by Producers Across the Cotton Belt*

The purpose of this survey is to assess the levels of importance for advantages and barriers to using precision agricultural technologies in cotton production.

In the first round of this survey, you and your colleagues identified **21 advantages** and **21 barriers** to using precision agriculture technologies in cotton production. These advantages and barriers are listed below in no particular order. Now, we need to know their importance levels as factors that determine adoption or non-adoption of precision agriculture in cotton production.

**Required Information:**
Please enter the two-letter abbreviation of your home state.
Type in your e-mail address (Optional; used to verify participation only):

How many years of experience do you have in cotton production?

**Instructions**: Rate each **advantage** by clicking the circle that best describes how much it **promotes** adopting precision agriculture technologies.

| **Advantages** | Not Important | Somewhat Important | Important | Very Important |
|---|---|---|---|---|
| Ability to get precise acres and field size | | | | |
| Assistance in maneuvering larger equipment | | | | |
| Better fiber quality | | | | |
| Conserve chemicals and inputs | | | | |
| Cutting costs of overall production | | | | |
| Decrease driver fatigue | | | | |
| Identify high and low yielding areas | | | | |
| Identify low pH, low fertility areas | | | | |
| Increased production | | | | |
| Increased profitability on overall farm by increased efficiencies and production | | | | |
| Leads to fewer tons of chemical and nutrients to the environment | | | | |
| Less waste of equipment – time, labor, fuel | | | | |
| Maximize inputs (fertilizer, herbicides, etc.) | | | | |
| More accurate farming (row spacing, reduced overlap, and cultivation) | | | | |
| Operate in all weather conditions (fog, night, dust, etc.) | | | | |
| Record keeping | | | | |
| Self guidance | | | | |
| Variable rate application, especially lime | | | | |
| Variable seeding rate | | | | |
| Yield monitor – establish realistic yield goals | | | | |
| Yield result for better input control on different field & soil types in each field | | | | |

**Instructions**: Rate each **barrier** by clicking the circle that best describes how much it **prohibits** adopting precision agriculture technologies.

| **Barriers** | Not Important | Somewhat Important | Important | Very Important |
|---|---|---|---|---|
| Accuracy of data questionable | ○ | ○ | ○ | ○ |
| Adapting new implements to older equipment | ○ | ○ | ○ | ○ |
| Adequate benefits may be questionable in smaller operations | ○ | ○ | ○ | ○ |
| Confidence to know what factors vary | ○ | ○ | ○ | ○ |
| Data not as believable as it is in grain production | ○ | ○ | ○ | ○ |
| Different brands of equipment not functioning together | ○ | ○ | ○ | ○ |
| Employee capability to operate equipment questionable | ○ | ○ | ○ | ○ |
| Farmers slow to change | ○ | ○ | ○ | ○ |
| Few suppliers with technical experience | ○ | ○ | ○ | ○ |
| Initial cost | ○ | ○ | ○ | ○ |
| Lack of "hi-tech" talent to meet potential demand | ○ | ○ | ○ | ○ |
| Lack of support from industry | ○ | ○ | ○ | ○ |
| Learning curve | ○ | ○ | ○ | ○ |
| No accurate yield monitor for cotton strippers | ○ | ○ | ○ | ○ |
| Return to investment questionable | ○ | ○ | ○ | ○ |
| Software problems and incompatibility | ○ | ○ | ○ | ○ |
| Suppliers not geared up with application equipment | ○ | ○ | ○ | ○ |
| The ability to manipulate data for better results | ○ | ○ | ○ | ○ |
| Too complex for older laborers | ○ | ○ | ○ | ○ |
| Unfamiliar with technology | ○ | ○ | ○ | ○ |
| Untested equipment | ○ | ○ | ○ | ○ |

Submit Reset

# APPENDIX D

## SECOND ROUND REMINDER EXAMPLE

**From:** lavergne@tamu.edu
**Subject: American Cotton Producers Precision Agriculture Study**
**Date:** June 1, 2004 12:13:02 PM CDT
**To:** (First Name)(Last Name)@cotton.com

Howdy,

I just wanted to send a reminder request for assistance with my master's research. We currently have 5 responses, and could use a few more. Your expert opinion is key to this research. Accessing http://www.ag-communicators.org/surveys/cotton.asp will bring you to a one-page questionnaire that lists the advantages and disadvantages of precision agriculture, which you and colleagues listed at the American Cotton Producer Dallas meeting on April 15. Please view the link to rank the factors. The conclusion of this study will be a consensus among experts of the benefits and barriers of adopting precision agriculture in cotton. I appreciate your time and contribution to this study.

Best regards,

Christopher Lavergne
Texas A&M University
Phone: 979.458.0947
Fax: 979.458.3405
lavergne@tamu.edu

# APPENDIX E

## THIRD ROUND NOTIFICATION AND INSTRUMENT

**From:** lavergne@tamu.edu
**Subject: American Cotton Producers Precision Agriculture Study - Last Round**
**Date:** July 21, 2004 3:11:49 PM CDT
**To:** (First Name)(Last Name)@cotton.com

(First Name),
Thank you for your previous participation in my master's thesis research. This is round 3, the last step in the process. Please access http://www.ag-communicators.org/surveys/cotton3.asp for the last short component of the study. I will be sure to send the conclusions to ACP for everyone's review.
(First Name), I can't thank you enough for your assistance. The results from this research will help Extension personnel and service providers to better meet the needs of cotton producers.

Best regards,

Chris

Christopher Lavergne
Texas A&M University
Phone: 979.458.0947
lavergne@tamu.edu

Texas Cooperative EXTENSION
The Texas A&M University System

## *Factors Determining Adoption or Non-adoption of Precision Agriculture by Producers Across the Cotton Belt*

The purpose of this survey is to assess the levels of importance for advantages and barriers to using precision agricultural technologies in cotton production.

In the second round, you rated the importance of **21 advantages** and **21 barriers** to using precision agriculture technologies in cotton production. The results of round two are listed below in their original order (in blue). **How much you agree or disagree with the importance levels for each advantage and barrier**?

**Required Information:**
Please enter the two-letter abbreviation of your home state.

**Instructions**: Rate each **advantage** by clicking the circle that best describes how much you agree/disagree with its **level of importance for adopting** precision agriculture technologies.

| **Advantages** | Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|---|
| Ability to get precise acres and field size (**3.10**) | ○ | ○ | ○ | ○ |
| Assistance in maneuvering larger equipment (**2.60**) | ○ | ○ | ○ | ○ |
| Better fiber quality (**2.80**) | ○ | ○ | ○ | ○ |
| Conserve chemicals and inputs (**3.40**) | ○ | ○ | ○ | ○ |
| Cutting costs of overall production (**3.60**) | ○ | ○ | ○ | ○ |
| Decrease driver fatigue (**3.20**) | ○ | ○ | ○ | ○ |
| Identify high and low yielding areas (**3.30**) | ○ | ○ | ○ | ○ |
| Identify low pH, low fertility areas (**2.90**) | ○ | ○ | ○ | ○ |
| Increased production (**3.67**) | ○ | ○ | ○ | ○ |
| Increased profitability on overall farm by increased efficiencies and production (**3.80**) | ○ | ○ | ○ | ○ |
| Leads to fewer tons of chemical and nutrients to the environment (**3.20**) | ○ | ○ | ○ | ○ |
| Less waste of equipment – time, labor, fuel (**3.60**) | ○ | ○ | ○ | ○ |
| Maximize inputs (fertilizer, herbicides, etc.) (**3.50**) | ○ | ○ | ○ | ○ |
| More accurate farming (row spacing, reduced overlap, and cultivation) (**3.80**) | ○ | ○ | ○ | ○ |
| Operate in all weather conditions (fog, night, dust, etc.) (**2.80**) | ○ | ○ | ○ | ○ |
| Record keeping (**3.00**) | ○ | ○ | ○ | ○ |
| Self guidance (**3.10**) | ○ | ○ | ○ | ○ |
| Variable rate application, especially lime (**2.70**) | ○ | ○ | ○ | ○ |
| Variable seeding rate (**2.70**) | ○ | ○ | ○ | ○ |
| Yield monitor – establish realistic yield goals (**3.40**) | ○ | ○ | ○ | ○ |
| Yield result for better input control on different field & soil types in each field (**3.50**) | ○ | ○ | ○ | ○ |

**Instructions**: Rate each **barrier** by clicking the circle that best describes how much you agree/disagree with its **level of importance for prohibiting** the adoption of precision agriculture technologies.

| **Barriers** | Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|---|
| Accuracy of data questionable (3.10) | ○ | ○ | ○ | ○ |
| Adapting new implements to older equipment (3.10) | ○ | ○ | ○ | ○ |
| Adequate benefits may be questionable in smaller operations (2.80) | ○ | ○ | ○ | ○ |
| Confidence to know what factors vary (3.10) | ○ | ○ | ○ | ○ |
| Data not as believable as it is in grain production (3.00) | ○ | ○ | ○ | ○ |
| Different brands of equipment not functioning together (3.50) | ○ | ○ | ○ | ○ |
| Employee capability to operate equipment questionable (3.70) | ○ | ○ | ○ | ○ |
| Farmers slow to change (2.410) | ○ | ○ | ○ | ○ |
| Few suppliers with technical experience (3.30) | ○ | ○ | ○ | ○ |
| Initial cost (3.80) | ○ | ○ | ○ | ○ |
| Lack of "hi-tech" talent to meet potential demand (3.40) | ○ | ○ | ○ | ○ |
| Lack of support from industry (3.30) | ○ | ○ | ○ | ○ |
| Learning curve (3.40) | ○ | ○ | ○ | ○ |
| No accurate yield monitor for cotton strippers (2.30) | ○ | ○ | ○ | ○ |
| Return to investment questionable (3.22) | ○ | ○ | ○ | ○ |
| Software problems and incompatibility (3.40) | ○ | ○ | ○ | ○ |
| Suppliers not geared up with application equipment (3.30) | ○ | ○ | ○ | ○ |
| The ability to manipulate data for better results (2.90) | ○ | ○ | ○ | ○ |
| Too complex for older laborers (3.30) | ○ | ○ | ○ | ○ |
| Unfamiliar with technology (2.90) | ○ | ○ | ○ | ○ |
| Untested equipment (2.90) | ○ | ○ | ○ | ○ |

Submit Reset

# VITA

**CHRISTOPHER BERNARD LAVERGNE**
1201B Webhollow Circle
Bryan, TX 77801

## Education

| | |
|---|---|
| M.S. | Texas A&M University, College Station, Texas, Agricultural Education, Emphasis – Adult and Extension Education, December 2004 |
| B.S. | Kansas State University, Manhattan, Kansas, Agricultural Communications & Journalism, Minor – Animal Sciences & Industry, December 2002 |

## Professional Experience

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| Nov. 2003 – Present | Communications Specialist – Public Outreach, Strategic Marketing, Institute of Food Science & Engineering, Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas |
| Jan. 2003 – Nov. 2003 | Graduate Teaching Assistant, Department of Agricultural Education, Texas A&M University, College Station, Texas |